DAIRYAUSTRALIA

Delivering for the dairy industry

Australian Dairy Ingredient Reference Manual

DAIRY GOOD

From Australia, with pride.

SECOND EDITION

Foreword

We are very pleased to present you the Second Edition of the Australian Dairy Ingredient Reference Manual, a technical guide to using Australian dairy ingredients in the key Australian export markets.

The first edition of the Reference Manual was released to the Chinese dairy market in September 2005 and has been greatly welcomed by the market. A small number of the English version of the Manual has been distributed to South East Asian dairy markets.

Given the great popularity and high demand for the Reference Manual, Dairy Australia is now happy to launch the second edition of the Manual. In the new edition, six new chapters have been added on topics such as raw milk quality control and food safety systems in Australia, applications of milk powders and cheese in food service and bakery sectors, world trends of dairy products and processing technologies and milk fat products. All those chapters were written by leading dairy specialists in Australia. The chapter of the Australian dairy industry overview has also been updated by Dairy Australia.

Dairy Australia would also like to encourage the Manual users to maintain discussions with their Australian ingredient suppliers on the best use of Australian dairy ingredients.

Dairy Australia would like to thank the following authors, editors and consultants to both editions of the Reference Manual:

- Phil Clarke, Food Science Australia
- Christine Margetts, Food Science Australia
- Dr Peter Roupas, Food Science Australia
- Sam Cutri, Royal Melbourne Institute of Technology
- Dr Hilton Deeth, Dairy Innovation Australia
- Dr Sandra Ainsworth, Dairy Innovation Australia
- Geraldine Tinkler, Dairy Innovation Australia
- Michael Robinson, National Centre of Dairy Education Australia
- Paul Winfield, National Foods
- Matthew Freeman, Dairy Marketing International
- Bernie Harrison, Sustainable Training Pty Ltd
- Bob Munns, dairy consultant
- Dr Ranjan Sharma, OzScientific Food Research & Innovation
- Dr Alan Smyth, dairy consultant
- Neil Willman, Cheese Expertise
- Dr Greig Zadow, J. G. Zadow & Associates
- Harley Juffs, Harley Juffs & Associates Pty Ltd
- Bob Prince, APREE Assurance Services Pty Ltd
- Dr Liebing Zhang, Beijing Pasteur R&D Co Ltd
- Dr Jinghua Yu, Beijing Pasteur R&D Co Ltd

DAIRY AUSTRALIA
Delivering for the dairy industry

Special thanks are extended to Dairy Innovation Australia who shared half of the costs for authoring two chapters on applications of cheese in food service and bakery sectors and milk fat products.

Dairy Australia would also like to thank the Australian dairy industry for their support, review and inputs to the Reference Manual:

- Australian Dairy Farmers Limited: www.australiandairyfarmers.com.au
- Ballantyne Foods: www.ballantyne.com.au
- Bega Cheese: www.begacheese.com.au
- Burra Foods: www.burrafoods.com.au
- Challenge Dairy: www.challengedairy.com.au
- Dairy Farmers Cooperative: www.dairyfarmers.com.au
- Fonterra Australia: www.fonterra.com
- Murray Goulburn Cooperative Co Limited: www.mgc.com.au
- National Foods: www.natfoods.com.au
- Parmalat Australia: www.parmalat.com.au
- Tatura Milk Industries Limited: www.tatmilk.com.au
- Warrnambool Cheese and Butter Factory Company Holdings Ltd: www.wcbf.com.au

We would like to thank colleagues at Dairy Australia, Dr Mani Iyer, Helen Dornom, Karen Armitage and Robin Condron for their contributions to the Reference Manual.

Dairy Australia would like to thank Austrade Beijing Office, Pang & Heig Design and Ultra Intelligence Co Ltd for their contributions to the production of the Reference Manual.

We look forward to receiving your comments and suggestions on the Reference Manual. Please email them to Sarah Xu, International Market Manager at sxu@dairyaustralia.com.au .

I hope the Manual will further contribute to the building of your trust and understanding of the Australian dairy industry and products, and I am confident that the relationship between our industries will continue to grow.

Yours sincerely,

Phillip Goode

Phill Goode
Manager International Market Development
Dairy Australia

DAIRYAUSTRALIA
Delivering for the dairy industry

Content

1	1	Australian Dairy Industry and Global Trends
20	2	Food Safety in the Australian Dairy Industry
33	3	Raw Milk Quality Assurance in Australia
69	4	Global Trends and Innovations in Dairy Ingredients, Products and Processing
90	5	Milk Powders
127	6	Milk Powders in Non-Dairy Applications
142	7	Cheese
168	8	Cheese Applications in Food Service and Bakery Sectors
194	9	Butter and Milk Fat Products
225	10	Bioactive Dairy Ingredients
250	11	Whey Products and MPC
278	12	Applications of Australian Dairy Ingredients in UHT Milk
312	13	Using Australian Dairy Ingredients in Yogurt
335	14	Applications of Australian Dairy Ingredients in Ice Cream

DAIRY AUSTRALIA
Delivering for the dairy industry

1

Australian Dairy Industry and Global Trends

Content

7 1.1 Dairy Farming

8 1.2 Dairy Processing

13 1.3 Dairy Consumption in Australia

14 1.4 Dairy Exports

15 1.5 Outlook for the Australian Dairy Industry

16 1.6 Australian Government Involvement in the Dairy Industry

16 1.7 Industry Organisations and Structure

18 1.8 Industry Levies

20 1.9 Dairy 2007: Situation & Outlook

The dairy industry is a major rural industry in Australia. At the ex-factory level, the industry output was estimated to be around AUD$9.2 billion in 2006/07. There are approximately 1.81 million dairy cows in Australia with a total milk yield of 9.9 million tonnes in 2006/07 – a fall of 5% over the year before as the Australian industry once again dealt with widespread drought conditions in the winter / spring period of the year. The major manufactured product streams are drinking milk; skim milk powder / butter; butter / casein; cheese; wholemilk powder; and other consumer products such as yogurts, custards, dairy desserts; together with specialised ingredients such as whey proteins.

Approximately 50% of Australian milk production is exported – as manufactured products – at international market prices for a value of AUD$2.5 billion. Australia's market share of international dairy trade was 12% (in milk equivalents), compared to New Zealand (32%) and European Union (30%) in 2006.

1.1 Dairy Farming

Australia's climate and natural resources are generally favourable to dairying and allow the industry to be predominantly pasture-based, with approximately 75% of the cattle feed requirements coming from grazing in a year of 'normal' seasonal conditions. This results in efficient, low-cost, high-quality milk production.

Most dairy production is located in coastal areas where pasture growth generally depends on natural rainfall. Nevertheless, there are several inland irrigation schemes – most notably in northern Victoria and southern New South Wales. Feedlot-based dairying remains unusual in Australia, although the use of supplementary feed, with hay, silage and grains, is becoming increasingly more widespread. Australian dairy farmers continue to increase on-farm productivity through improved pasture, feed and herd management techniques.

While the bulk of milk production occurs in Victoria (66% in the latest season), all states have viable, productive industries, supplying fresh milk to nearby cities and towns. In addition, a wide range of high quality manufactured products – from fresh lines such as yogurt and a wide variety of cheese types to bulk and specialized milk powders – are produced in most Australian states.

The number of farms has more than halved over the last two decades, from 22,000 in 1980 to 8,055 currently. The majority of Australian dairy farms remain family owned and operated. Share farming is a significant mode of operation employed on 15% of farms in the industry, as it operates successfully within the family ownership model.

Average herd size has increased from 85 cows in 1980 to an estimated 225 currently. We are also seeing the emergence of larger farm operations where the one property might support up to 1,000 head of dairy cattle.

The dominant breed in Australia is the Friesian Holstein, accounting for over 70% of all dairy cattle. Other important breeds include the Jersey, and Australia's own breed, the Illawarra. Most breeding is by artificial insemination, and so Australian farmers have access to some of the best genetic material in the world. Herd recording is widely practiced, with an estimated 70% of farms regularly recording herd performance.

Improved herd genetics, as well as advances in pasture management and supplementary feeding regimes, have seen average annual yield per cow increase from 2,850 litres to around 5,150 litres over the past two decades.

Combining this increase in yields per cow with the average herd sizes, the average milk production per farm has increased from 247,000 litres to 1,190,000 litres per year over the same period.

Australian milk production costs are well below those in many other major dairy producing countries around the world. Unlike many other countries, there is no legislative control over the price processors pay farmers for milk. Farmgate prices can vary between manufacturers, with individual company returns being affected by factors such as product mix, marketing strategies and processing efficiencies. Most milk prices are based on both the milkfat and solids non-fat content of fresh milk. Payments from processors to individual farmers can also vary marginally as firms operate a range of incentive / penalty payments relating to milk quality, volumes and out-of-season supplies. The average milk price in 2006/07 was approximately $A 33.2 cents per litre.

1.2 Dairy Processing

As in the farm sector, the milk processing sector is undergoing continuing rationalisation. This has resulted in improved factory capacity, as larger operations have improved their efficiency and economies of scale. The lack of growth in milk production over the past six years has relieved the pressure on Australian dairy companies to continue to invest in increasing processing capacity – at least in the short to medium term. Instead, the challenge has been to utilise the existing capacity as profitably as possible.

The Australian dairy manufacturing sector is diverse and includes farmer-owned co-operatives, public, private and multi-national companies. Co-operatives no longer dominate the industry, but still account for approximately 55% of the milk output. While the largest co-operative (Murray Goulburn) accounts for 35% of Australia's milk production, there are also a number of small to medium-sized co-operatives with milk intake volumes between 100 and 1,000 million litres, including the Dairy Farmers Group, Tatura Milk Industries, and the Bega, Norco and Challenge co-operatives.

Major multi-national dairy companies operating in the Australian dairy industry include Fonterra, San Miguel and Parmalat.

Other Australian dairy companies cover a diverse range of markets and products, from the publicly listed Warrnambool Cheese and Butter Factory to many highly specialised farmhouse cheese manufacturers.

In line with international trends, there was a general movement in Australia's product mix toward increased cheese and whole milk powder production, and away from butter and skim milk powder lines, in recent

The table below lists the major products manufactured in Australia.

Product	Output 2006/07 (tonnes)	% Chg over 2005/06
Liquid milk	2,225,000	+4%
BMP	13,600	-15%
Butter	101,700	+9%
Butteroil	31,400	-40%
Cheese	363,800	-2%
SMP	195,300	-8%
WMP	135,400	-14%
Whey products	86,200	-12%

years. However, this trend has eased in the last couple of years as companies responded to the high international commodity prices in the market for butter and SMP.

Drinking Milk

Regular or whole milk is standardised to a milkfat content of around 3.8%. Modified, reduced and low-fat milks are standardised to other specifications, with varying milkfat and solids non-fat levels. The cream removed during standardisation can be bottled as table cream or manufactured into butter or other dairy products.

The major players in the Australian drinking milk market are National Foods (Pura brand), Dairy Farmers (Dairy Farmers brand) and Parmalat (Pauls brand); together with a number of smaller players with strong regional brands.

The supermarket channel share of Australian drinking milk sales slipped marginally to 56% in 2006/07; after increasing from 50% in 1999/00 to reach 57% in 2005/06.

Private label brands account for nearly 55% of total supermarket milk volumes, up from 25% in 1999/00 and at an average price significantly less than branded product. This lower average price is due to a combination of product mix – i.e. regular vs. reduced-fat vs. low-fat milks – and pack size mix – i.e. 1-litre vs. 2-litre vs. 3-litre bottles.

On the packaging front, plastic bottles now account for 78% of all milk sales in supermarkets, with the balance split between gable-top cartons and UHT packs.

There have also been significant movements within the pack sizes bought by consumers in supermarkets. While the 2L plastic bottle remains the most popular size, with a 41% share, this is down from 49% seven years ago. Similarly, the combined share of the 1L carton and 1.1L plastic bottles has slipped from 33% to 21%. The major change has been in the explosive growth of the 3L plastic bottle, with a growth in the share of all supermarket milk sales from 13% to 34% since it first appeared in June 1998.

In 2006/07, the average price of branded milk increased 3.9% to $1.88 a litre and when combined with a 1.7% increase in the average private label price to $1.18 a litre, delivered an increase in the supermarket average price of 5¢ a litre to $1.50 a litre.

Australia exports relatively small volumes of milk – predominantly as UHT product – with nearly 80% of that going into the Asian region.

Cheese

Australia produced 365,500 tonnes of cheese in 2006/07 – a 2% decrease on the previous year. While the production of most cheese types dipped, the production of fresh cheeses was particularly strong.

Australian cheese production is now almost 50/50 between the cheddar and non-cheddar cheese segments. The trend away from cheddars towards non-cheddar cheese types has been apparent in both the production and consumption data for some time. In the six years covered in the table below, the non-cheddar share of total production has increased from 47% to 51%.

Australian cheese production by type of cheese (tonnes)

	2001/02	2002/03	2003/04	2004/05	2005/06 (r)	2006/07 (p)
Cheddar	220,239	212,811	207,795	195,887	191.693	179,134
Semi Hard	91,636	83,973	88,712	90,737	76,834	75,797
Hard Grating	16,290	12,118	11,332	13,267	23,022	18,618
Fresh	80,118	64,105	70,940	83,759	75,588	86,044
Mould	3,688	5,945	4,983	4,794	5,775	5,932
Total Cheese	**412,063**	**378,952**	**383,762**	**388,444**	**372,912**	**365,525**

Source: Dairy manufacturers

It is estimated that some 55% of domestic cheese sales are through supermarkets. Nevertheless, a significant proportion – mostly specialty cheeses – is sold through the smaller, independent retail trade, with the remainder used in the foodservice sector and food processing applications. Cheese is a major product for the Australian dairy industry, with sales of nearly 185,000 tonnes within Australia, valued at an estimated A$1.3 billion, and export sales of 212,500 tonnes, worth more than A$825 million in 2006/07.

Japan remained Australia's most important overseas cheese market in 2006/07 and accounted for 45% of product exports, followed by Saudi Arabia and the United States. All up, Australian cheeses found their way to over 70 countries around the world last year. The trend away from cheddar cheeses to non-cheddar cheese types evident in the domestic market is also being reflected in Australia's cheese exports, where the non-cheddar share of total export sales has increased from 45% to 57% over the past seven years.

Butter

In 2006/07, Australia produced 133,100 tonnes of butter and anhydrous milkfat (AMF) or butteroil in commercial butter equivalent terms (CBE).

AMF is primarily produced for export and domestic food processing applications, such as bakery and confectionery. These sectors also use butter, but most domestic butter sales are through retail and foodservice outlets.

The introduction of butter and vegetable oil-based dairy blends, which are easier to spread and lower in saturated fat, has helped to stabilise this market in recent years, after a sustained decline from the 1970s.

Nevertheless, Australia's total retail market for tablespreads has steadily decreased in size over the past seven years. Consumer concerns about margarine consumption have meant a continuing decline of more than 2% in the latest year; with dairy spreads taking further retail market share from margarine. This has been a continuing trend over the past seven years, as dairy spreads' share of the category has steadily increased from 30% in 2000/01 to 40% in 2006/07.

Australian exports of butter and AMF vary significantly from year to year – with a declining trend over the five years to 2004/05. However, Australian butter/AMF exports have increased significantly in the last two years in response to strong world commodity prices; and totalled 81,000 tonnes and were valued at A$179 million in 2006/07.

Australia's most important overseas markets for butter/AMF were the Egypt, Singapore and Korea.

Fresh products

Australian manufacturers also produce a range of other dairy products, including fresh products such as yogurt, dairy desserts, chilled custard and cream, and frozen products such as ice-cream.

Yogurts have been a category of considerable growth for the dairy industry over the past decade, particularly because of their favourable consumer image as a convenient, healthy snack. Reflecting this image, low-fat and diet variants account for some 65% of the annual supermarket sales of yogurt. Another indication of the 'healthy' focus of this product segment is that fruit flavours have a 65% share, while the natural yogurt flavour profile has a 15% share. The segment is dominated by strong international brands, such as Ski, Yoplait and Nestlé.

Growth in yogurt sales has been underpinned by continued product innovation in the areas of packaging, flavours and the use of probiotic cultures, as well as new products, such as drinking yogurts.

Dairy desserts are a smaller dairy category. Marketed as an indulgence or treat item, these products are generally targeted to adult consumers and include mousses, crème caramels and fromage frais. Children's products include fromage frais and flavoured custards and they often feature popular cartoon characters on the pack.

Chilled custards, a traditional favourite, are showing some growth as manufacturers expand their product offerings into small, snack-sized plastic cups sold in multi-packs.

The overall market for cream has declined in recent years. Regular and sour creams are both used extensively as accompaniments or ingredients, but are facing significant competition on the health front, often from other dairy products such as natural yogurt.

Australia's consumption of ice-cream is relatively high by world standards and the market is stable in volume terms, if highly seasonal.

The major market development in recent years has been in premium indulgent treats, in both stick lines and smaller-sized take-home tubs. Nevertheless, sales of larger tubs (2L or greater) and multi-packs of stick lines continue to make up the majority of sales in supermarkets, while mid-range stick lines and ice-cream cones are the major volume products in the route trade. Once again, strong international brands, such as Streets, Nestlé (Peters) and Cadbury, dominate the category.

Milk powders

Australian manufacturers produce a range of milk powders. New technology used in the production and use of powders has seen the range of specifications available from Australian manufacturers expand in line with customers' needs.

In the years up until the peak production season of 2001/02, the most obvious trend in powder production was an increase in wholemilk powder (WMP) output, with skim and butter milk powders (SMP/BMP) remaining relatively stable. However, since the drought of 2002/03, total volumes of milk powders have been most affected by the reduced availability of milk and the trend has changed. The production of both forms of powder fell sharply, followed by similar patterns of recovery, with WMP volumes making up nearly half of the total milk powder production for four years. However, the recent strong commodity prices saw a significant re-balancing of company product mixes from 2005/06 towards SMP/BMP (and butter/butteroil) to take advantage of the higher relative export returns available from these products.

Less than 15% of Australia's powder production is sold domestically. Retail outlets account for only a small percentage of domestic sales, with local usage being mainly as a food ingredient.

Milk powder is recombined into liquid milk products, particularly in tropical climates where fresh milk supplies are not available. It is also used in bakery products (improving the volume and binding capacity of bread, and ensuring crisper pastry and biscuits), confectionery and milk chocolates, processed meats, ready-to-cook meals, baby foods, ice-cream, yogurt, health foods and reduced-fat milks. Industrial-grade powder is used for animal fodder.

The major export markets for Australian milk powders are concentrated in Asia, with 75% of SMP/BMP export volumes and 70% of WMP, destined for the region in 2006/07.

Singapore was the largest single export market for Australian SMP/BMP, followed by Malaysia, Thailand, the Philippines and Indonesia.

Malaysia was the largest single export market for Australian WMP, followed by Indonesia, Singapore, Oman and Bangladesh.

Australian exports of skim milk and buttermilk powders by region (tonnes)

	2001/02	2002/03	2003/04	2004/05	2005/06 (r)	2006/07 (p)
Asia	197,278	174,553	151,868	141,932	176,627	150,950
Middle East	15,714	12,588	11,834	10,290	19,876	21,586
Africa	8,469	7,787	4,962	6,392	4,517	6,567
Pacific	4,411	6,230	5,627	7,386	9,933	14,410
Americas	16,959	15,341	11,949	6,501	5,257	6,555
Europe	771	499	1,287	1,532	860	2,149
Others	0	1	0	0	17	0
Total	**243,602**	**216,999**	**187,527**	**174,033**	**217,087**	**202,217**

Includes dairy component of mixed powders

Source: Dairy Australia & ABS

Australian exports of wholemilk powder by region (tonnes)

	2001/02	2002/03	2003/04	2004/05	2005/06 (r)	2006/07 (p)
Asia	157,839	153,778	1 27,188	114,566	123,039	99,837
Middle East	22,373	22,221	21,354	24,232	10,420	18,519
Africa	21,020	13,677	12,738	7,732	12,404	10,069
Pacific	4,809	4,778	6 ,970	6,803	5 ,879	3,480
Americas	11,433	5,720	3 ,452	6,713	1 3,068	11,111
Europe	617	185	1,700	411	26	450
Others	0	0	0	0	0	0
Total	**218,091**	**200,359**	**173,402**	**160,457**	**164,836**	**143,466**

** Includes dairy component of mixed powders*

Source: Dairy Australia & ABS

Whey products and casein

Whey is a by-product of the cheese-making process. Traditionally this product was disposed of in liquid form. However, recognition of the value of whey's components has seen the production of whey powders and protein concentrates increase significantly in recent times.

Food-grade whey powder is used in the manufacture of ice-cream, bakery products (cakes, biscuits), chocolate flavouring, infant formula, yogurt, beverages and processed meat. Industrial uses include animal feed (pigs, horses and poultry), calf milk replacer and even as a carrier for herbicides.

Whey protein concentrates are used in snack foods, juices, confectionery, ice-cream, biscuits, processed meats, (milk) protein drinks, desserts, infant foods and dietetic products. Products such as cosmetics, skin creams, bath salts and detergent also contain protein concentrates.

Approximately 25% of Australia's whey production is used domestically in the manufacture of infant formula, biscuits and ice-cream. The remainder is exported, with Indonesia, China, Singapore, Thailand and the Philippines being the largest export markets for Australian whey powders in 2006/07.

Casein and caseinates are ingredients in noodles, chocolate, sweets, mayonnaise, ice-cream and cheese manufacture. They are used as binding ingredients, emulsifiers and milk substitutes in processed foods. Industrial uses of casein and caseinates include: plastics (buttons, knitting needles); the manufacture of synthetic fibres and chemicals (plants, glues, glazed paper, putty and cosmetics); as a reinforcing agent and stabiliser for rubber in automobile tyres; a nutritional supplement and binder in calf milk replacers; and a range of other technical applications.

The majority of Australia's production of casein and caseinates is for export markets. The United States and Japan have been the largest export markets in recent years.

1.3 Dairy Consumption in Australia

Drinking Milk: The average per capita consumption of drinking milk has been marginally increasing over recent years, to an estimated level of 103 litres in 2006. In recent years Australian consumption of milk has been changing from regular full cream milk to more specialty milk types such as reduced and low fat milks. Flavoured milks have also been increasing their share of the market at the expense of white full cream milk; while we have also seen growth in UHT milk. Competition between the milk processors has seen the development of innovative specialty milks delivering varying fat contents, or fortified with extra vitamins and minerals. Other milks have been developed to address particular consumer needs, such as lactose-free or extra frothing milk for cappuccinos.

Cheese: Australians consume an average of around 12 kilograms of cheese per head each year – with more than half being cheddar or cheddar-type cheeses. Nevertheless, consumption of non-cheddar cheese is growing, reflecting the increasingly diverse and cosmopolitan nature of the Australian diet.

Butter: Annual per capita consumption of butter in Australia is over 3.5 kilograms. There was a long-term decline in butter consumption during the 1970's and 1980's, as consumers have sought to reduce their levels of saturated fat intake. However, the introduction of butter and vegetable oil based dairy blends, which are easier to spread and lower in saturated fat, have helped to stabilise this trend in recent years.

Yogurt: Yogurts have been an area of considerable growth for the dairy industry. The average per capita consumption of yogurt is nearly 7 kilograms. Yogurt has a favourable consumer image as a healthy and convenient snack. Reflecting this, low fat and diet variants account for more than half the annual supermarket sales of yogurt. Growth in yogurt has been underpinned by product innovation in the areas of packaging, flavour, pro-biotic cultures, drinking yogurts and yogurt snacks.

Milk Powders: Less than 15% of Australian powder production is sold domestically. Retail outlets account for only a small percentage of domestic sales – with local usage being mainly as a food ingredient.

Ice Cream: Australian consumption of ice cream is high by world standards – 18 litres per head per year. The market is stable and highly seasonal. Sales of large tubs – one litre or greater still dominate sales in supermarkets, while stick and impulse lines dominate the route trade. In recent times, licensing of popular confectionery brands has created interest in the category. Many of these lines are higher-priced indulgence items.

Dairy Desserts and Cream: Dairy desserts are a small but growing dairy market. Marketed as an indulgence or treat item, products are generally targeted at either adult consumers with products such as mousses, crème caramels and fromage frais; or to children, with fromage frais and flavoured custards often featuring popular cartoon characters on pack.

The market for cream in retail and foodservice remains stable. Cream – both regular and sour – is used extensively as an accompaniment or as an ingredient.

1.4 Dairy Exports

While Australia accounts for an estimated 2% of world milk production, it is an important exporter of dairy products. Indeed Australia ranks third in terms of world dairy trade, accounting for 12% of all dairy product exports.

Australia consistently exports approximately 50% of its annual milk production.

The total value of Australian dairy exports was over AUD$2.5 billion in 2006/07. Australian exports are concentrated in Asia / East Asia – making up 66% of the total. Japan is the single most important export market to Australia – accounting for nearly one fifth of Australia's exports by value.

Australia's top five export markets by volume in 2006/07 were Japan, Singapore, Malaysia, Indonesia and the Philippines; while the top five export markets by value were slightly different in Japan, Singapore, Malaysia, Indonesia, and Saudi Arabia - displacing the USA from 5th position. There has been little change in the ranking of these markets over recent years.

The table below lists the key export products from Australia.

Product	Exports 2006/07 (tonnes)	% Chg over 2005/06
Liquid milk	82,400	-4%
Butter/Butteroil	80,100	-2%
Cheese	212,500	+5%
SMP, BMP & SMP/BMP mixture	202,200	-7%
Wholemilk powder	143,500	-13%

Australian exports to Mainland China are 3% by both volume and value of Australia's total exports and are growing steadily. Total exports from Australia to Mainland China were 27,100 tonnes in 2006/07 for a value of AUD$82 million. The key products exported from Australia to Mainland China were whey powder (8,100 tonnes), skim milk powder (7,200 tonnes) and cheese (3,350 tonnes).

Australian exports to Hong Kong are 4% by volume and 3% by value of Australia's total exports. Total exports from Australia to Hong Kong were 32,893 tonnes in 2006/07 for a value of AUD$73 million. The key products exported from Australia to Hong Kong were milk (17,596 tonnes), cheese (6,807 tonnes) and butter (2,506 tonnes).

Australian exports to Taiwan are 3% by both volume and value of Australia's total exports. Total exports from Australia to Taiwan were 27,352 tonnes in 2006/07 for a value of AUD$82 million. The key products exported from Australia to Taiwan were skim milk powder (9,580 tonnes), cheese (5,464 tonnes) and whole milk powder (4,763 tonnes).

1.5 Outlook for the Australian Dairy Industry

In each of the last four years Dairy Australia has prepared a comprehensive "*Dairy: Situation and Outlook*" report- with the 2007 report now available from our website www.dairyaustralia.com.au. This report provides a wide-ranging review of the current market situation and factors that will shape the outlook for the industry over the short to medium term.

In late 2007 the Australian dairy industry is balancing the uncertainty faced by farmers, many of whom are looking at the prospect of re-emerging drought conditions for a second consecutive season, with the optimism that reflects the best world market conditions in decades.

International dairy commodity prices continue to rise in response to consistent strong demand and tight supplies. However, the benefits of record high prices for Australian exporters have been offset to some extent by the strength of the local currency. Nevertheless the strong international outlook has meant that significant increases of 30 – 40% in opening farmgate prices for the new season were announced in all dairy regions.

These increases reflect the continued surge in world dairy prices; the increased competition for depleted milk supplies between dairy companies within Australia; and the tightening balance between supply and demand in the northern and western fresh dairy product regions of Australia. These prices will assist in improving the financial position of many drought-affected farmers; however, the extent of recovery will depend critically on conditions for the coming season.

Into the medium term, the market outlook for dairy remains positive.

While there are some regional differences, climate was identified in this year's National Dairy Farmer Survey as the major current and future challenge for most dairy farmers. The uncertainty surrounding future climate variability; what it means for current farming systems, access to water, inputs costs and future profitability is undermining some of the confidence of Australian dairy farmers in their future prospects, despite the very positive market outlook.

1.6 Australian Government Involvement in the Dairy Industry

The Australian dairy industry is a fully market-driven industry. It was gradually de-regulated over the two decades of the 1980's and 1990's. The last stage in the journey was in July 2000 when regulated drinking milk prices were removed; so that there is now no government involvement in any aspect other than the setting of minimum food safety requirements and food standard (labelling, advertising claims, etc.) regulations.

1.7 Industry Organisations and Structure

The Australian dairy industry is diverse, incorporating primary production, manufacturing and marketing. Accordingly, a number of bodies represent the various sectors and provide a framework for the industry to work together.

Dairy Australia

Dariy Australia is the industry-owned service organisation. Formed on 1 July 2003, Dairy Australia replaced the Australian Dairy Corporation and the Dairy Research and Development Corporation.

Dairy Australia is a company limited by guarantee, operating under the Corporations Act. It is fully accountable to its members – those levy payers who elect to become members and the peak industry bodies.

The structure provides farmers, as members, with a direct say in the activities of the organisation. To help the Australian dairy industry achieve its vision of growing an internationally competitive, innovative and sustainable industry, the organisation is delivering increased effectiveness through the integration and co-ordination of activities to provide better value for farmers' levy investment.

Together with the farmer-paid levy, the company receives matching government research and development (R&D) funds.

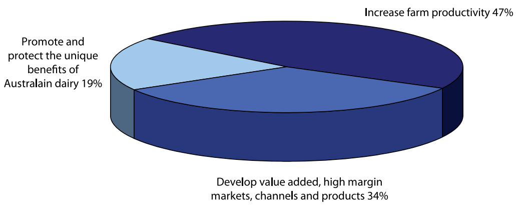
An on-going series of industry reviews facilitated by Dairy Austalia during 2006/07 helped fine-tune the organisation's multitude of key issues to a more focused set of Strategic Business Objectives that will ensure a constant focus on delivering sustained value to levy payers.

This approach puts Dairy Australia's activities into a clearer context by taking a holistic, rather than a component-based, approach to delivering outcomes.
For the current 2008-2012 planning cycle, Dairy Australia's business focus will be to:

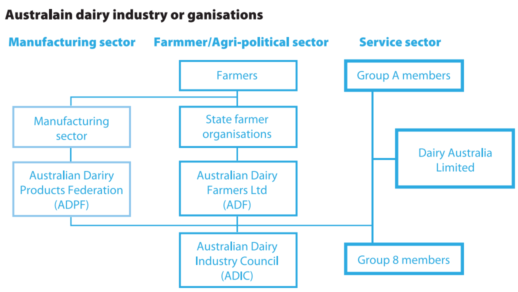
- Increase farm productivity.
- Develop value-added, high-margin markets, channels and products.
- Promote and protect the unique benefits of Australian dairy.

The organisation prepares an annual rolling five-year Strategic Plan. The current plan can be downloaded from www.dairyaustralia.com.au.

Dairy Australia's planned expenditure by business objectives for 2008 to 2012



Australian dairy industry organisations



Australian Dairy Industry Council

The Australian Dairy Industry Council (ADIC) is the dairy industry's peak policy body. It co-ordinates industry policy and represents all sectors of the industry on national and international issues.

The ADIC represents farmers, dairy product manufacturers and milk processors through its constituent organisations:

- Australian Dairy Farmers Limited; and
- Australian Dairy Products Federation.

The ADIC has the task of bringing these bodies together to form a united view on issues affecting the dairy industry.

Australian Dairy Farmers Limited

Australian Dairy Farmers Limited (ADF) provides national representation for dairy farmers and forms the dairy commodity council of the National Farmers' Federation.

There are six member dairy farmer organisations, one from each State:

- New South Wales Farmers' Association, Dairy Committee (NSWFA);
- Queensland Dairyfarmers' Organisation (QDO);
- South Australian Dairyfarmers' Association (SADA);
- Tasmanian Farmers and Graziers Association, Dairy Council (TFGA);
- United Dairyfarmers of Victoria (UDV); and
- Western Australian Farmers' Federation, Dairy Council (WAFF).

Australian Dairy Products Federation

The Australian Dairy Products Federation (ADPF) is the national organisation representing the interests of dairy product manufacturers and traders. The ADPF's primary purpose is to promote the interests of its members, and the dairy industry in general, to the Australian and State Governments and other sectors of the community.

State food safety organisations

Each State has a food safety organisation to ensure that individual processors and dairy farmers comply with food safety standards.

The Australian Dairy Authorities Standards Committee (ADASC), with representatives from each state food safety organisation, ensures there is a national approach to dairy food safety issues. ADASC is responsible for the Australian Milk Residue Analysis (AMRA) survey.

The six relevant state food safety organisations are:

- Safe Food Queensland;
- Dairy Food Safety Victoria;
- New South Wales Food Authority;
- Dairy Authority of South Australia;
- Department of Health, Western Australia Dairy Safety Unit; and
- Tasmanian Dairy Industry Authority.

1.8 Industry Levies

Dairy Services

Dairy Australia is funded by farmer-paid levies that are imposed on the fat and protein content of all milk produced in Australia.

The Australian Government matches expenditure on the industry's research and development activities that meet established criteria.

All Australian dairy farmers had the opportunity to participate, by mail, in the Dairy Poll 2007 conducted during February and March 2007. A comparatively high 53% participation rate was achieved; with 68% of votes cast in favour of maintaining the Dairy Service Levy at its current rate.

Animal Health Australia

Australian dairy farmers also contribute to the funding of Animal Health Australia (AHA), as do farmers in all other livestock industries. AHA is a non-profit public company limited by guarantee. Members include the Australian, State and Territory Governments, and key commodity and interest groups. AHA's task is to facilitate partnerships between governments and livestock industries, and provide a national approach to animal health systems. The Animal Health Levy is the dairy industry's contribution to AHA programs.

Dairy Adjustment Authority

As part of the Dairy Structural Adjustment Program, the Dairy Adjustment Levy was imposed on domestic (retail) sales of products marketed as dairy beverages from 8 July 2000. The levy is set at 11¢/L and is expected to continue until the end of the decade. It is administered by the Dairy Adjustment Authority, through the Dairy Structural Adjustment Fund.

Average rate of milk levies for 2007/08

	Milkfat (cents/kg)	Protein (cents/kg)	Milk* (cents/litre)	Milksolids (cents/kg)
Animal Health	0.0373	0.0880	0.004	0.06
Dairy Services	2.6075	6.3558	0.315	4.29
Dairy Adjustment#			11.000	

** Based on average 2006/07 Australian milk composition of 4.04% milkfat and 3.30% protein*

 # Levied on dairy beverages only at retail

Table of Products and Manufacturers

Manufacturers Summary - Ranked by Production 2006/07		
Milk Production	**Cheese: Cheddar types**	**Cheese: Non Cheddar types**
Murray Goulburn Co-operative Co Ltd	Murray Goulburn Co-operative Co Ltd	Murray Goulburn Co-operative Co Ltd
Fonterra Milk Australia	Fonterra Milk Australia	Fonterra Milk Australia
Dairy Farmers	Warrnambool Cheese & Butter Factory Co Ltd	Dairy Farmers
Warrnambool Cheese & Butter Factory Co Ltd	Bega Co-operative Society Ltd	Tatura Milk Industries Ltd
National Foods Ltd	National Foods Ltd	Kraft Foods Ltd
Parmalat Australia Ltd	Dairy Farmers	Lactos Pty Ltd
Tatura Milk Industries Ltd	De Cicco Industries Pty Ltd	Burra Foods Pty Ltd
United Dairy Power	Challenge Dairy	Lemnos Foods Pty Ltd
Bega Co-operative Society Ltd	King Island Dairy	Murrumbidgee Dairy Products Pty Ltd
Norco Co-operative Ltd	Margaret River Cheese	De Cicco Industries Pty Ltd
Challenge Dairy	Ashgrove Cheese Pty Ltd	Riverina Cheese Pty Ltd
Lactos Pty Ltd	The Old Cheddar Cheese Company	National Foods Ltd
Cadbury Scheweppes Pty Ltd	Hastings Co-operative	King Island Dairy
Burra Foods Pty Ltd	Pyengana Cheese Factory	Hillwood Cheeses
Longwarry Food Park	Maffra Farm House	Floridia Cheese
Total production 9,583 million litres	Total production 179,100 tonnes	Total production 184,800 tonnes
Top 5 = 81%	Top 5 = 93%	Top 5 = 75%

Skim Milk Powder	Whole Milk Powder	Butter / Butteroil
Murray Goulburn Co-operative Co Ltd	Fonterra Milk Australia	Murray Goulburn Co-operative Co Ltd
Fonterra Milk Australia	Murray Goulburn Co-operative Co Ltd	Fonterra Milk Australia
Warrnambool Cheese & Butter Factory Co Ltd	Tatura Milk Industries Ltd	Warrnambool Cheese & Butter Factory Co Ltd
Tatura Milk Industries Ltd	Longwarry Food Park	Dairy Farmers
Challenge Dairy	Dairy Farmers	Tatura Milk Industries Ltd
Bega Co-operative Society Ltd	Challenge Dairy	Challenge Dairy
Dairy Farmers		
Total production 205,000 tonnes	Total production 135,400 tonnes	Total production 133,900 tonnes
Top 5 = 100%	Top 5 = 100%	Top 5 = 100%

1.9 Dairy 2007: Situation & Outlook

Background

The Situation & Outlook report has been compiled for the last four years to provide a comprehensive picture of what is impacting on the key drivers across the value chain of the Australian dairy industry.

The report draws on the National Dairy Farmer Survey results; plus the views and opinions of global dairy market analysts, retail analysts, dairy company management, farm consultants and farm leaders.

As well as informing farmers, the report aims to provide factual insights into dairy for banks, governments, and suppliers of products and services to the dairy industry.

The industry in 2007

In late 2007 the Australian dairy industry is balancing the uncertainty faced by farmers, many of whom are looking at the prospect of re-emerging drought conditions for a second consecutive season, with the optimism that reflects the best world market conditions in decades.

International dairy commodity prices continue to rise in response to consistent strong demand and tight supplies. However, the benefits of record prices for Australian exporters have been offset to some extent by the strength of the local currency.

Farmgate prices in southern regions dipped slightly in 2006/07 from the record prices of the previous year. This was due to sales negotiated early in the year at lower prices and there was little product available for spot trade in the latter months of the season.

Nevertheless the strong international outlook has meant that significant increases in opening farmgate prices for the 2007/08 season were announced in all dairy regions. South-east Queensland and north-east New South Wales saw increases in milk prices, and drought assistance extended by the major companies, raising base milk prices by approximately 20% in the region to around 42 – 43 cpl. The West Australian dairy industry also saw base prices increase by a similar margin. Meanwhile, the major companies in the southern dairy industry – across Victoria, South Australia and Tasmania – announced increases in opening prices ranging from 30 - 40% - to an estimated price around 37 - 38 cpl (around $5 per kg milksolids). If step-ups through the season follow the traditional pattern of adding a further 10 – 15%, this would suggest an average southern milk price also in the range of 42 – 43 cpl ($5.70 per kg milksolids) for 2007/08.

These dramatic movements reflect the continued surge in world dairy prices; the increased competition for depleted milk supplies between dairy companies within Australia; and the tightening balance between supply and demand in the northern and western fresh dairy product regions of Australia. These prices will assist in improving the financial position of many drought-affected farmers; however, the extent of recovery will depend critically on conditions for the coming season.

The second major drought in five years affected almost 90% of dairy farmers; with many using the lessons of 2002/03, implementing plans to purchase feed and manage herds through the dry conditions. Dairy farm cash incomes are estimated to be 80% lower on average, as farmers have suffered reduced production, as well as a 43% increase in feed costs – with significant variations across the dairying regions.

A later than hoped for late autumn break tested the resolve of dairy farmers, many of whom faced a critical shortage of fodder that triggered a new round of herd culling.

Into the medium term, the market outlook for dairy remains positive. However, Australia's participation in world markets will depend on the industry's ability to recover from the 2006/07 drought and the confidence that farmers have to invest and grow into the future.

While there are some regional differences, climate has been identified in this year's survey as the major current and future challenge for most dairy farmers. The uncertainty surrounding future climate variability; what it means for current farming systems, access to water, inputs costs and future profitability is undermining the confidence of Australian dairy farmers in their future prospects, despite the very positive market outlook.

What did farmers say?

For the fourth successive year, the industry conducted the National Dairy Farmer Survey [NDFS] in February and early March 2007. Approximately 1,000 dairy farmers across all dairy regions were contacted and interviewed as part of the survey.

The continuing dry conditions throughout March and April prompted a short supplementary survey; where in late-April some 200 farmers in 5 regions were re-contacted, to determine if and how their plans and attitudes had shifted.

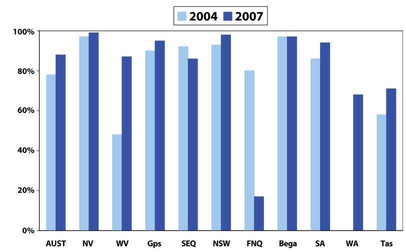
The NDFS results included the following findings.

Drought impact and planning

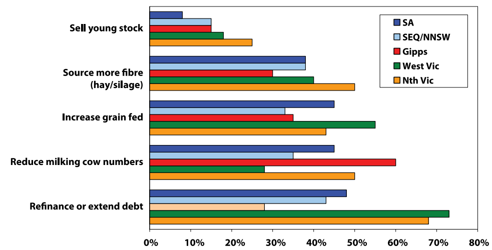
- Almost 90% of farmers were affected by drought in the last 12 months. Drought plans were implemented by almost 8 in 10 affected farmers, although few of them were written.

- The key objectives of most drought plans were to minimise financial losses (64% of affected farmers) or maintain asset base (57%).
- As part of their drought plan, dairy farmers mostly purchased additional feed supplies (52% of affected farmers), increased per cow feeding (48%), maintained young stock (48%) and culled their milking herd early (44%).

Percentage of farms affected by drought



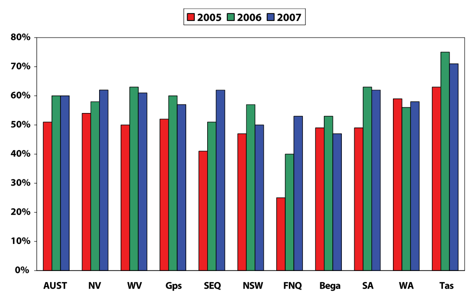
Management decisions - to cope with extended drought



Investment

- Despite the tough seasonal conditions, 60% of dairy farmers made on farm capital investments in the last 12 months, similar to the previous year.
- Machinery remained the main area of investment, however there were small increases in expenditure on irrigation plant, land and feed systems.

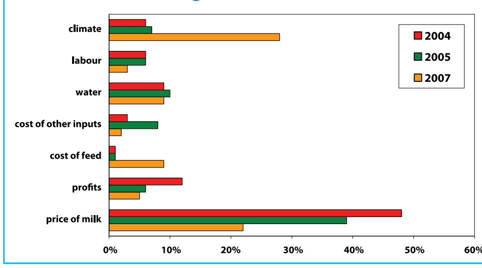
Percentage of farms investing in the last 12 months



Attitude and Challenges

- 54% of farmers felt positive about the future of the dairy industry, down from 61% in 2006.
- Tasmanian farmers were the most positive about the industry's future (72%) while Queensland farmers were least positive (35%).
- Concerns about drought and climate variability have overtaken price as the greatest current challenge for 32% of dairy farmers. Price remained the main challenge for 20% of farmers.
- Drought and climate will remain the major future challenge for 28% of farmers.

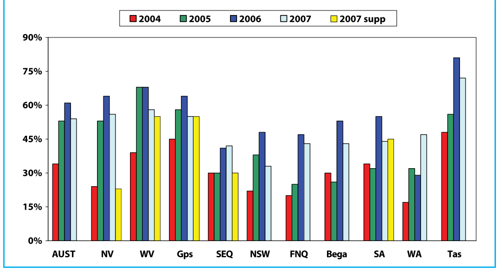
Percentage of farms nominating greatest FUTURE challenge



The April Supplementary Survey results include the following findings:

- In April, 23% of Northern Victoria/Riverina farmers remained positive about the future of the industry, compared to 55% in the main survey. Most farmers were unsure about the future (58%).
- Farmers in south-east Queensland / northern NSW were similarly less positive in April (30%) compared to February-March (50%).

Percentage of farms feeling positive about the industry future

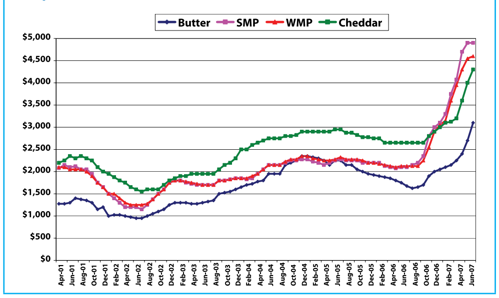


World market demand remains strong for dairy

The world market for dairy products has entered new territory in 2007, with commodity milk powder prices sustained well beyond traditional "ceilings" and approaching historically high spot prices of US$5,000 / tonne. Lower supplies from traditional exporting regions have pushed up the value of products to historically high levels, and demand has continued to prove resilient. Cheese and butter prices have also increased sharply in value.

A strong global economy has underpinned demand in importing countries. Growing consumption in large milk producing countries such as Brazil, Russia and China has kept them as net importers of dairy.

Surveyed spot prices of Australian exporters [$US / tonne]



As dairy prices rise, ingredient buyers traditionally consider substituting lower priced vegetable-based substitutes. However, strong demand – some of it bio-fuel induced - has raised prices of competing products. In addition, dairy's functionality is limiting the ability and willingness of end-users to further dilute dairy content in ingredient formulations. Instead they are either absorbing or passing on higher costs.

Improving perceptions of the nutrition, convenience and taste benefits of dairy is also driving consumer demand for dairy, particularly in developing countries.

World supply remains constrained

While Australian supply has been reduced by drought, other dairy exporters have struggled to fill the international trade gap.

The European Union [EU] has taken advantage of favourable market conditions to push ahead with reforms to its Common Agricultural Policy. Export subsidies on butter, cheese and milk powders have all been set at zero.

The EU dairy sector is also benefiting from increased consumption within the expanded EU – now comprising 27 member states. Increased internal cheese demand has seen a significant shift in EU product mix away from butter and powders; which has also meant that stocks have been reduced to zero.

US production growth is slowing, as rising feed grain prices start to affect farmer margins. Steady export volumes have effectively reduced stocks to zero.

Meanwhile, in New Zealand production growth has been steady, if unspectacular; while the South American countries of Argentina and Brazil have seen falling milk volumes during to severe flooding in the first, and rising feed costs across the continent, reducing the incentive to practice dairy farming.

Australian market

The Australian market for dairy products is a mature one, but has nevertheless delivered solid volume and value growth. Australians drink about 2 billion litres - just over 20% of annual milk production. A further 30% of milk production is consumed domestically in products such as cheese, dairy spreads and yogurt.

Supermarket sales of dairy products continue to grow steadily. Large supermarket chains account for around 55% of the Australian dairy market. In the face of little real growth in same-store sales, larger retailers are responding with strategies to cut supply chain costs, expand private label ranges and expand their convenience store networks. While private label already accounts for a large share of drinking milk sales, retailers are likely to take a more aggressive approach in the future, particularly in other dairy products such as cheese and yogurt.

Nevertheless, supermarket chains are feeling the impact of changing consumer lifestyles, which favour easier meal preparation and more out-of-home eating. The foodservice sector – cafes, restaurants, hotels - is growing at a faster rate than supermarkets. These outlets offer growing opportunities for dairy, although they are often more challenging to service.

DAIRYAUSTRALIA
Delivering for the dairy industry

2

Food Safety in the Australian Dairy Industry

Content

26 2.1 Introduction

26 2.2 Brief History of Food Safety in the Australian Dairy Industry

27 2.3 What Has Changed in the Regulatory Framework?

28 2.4 Australian Export and Domestic Food Manufacture Policies and Standards

29 2.5 AQIS and State Dairy Authorities

31 2.6 Traceability

33 2.7 Support Programs

34 2.8 Conclusion

34 FAQ

37 References

Abbreviations

ANZDAC	Australia New Zealand Dairy Authorities Committee
AMRA	Australian Milk Residue Analysis Survey
AQIS	Australian Quarantine Inspection Services
BVD	By-Products Vendor Declaration
CVD	Commodity Vendor Declaration
DFSV	Dairy Food Safety Victoria
ECOs	Export Control (Milk & Milk Products) Orders 2005
FSC	Food Standards Code
FSANZ	Food Standards Australia and New Zealand
NDV	National Vendor Declaration
NLIS	National Livestock Identification System
PGGOs	Prescribed Goods (General) Orders
SDAs	State Dairy and Safe Food Authorities
FSP	Food Safety Program

2.1 Introduction

Food safety is a very important part of Australian dairy food manufacturing, to ensure that dairy products are manufactured, stored and distributed in a safe and controlled environment.

All manufacturers of dairy products must have a current HACCP based Food Safety Program (FSP) before they can manufacture dairy product for both domestic and export markets. Dairy manufacturers are licensed by the relevant State Dairy and Safe Food Authority (SDA) for domestic production and must be registered with AQIS for export. Manufacturers' FSPs are regularly and independently audited to ensure they are being followed and comply with government and overseas customer requirements.

2.2 Brief History of Food Safety in the Australian Dairy Industry

Food safety is one of the main objectives of food regulation. Regulators responsible for developing food standards in Australia recognised that the best way to assure food safety is not just through a set of prescriptive requirements but also by requiring food businesses to implement auditable outcomes-based FSPs based on HACCP. The dairy industry adopted HACCP based FSPs first in the manufacturing sector, then in the production sector.

HACCP based FSPs for dairy manufacturers were introduced for Victorian manufacturers in the early 1990's. In the late 1990's all states made it compulsory for all new and current manufacturers to have a HACCP based FSP in place before they could start manufacturing. Manufacturers all over Australia have been continuously improving their systems since then.

Mandatory regulatory requirements for on farm FSPs were progressively introduced in all States during the early 2000s. This has ensured a whole chain approach to food safety across the dairy industry.

AQIS and the SDAs work very closely together to ensure a more uniformed approach to food safety using the support and expertise of FSANZ and the FSC.

Regulatory Framework Chart (from previous edition)

2.3 What Has Changed in the Regulatory Framework?

2.3.1 Current Legislative Framework

The legislative framework for export dairy production and manufacture is included in the Export Control Act 1982, Prescribed Goods (General) Orders (PGGO's) and the Export Control (Milk & Milk Products) Orders 2005 (ECOs) and the Food Standards Code (FSC).

2.3.2 Changes to the Regulations

New national regulations come into effect on 5th October 2008 under FSANZ – the Dairy Primary Production and Processing Standard. This will mandate FSPs at the national level (currently mandated by each State) across the dairy supply chain – with SDAs responsible to ensure they are implemented.

Changes have also occurred through the introduction of the ECOs in 2005 that replaced the Export Control (Processed Food) Orders 1992. The new ECOs are less prescriptive which means that manufacturers are more accountable for their own operations and must ensure that they comply with the requirements in the ECOs. Manufacturers must justify in more detail why and how they carry out and control: the collection of milk; the manufacture of various dairy products. Furthermore, maintenance of the premises must be shown to be regular and upto date. The whole FSP has to undergo an annual review to show that the program is currently still relevant. Manufacturers and farms are subject to mandatory audits under the regulations.

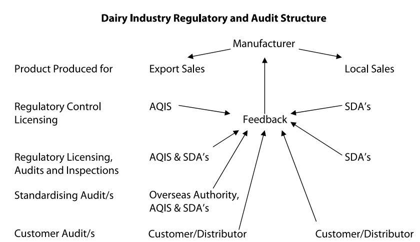
The manufacturer must be able to answer the question, "Show me the proof" to all aspects of their operations when being audited. This has seen a big shift in the way the regulations are implemented, with each manufacturer being more accountable through regulations for all dairy products manufactured.

2.3.3 External and Standardising Audits

External reviews of the Australian dairy food safety system (standardising audits) are regularly undertaken by importing countries such as the European Union (EU) and the USA. Regulators form these importing countries send audit teams to Australia to check that Australian dairy exports meet the regulatory requirements of the importing countries. This helps to verify that Australian dairy manufacturers are meeting or exceeding the benchmark of the world standards in both premises and manufacturing techniques. This also allows other importing countries to have a high level of confidence in the products imported from Australia. Other importing countries also carry out audits of the Australian dairy food safety system at various times.

The standardising audits (Figure 1) consist of a team from the importing country visiting a number of small, medium and large manufacturers with the AQIS and SDA regulators. The objective of these visits is to conduct an audit and compare notes at the end of the audit to see if the standard of the premises, production and food safety programs all meet the expectations of the visiting country.

Figure 1 Regulatory and Audit Structure



The findings of these audits are then further discussed between the visiting country, AQIS and SDAs to see if there are any areas of concern raised during the audits. If there are concerns, discussions followed by the corrective actions need to be taken and the time frames decided. Then a decision is made as to whether or not a return audit is required.

2.4 Australian Export and Domestic Food Manufacture Policies and Standards

2.4.1 Key points

- The system of food regulation policy and Standards in Australia and New Zealand is a co-operative arrangement between the Australian Federal, State and Territory governments and the New Zealand Government to develop and implement uniform food Standards.
- From this co-operation a body currently called the Food Standards Australia and New Zealand (FSANZ) was formed and a Food Standards Code (FSC) was developed which covers all aspects of food safety standards. The FSC covers ingredients and disclosures of all additives, uniform labelling of products to make sure size of print, nutritional information and the declaration of all allergens is included in a standard format. www.foodstandards.gov.au
- The standard for an exporting manufacturer's premises is covered under the Export Control (Milk & Milk Products) Orders 2005 which is the key document for all exporting manufacturers.
- The audits of domestic manufacturers are carried out by either SDA's or a third party auditing company contracted to the SDA.
- The Food Safety Program (FSP) is HACCP based and for exporters, must meet all the basic requirements for export registered premises.
- Export manufacturers are audited by either AQIS or the relevant SDA at the minimum rate of 3 audits per year (Figure 3).

2.4.2 Australian Quarantine Inspection Services (AQIS)

www.aqis.gov.au

AQIS is the Commonwealth Government body responsible for inspection and certification of Australian dairy products for export. It is the competent authority that sets export policy/regulations Australia wide, to ensure that all dairy products produced in Australia for export meet the requirements of importing countries .

AQIS is supported by a number of government, statutory authorities and industry (non-government) bodies that have input in various ways to support the formulation of these policies.

AQIS introduced the Export Control (Milk & Milk Products) Orders 2005, which superseded the previous Export Control (Processed Food) Orders 1992. The Export Control (Milk & Milk Products) Orders 2005 is used to ensure all export dairy manufacturers maintain their premises and implement Food Safety Programs (FSP).

2.4.3 Implementation of the Australian Dairy Food Safety System

The SDAs ensure compliance with the ECOs on behalf of AQIS in the prescribed timeframe of a minimum of three audits per year. These detailed audits ensure that the FSP is being followed, all records and testing are verified and the standard of the premises is being maintained.

2.4.4 Export Control

At all times during the production chain from the manufacturer through to the shipping of the export products, all dairy products must only be processed in or stored at export registered premises. As product is shipped from one export registered premises to another, Transfer Documentation must accompany the shipment as a means of tracking compliance to export requirements. All these registered places are audited by either AQIS or the SDAs according to the perceived food safety risk associated with either the processing or storage of the dairy products.

2.5 AQIS and State Dairy Authorities

2.5.1 Structure

AQIS is the Commonwealth regulator, which has control over all export registered dairy premises who want to manufacture products for export. AQIS has the authority to suspend or prevent the export of products until any faults found, are corrected. AQIS issues the export licences and handles all the export documentation.

The SDAs register all dairy manufacturers and issue licences in each state for domestic manufacture. SDAs also licence each dairy farm and are responsible for ensuring individual farmers comply with the State and Commonwealth legislation. If a company is found to be in breach of regulations, the company's export licence can be suspended. This prevents a company from exporting products until it can prove it has corrected the breach and has control of the situation that resulted in the regulators acting to suspend the licence or withholding the product from export.

2.5.2 Factory Registration

The factory registration includes:

- Applying to the relevant SDA for a licence to build, alter or renovate existing premises for the manufacturing of dairy products. If the intention is to export dairy products, an application for an AQIS registration must also be submitted at the same time.
- Plans must be inspected and approved by both SDA and AQIS, before any building or renovation occurs.
- A Food Safety Program must be submitted and approved for any new premises or renovation that will allow a new process or production line to be incorporated.
- When the premises are ready for licensing, an audit of the premises and food safety program is completed to ensure all requirements of the ECOs are met.
- After any faults found during audit have been rectified, the new or renovated premises are issued a licence and only then can product be produced for sale.
- Any new product that has been developed must have an accompanying food safety program that has been approved by AQIS and SDAs before production and sale of the product can occur.
- Any exporting premises must have a registration number received from AQIS and have evidence that they fully understand and are able to comply with all the export requirements and documentation.

2.5.3 The Audit System

Each factory is given a rating depending on the type and number of faults found during an audit.

Figure 2 Example of Faults and Ratings given

Fault Rating	Critical	Serious	Major	Minor
Example of Fault Found	Pasteuriser chart not working	Equipment with dirt / dust present on ledges	Damaged floor surface	Rust starting to show on equipment low down

Based on the inspection during each audit, the defects (non compliances) are given a rating of: Critical, Serious, Major or Minor. Corrective actions have to be implemented to ensure the non-compliance is corrected in a timely manner.

- Critical means the defect must be corrected immediately.
- Serious must be completed in seven days.

Both of these ratings means the manufacturer must be revisited by the auditor to ensure the defects have been corrected.

Major and Minor defects are given time frames for completion depending on the faults and the manufacturer must provide evidence at the completion of the defect and then all defects found will be inspected at the next audit.

During an audit, the auditor inspects the following items:

- Premises - to ensure that they are soundly constructed and maintained in good condition.
- Equipment - to make sure each piece is manufactured from food grade materials (product contact surfaces) and can be easily kept hygienic and maintained in good condition.
- Support Programs - these cover Management structure and quarterly meetings, Approved Supplier Program, Calibration Program, Cleaning and Sanitation Program, Pest Control Program, Product Sampling and Testing Program, Recall Procedure, Food Safety Review Program and Training.
- The auditor looks at all these programs and for any evidence to verify that the system is functioning correctly. If there is evidence that shows there is a problem, the auditor will look for evidence that corrective actions are in place to control the problem.
- Then the auditor will look at what action has been taken to ensure the fault has been corrected and the system modified (if required) to make sure the fault will not occur again.
- After all faults found are rated according to the rating system shown in Figure 2, they are then assessed against the rating system of Figure 3 to determine the audit frequency.
- A meeting is then held between the auditor and the factory representative to discuss any outcomes and completion dates required to fix any faults and discussions are held in relation to the audit and its findings.
- The type of faults and the final rating received will determine whether a follow-up audit is required.

Figure 3 Audit Rating System for Dairy Factories

Rating	Audit Frequency	Comments
A	4 monthly	Allowed to export
B	2 monthly	Allowed to export
C	1 monthly	Allowed to export
D	2 weeks	Not allowed to export

2.5.4 Export Audit Process

The SDAs work with and on behalf of AQIS by carrying out all the regular export audits on AQIS' behalf ensuring complete compliance with the regulations. If any non-compliances are found during the audits (See Figures 2 & 3 above) they are given a rating of Critical, Serious, Major or Minor and corrective actions have to be implemented to ensure the non-compliance is corrected in a timely manner.

The audit report is sent to AQIS and if a Critical non-compliance is found during an audit, the export licence is immediately suspended until the non-compliance is corrected. All Critical defects must be corrected immediately, any Serious defects must be completed within 7 days. Major and Minor defects are given time frames for completion that must be completed in a reasonable time and are inspected at the next audit. The manufacturer must be able to provide proof of completion of the defect to the auditor, by the time given.

Every year AQIS checks a sample of manufacturers, by completing a standardising (verifying) audit with the SDAs. During these standardising audits, an AQIS officer is present during the audit carried out by the SDA. After completion of the audit, the results are discussed to make sure that the interpretations of both AQIS and SDAs are the same.

As exports of dairy products to new and established markets increase, more audits from importing companies and countries are expected. All exporting Australian dairy companies have to continually monitor and improve their processes to meet both regulatory and customer demands.

2.5.5 Export Documentation

- AQIS controls all the documentation in relation to products being exported to ensure compliance with the regulations and to make sure all requirements of importing countries are met.
- The AQIS website www.aqis.gov.au is kept up to date with each country's requirements and all exporting companies have access to this website and must regularly check for any changes. AQIS also produce regular updates which are circulated to all export registered companies alerting them to any changes in exporting conditions.
- Checking of this website and receipt of the updates is part of the verification process during audits by auditors to ensure that manufacturers are keeping abreast of all changes.

The supporting bodies consist of:-
Food Standards Australia and New Zealand (FSANZ)
State Dairy and Safe Food Authorities (SDAs)

2.6 Traceability

All dairy products, as part of the food safety program, must have a code that can be used to trace the product through all stages of harvesting, production and distribution.

2.6.1 Animal Traceability

There is a full management system in place for the control of cattle for both milk and meat production in Australia via the National Livestock Identification System (NLIS).

- This system uses electronic tagging of all cattle and records all the details of the animal's history from birth to slaughter.
- Each farmer records and keeps records of all veterinary treatments for all animals and any pasture treatments for the property.
- If an animal is sold, a National Vendor Declaration (NDV) must accompany the animal to the selling agent and the new owner. More information can be obtained from the Meat and Livestock Australia website www.mla.com.au.

2.6.2 Stockfeed Traceability

- Any dairy farmer buying supplementary rations (stockfeed) for their cattle must obtain a declaration from the feed supplier - a Commodity Vendor Declaration (CVD) (see FAQ's 2) which will indicate if there has been any exposure of the feed to any chemical materials or Genetically Modified material.
- By-Products Vendor Declaration (BVD) (see FAQ's 2) is a declaration that the feed does not contain any animal by-products.

All this information is part of the basic record keeping requirements for each on farm Food Safety Program which is audited by the SDAs and the Dairy Manufacturers who purchase the milk. Each farmer must keep records of pesticides purchased and used for spraying of any crops and pastures and the rates of usage, dates of spraying and with-holding periods of cattle from any pastures that have been sprayed.

The same applies with any veterinary medicines purchased by the farmer or any veterinarian who attends to any farmers cattle. The veterinarian must notify the farmer of any withholding period after the treatment.

All this information must be documented by dairy farmers and presented to SDA approved auditors during audits by SDAs and the dairy company purchasing the milk from the farm.

2.6.3 Product Traceability

Product traceability is the ability to be able to trace all ingredients used in the final products from their original source, the supplying farmer or ingredients' manufacturer, through all the various stages of transformation till they finish up in the final product produced by the dairy manufacturer. It also involves the ability to trace final product from the customer/consumer back to the manufacturer.

Product traceability is important and there are systems in place to trace inputs from farm to fork.

- That means that dairy farmers must have systems in place to record all inputs, including: all stockfeed purchased; all herd health and veterinarian treatments of cattle; all fertilisers, weed and pest sprays used to treat pastures to improve the health of the pastures for better feed production; water used for stock.

- This carries through to the manufacturer of dairy products who test the milk received for presence of antibiotics
- SDAs and AQIS conduct a national monitoring program (Australian Milk Residue Analysis – AMRA- Survey) of milk for the presence of any agricultural or veterinary chemical residues in milk received at the manufacturer's premises.

2.6.4 Dairy Products Manufacturer

During manufacture, records are completed to allow full traceability of all ingredients and treatments that each batch of product receives. Once product is manufactured, tests are then carried out in a systematic way to ensure the products produced are fit for human consumption. The manufacturer must have records of where the final product has been stored and/or shipped, enabling full traceback from the customer in the advent of a food recall.

2.7 Support Programs

2.7.1 Agricultural and Veterinarian Chemical Testing

The Australian Milk Residue Analysis (AMRA) Survey monitors farm milk across Australia for agricultural and veterinary chemical residues. This key independent monitoring program is coordinated by DFSV on behalf of Australian New Zealand Dairy Authorities Committee (ANZDAC). ANZDAC undertakes a risk analysis to determine the sample frequency and the targeted chemical residues to be monitored. These are reviewed annually and the testing regime amended according to the revised risk analysis or as intelligence is received of any new or possible emerging chemical risks.
Additional antimicrobial testing is carried out by each manufacturer on all milk supplied daily and is constantly being reviewed as new or more sensitive test kits are being developed.

2.7.2 Food Bio-Security for Victorian Dairy Products: Project MP1/016

This is a collaborative project with a number of key partners and objectives and updated information on this project can be obtained from the website www.dairysafe.gov.vic.au.

2.7.3 Cold Chain System

The Cold Chain System was introduced by South Australia in 2005 as a support program to the current export system. It was developed to enable both exporters from Australia and importing countries in Asia to have systems in place that ensures products are handled and stored correctly and uniformly during exporting to enable products from Australia to arrive in Asia in the best possible condition. The Cold Chain System covers both chilled and frozen products and products being transported either by sea or by air. This system was developed after a study of handling and storage techniques found that there were discrepancies in the control and handling of both chilled and frozen goods being exported. Some of the problems found related to unloading times or delays with products being left on tarmacs and wharves without being immediately placed into the relevant chilled or frozen storage. Another major issue was the use of non-refrigerated and frozen transport during distribution once product had arrived in importing countries.

Web links:
SAFC South Australia Freight Council Inc – *http://www.safreightcouncil.com.au*
Cold Chain Centre – *http://www.coldchaincentre.con.au*

2.8 Conclusion

Food Safety Programs (FSPs) are an integral part of the Australian dairy industry for the production of safe food from paddock to fork. These programs also ensure the products are produced to meet both domestic and overseas customer requirements. The programs are vigorously and regularly reviewed by both internal and external audits.

There is close collaboration between AQIS and the SDAs to ensure regulations are in place and appropriately implemented. This provides a very sound base for the manufacture and control of all dairy products that are produced in Australia for both domestic and export markets.

FAQ

1. *How can the importer know if Genetically Modified (GM) ingredients have been used?*
   This can be checked by obtaining a declaration from the manufacturer. The manufacturer can further trace back to its supplier – manufacturers require all suppliers to obtain and record in their on farm FSPs declarations they receive from their cattle feed suppliers about the GM status of dairy feeds.

2. *What type of questions are contained in the various Declaration Forms and information to be supplied by feed suppliers?*
   Fodder Declaration - Has the fodder been tested for pesticide residues? If Yes attach a copy of the results to the delivery docket.
   Does the property from where the fodder is grown carry accreditation under an independently audited QA program? If Yes give details of the program.
   Commodity Declaration - Does the property from which the commodity is grown, or where the commodity is stored carry accreditation under an independently audited QA program which includes chemical residue management for the commodity being supplied?
   If any chemicals were applied to the product, were they registered for use on that product, were all chemicals applied in accordance with the directions on the label and have all withhold

periods on the label been adhered to prior to harvest?

Was the commodity tested for chemical residues? If Yes attach copy of tests with delivery of commodity.

If chemicals are applied to the commodity while under your control then supply details of chemicals used, rate of usage, date of application and withholding period.

Was any of the commodity subject to any spray drift from a neighbouring property?

Does the product conform with requirements relating to Specified Risk Material (SRM)?

By-Product Declaration - Do you have a declaration from the grower of the parent commodity or other evidence to confirm that any chemicals applied to the parent commodity were registered for use on that commodity, that all chemicals were applied in accordance with the directions on the label and that all withhold periods on the label were adhered to prior to harvest?

Has any chemical been applied while under your control? If Yes supply a copy of all details of the chemicals used, rate of usage, date of application and withholding period that applies.

Does the product conform with requirements relating to Specified Risk Material (SRM)?

3. *What are the controls for the transportation of liquid milk from farm to manufacturer?*

Milk must only be transported in suitably registered tankers of either an approved transport company or manufacturer in stainless steel insulated tankers that are used solely for the carting of food grade dairy products. The tankers must be washed and maintained according to the company's cleaning and sanitation and maintenance programs. Records of cleaning and maintenance must be kept for auditing purposes.

SDAs currently regulate milk transport, including audit requirements – this will also be covered under the FSANZ Dairy Primary Production and Processing Standard.

4. *What are the controls for the storage of milk on the farm?*

The milk must be cooled and stored in a suitable stainless steel refrigerated milk vat/silo at 5°C or less and must be collected at least every second day. The cooling ability of the vats/silos must meet the Australian Standard AS 1187-1996 Farm Milk Cooling and Storage Systems. Records of vat temperature must be kept as part of mandatory FSPs.

5. *What are the controls for the storage of milk at the manufacturers?*

Milk must be stored in insulated or refrigerated storage silos or vats that have suitable CIP systems that will ensure the silos/vats can be properly cleaned and sanitised. Records need to be kept to verify that cleaning and sanitation is carried out in accordance with their food safety programs.

6. *How is traceability during processing milk into milk products confirmed?*

Products have to have full traceability during production and this is confirmed internally at least annually by carrying out a mock recall to ensure that traceability is maintained throughout the processing and distribution systems. These mock recalls are confirmed during regular regulatory audits on the manufacturers by the auditor.

7. *How can exporters be sure the regulations are working?*

Evidence can be seen that the regulators are keeping a close watch on manufacturers by the audit results and the continuing licencing of manufacturers. As well, manufacturers are required under legislation to recall products due to the following main issues:

- Bacterial contamination in products that is either found by regulatory testing or by the companies own testing programs.
- Foreign Matter contamination found in products by manufacturers, regulators or consumers.
- Labelling that does not include a full list of ingredients that is included in some products.
- Labelling that does not declare all possible allergens.

8. *What are the controls on exporting milk and milk products?*

First and foremost, export products and exporting manufacturers must meet national standards, that are based on CODEX. As well, AQIS makes sure that all exporting companies are fully aware of all the importing country's requirements relating to ingredients, labelling and microbial standards. These requirements must be met before products can be certified for export by AQIS and exported. Again regulatory audits ensure compliance with these requirements by all manufacturers.

9. *What are the controls on documentation for exporting dairy products?*

Export registered establishments are required by legislation to keep all documentation in relation to manufacture and testing of all export dairy products and maintenance of their machinery for a minimum of three years. All documents have to be made available to all regulatory audits for the perusal of the auditor/s.

AQIS is responsible for issuing export certificates to export registered establishment, ensuring compliance with importing countries requirements. Any additional commercial requirements are agreed by importing customers and exporting manufacturers.

References

Websites –

www.aqis.gov.au
www.foodstandards.gov.au
www.dairysafe.vic.gov.au
www.foodauthority.nsw.gov.au
www.safefood.qld.gov.au
www.sa.gov.au
www.dpiw.tas.gov.au
www.population.health.wa.gov.au
www.dpiw.tas.gov.au

DAIRY AUSTRALIA
Delivering for the dairy industry

3

Raw Milk Quality Assurance in Australia

Content

39 3.1 Introduction

41 3.2 Milk Composition and Flavour

43 3.3 Contaminants of Raw Milk

51 3.4 Milk Spoilage Caused by Natural Milk Constituents

51 3.5 Storage and Transport of Raw Milk (Cold Chain)

54 3.6 Testing of Raw Milk: Standards, Methodologies and Interpretation of Results

56 3.7 Restrictions on the Sale of Raw Milk and Products Made from Raw Milk

56 3.8 Regulation of Raw Milk Quality

56 3.9 Dairy Company Programs for the Management of Raw Milk Quality

57 3.10 Recent Developments in Testing Methodologies

58 3.11 Conclusions

58 FAQ

70 Glossary

71 References

3.1 Introduction

3.1.1 Definition of Raw Milk

Milk is defined in Standard 2.5.1 of the Australia New Zealand Food Standards Code as follows:
'Milk means the mammary secretion of milking animals, obtained from one or more milkings for consumption as liquid milk or for further processing but excludes colostrum.'

The Code also sets out the minimum requirements for the composition of cow's milk. It is stated in Standard 2.5.1 that packaged cow's milk for retail sale must contain each of the components listed in column 1 of the table below in the corresponding proportion specified in column 2.

Column 1	Column 2
milk fat	minimum 32 g/kg
protein (measured as crude protein)	minimum 30 g/kg

The composition of packaged cow's milk for retail sale may be adjusted to comply with the compositional requirements in the above table by the addition of and/or withdrawal of milk components, provided the adjustment does not alter the whey protein to casein ratio of the milk being adjusted.
Note: The Food Standards Code was published by Food Standards Australia New Zealand (2002) and a copy can be viewed on their website- http://www.foodstandards.gov.au/thecode/foodstandardscode.cfm

The official definition of milk that has been adopted in Australia differs slightly from that adopted by the Codex Alimentarius Commission (1999), which reads as follows:
'Milk is the normal mammary secretion of milking animals obtained from one or more milkings without either addition to it or extraction from it, intended for consumption as liquid milk or for further processing.'

Raw milk is defined by the Codex Alimentarius Commission (2004) as milk that has not been heated beyond 40°C (which is the upper limit of the body temperature range for a healthy cow) or undergone any treatment that has an equivalent effect on the milk. The normal core body temperature of a healthy, resting cow is cow is 38.6°C; however a cow's body temperature can range from 37.8°C to 40.0°C.

The discussion on raw milk quality for the purposes of this paper is confined to cows' milk. It covers the period that commences with the milking of the cow and concludes with the processing of the raw milk by pasteurisation or an equivalent treatment. During this period, the raw milk will be filtered, cooled, stored, agitated, pumped and transported on one or more occasions, but not heat treated in any way.

3.1.2 Overview of Hygienic Milk Production Systems in Australia

Raw milk quality issues are discussed in this chapter from the perspective of the Australian dairy industry. Some key points about the Australian dairy industry of relevance to this discussion are:

- Owner-operated farms dominate the Australian dairy industry, i.e. the owner of the farmer also operates the farm, sometimes with the help of hired labour.
- There were about 8,900 dairy farms in Australia in 2006. Average number of milking cows per farm was 224; however, the number of cows per farm varies widely.
- The dominant breed of dairy cattle in Australia is the Holstein Friesian, which accounts for 67%

of all dairy cattle. Other important breeds are the Jersey (10%) and Holstein/Jersey crosses. Other breeds include the Illawara/Australian Red, Guernsey, Brown Swiss and Ayrshire.

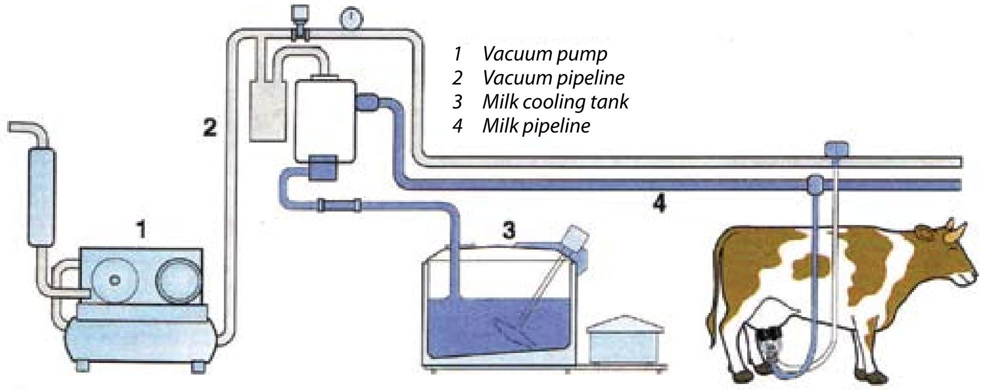
- Australia's climate and natural resources are generally favourable to dairying and allow the industry to be predominantly pasture-based, with approximately 75% of the cattle feed requirements coming from grazing. The balance of the feed intake is mainly in the form of grains, hay and silage, which are fed to improve milk yield and composition. Seasonality is most evident in south-eastern Australia, where milk production peaks in October/November and tapers off in the cooler months of May/June. However, the seasonality of milk output in Queensland, New South Wales and Western Australia is much less pronounced, due to a greater focus on drinking milk and fresh products in the product mix of these states.

For more information about the Australian dairy industry, refer to Sections 1.0 and 3.0 in the chapter titled '*An Introduction to the Australian Dairy Industry'* in this manual, and also to the publication *Australian Dairy Industry in Focus* (Dairy Australia, 2006).

Holstein dairy cows – the most popular breed of dairy cattle in Australia – grazing pastures, the main source of feed for dairy cows in Australia

On most farms, cows are machine-milked twice each day in a central milking shed on the farm, widely known as a 'dairy'. The cows are herded into the dairy from the pastures or feeding areas for milking and return to the pastures or feeding areas as soon as they are milked. The milk is cooled to and then stored at 4°C or less (typically 2-3°C) in an insulated stainless bulk milk tank or silo on the farm.

Depending on the capacity of the storage tank or silo and the policy of the milk processing company, the milk is collected from the farm usually after a maximum of four milkings and transported to the processing factory in an insulated stainless steel road tanker. At the processing factory, the milk is pumped into an insulated storage silo where it is held, usually for a maximum of 48 hours, prior to pasteurisation and further processing as required to convert the milk into end-products, e.g. liquid drinking milk, cheese or dried milk.



General design features of a dairy with a pipeline milking machine and cooling of milk to less than 4°C by direct expansion coils in the wall of the milk storage tank

Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

3.2 Milk Composition and Flavour

Milk is secreted by female mammals to provide their offspring with their complete nutritional requirements. However, milk also has several physiological functions in the young including protection (immunoglobulins and other antibacterial agents), digestive aids (enzymes and enzyme inhibitors, binding or carrier proteins) and growth factors/hormones. Because the nutritional and physiological requirements of each species of mammal differ, the composition of milk shows marked inter-species differences (Fox, 2003). The gross composition of the main commercial dairy species is shown the table below, together with that of human milk.

Typical composition (%) of milk from the main commercial dairy species and humans (after Fox, 2003).

Species	Total solids	Fat	Protein	Lactose	Ash
Cow	12.7	3.7	3.4	4.8	0.7
Buffalo	16.8	7.4	3.8	4.8	0.8
Goat	12.3	4.5	2.9	4.1	0.8
Sheep	19.3	7.4	4.5	4.8	1.0
Human	12.2	3.8	1.0	7.0	0.2

However the gross composition of milk belies its great complexity. For example, it has been reported that milk fat contains up to 400 fatty acids, resulting in several thousand triglycerides and complex lipids. In addition to the eight main proteins (α_{s1}-, α_{s2}-, β- and κ-caseins, β-lactoglobulin, α-albumin, blood serum albumin and immunoglobulins), milk contains at least 80 minor proteins, including approximately 60 enzymes. The ash fraction of milk contains at least 30 elements, which are important from technological, stability and nutritional viewpoints. Milk contains all known vitamins, some at quite high concentrations (Fox, 2003).

Milk is a highly variable biological fluid. The composition of cows' milk will vary with the individual animal, the breed of cattle, health of the animal (mastitis and other diseases), nutritional of the feed supply, stage of lactation, age of the cow and interval between milkings. Variability in milk composition due to these factors is evened out by co-mingling of milk from many farms at the processing factory, but some variability will persist and might be quite large when milk is produced on a seasonal basis. In addition, the actual structure of some of the constituents also varies, e.g. the fatty acid profile of the milk fat is strongly influenced by the cow's diet. The variations in the concentrations and properties of milk constituents can cause variations in the processing properties of milk and hence in the quality of dairy products. Some of the variability can be minimised by animal husbandry practices or processing technology, but some differences may persist (Fox, 2003).

From a physiochemical viewpoint, milk is a very complex fluid, the constituents of which occur in three phases. Quantitatively, about 40% of the dry matter of milk is a true solution of lactose, organic and inorganic salts, vitamins and other small molecules in water. In this aqueous solution are dispersed proteins, some (the whey proteins) at a molecular level, others (the caseins) as large colloidal aggregates (micelles) ranging in diameter from 50 to 600 nm, and lipids which exist in an emulsified state as globules ranging in diameter from 0.1 to 20 µm and stabilized by a lipoprotein membrane, known as the milk fat globule membrane (Fox, 2003).

Milk has a slightly sweetish taste due to the lactose, which has a low level of sweetness in comparison with other common sugars such as glucose and sucrose. The pleasant mouth feel of milk is due to its colloidal constituents, as well as the fat. The white colour of milk (appearance) of milk is due to the scattering of light by the colloidal particles, especially the casein micelles. Other physical properties of milk, e.g. freezing point and pH, are mainly determined by the low-molecular-mass compounds present in true solution (Fox, 2003).

Fresh milk is slightly acid in reaction, having a pH of 6.5 to 6.7. Because of many variables, it is difficult to give a definite value for titratable acidity, but the acidity of normal milk usually varies between 0.15 and 0.18% expressed as lactic acid (Webb ***et al.***, 1974).

The osmotic pressure of milk — and hence also its freezing point — is equal to that of the blood of the animal secreting it; hence the percentage of lactose and ash found in milks varies within narrow limits and is nearly constant for milk from a single species. Any increase or decrease in lactose content is compensated by a decrease or increase in other soluble components (Webb ***et al.***, 1974).

Milk was intended to be to be consumed directly from the mammary gland and to be expressed from the gland at regular intervals. However, in dairying operations, raw milk is stored for various periods ranging from a few hours to several days, during which it is cooled and agitated. These treatments will cause at least some physical changes and permit some enzymatic and microbiological changes which may impact adversely on the quality of the milk. Raw milk is thus a highly perishable product; however this perishability can be managed by a well-organised and efficient dairy industry (Fox, 2003).

Dairy products are susceptible to a wide range of quality defects. Some of these can originate in the feed of the milk-producing cow or arise from microbial, chemical or physical contamination of the raw milk during production, transport or storage. Testing of milk for all possible defects, including off-appearances, off-texture and off-flavour using laboratory equipment would be extremely laborious and may not be successful. For example, the compounds responsible for many off-flavours are present in concentrations below the detection limits for even sensitive laboratory equipment. In contrast, however, applications of sensory evaluation for quality control and quality judging in the dairy industry by experienced quality assessors have a history well in excess of 50 years (Delahunty, 2003).

Sensory evaluation of milk quality by trained operators is a key acceptance test for raw milk before it is collected from the farm and it is accepted at the processing factory. This process is termed 'milk grading'. However, sensory evaluation of raw milk is now usually restricted to an assessment of the suitability of the milk based on its odour and appearance, as the industry considers that tasting of the milk represents an unacceptable health risk to the taster.

3.3 Contaminants of Raw Milk

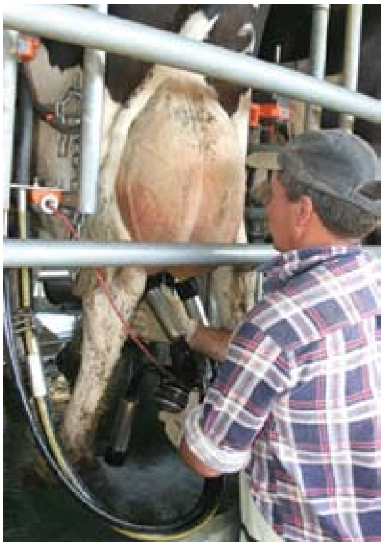
Milk must have a desirable chemical composition and be of a satisfactory hygienic quality. It must be wholesome and safe for humans to consume. This is essential in relation to public health, the quality of products made from milk and the suitability of milk for processing. Components that are foreign to milk from a well-fed and healthy cow, but enter the milk before, during or after milking, as well as any changes that occur in the milk as a consequence of this contamination, are often detrimental to milk quality or safety. The various types of milk contaminants, their sources and their effects, are discussed below.

3.3.1 Microbial Contaminants

The milk in a healthy udder is essentially free of microorganisms; however it is subject to contamination with microorganisms from several sources as soon as the milking process is commenced. These sources include: the teat canal and the exterior surface of the teat during the milking process, the environment (e.g. water, soil, dust), milking equipment and milk lines, farm bulk milk storage tanks or silos, the milk collection tanker, milk lines and pumps at the processing plant and the raw milk storage silos at the processing plant. Cows with mastitis can shed high numbers of the particular bacterium that is causing the udder infection in the milk (Frank and Hassan, 2003; Slaghuis ***et al.***, 2003; White, 2003).

Some microorganisms move up the teat canal causing aseptically drawn milk to be contaminated; these organisms are known as udder commensals and are part of the normal udder microflora. The udder commensals usually contribute relatively low levels of contamination to the milk, typically in the order of 1×10^2 – 1×10^3 colony-forming units (cfu) per mL; contamination from this source is largely unavoidable. The normal microflora of the udder is dominated by streptococci, staphylococci and micrococci (Frank and Hassan, 2003; Heeschen, 1996; White, 2003).

Further microbial contamination of the milk will occur during the milking process. However, provided hygienic milking practices and equipment are used, the total bacterial count of the milk in the farm storage vat should not exceed 1×10^4 cfu per mL. However, immediate cooling of the milk to below 4°C is required to ensure that growth on the contaminant bacteria is prevented or at least minimised. Under appropriate conditions of storage and provided the period of storage on the farm does not exceed two days, the total bacterial count of the milk when collected from the farm can be expected to be in the range in the farm 1×10^3 to 5×10^4 cfu per mL. Spoilage of cold-stored milk due to microbial activity can be first detected by sensory methods if the total bacterial count of the milk exceeds between 1 x 10^6 and 1 x 10^7 cfu per mL; however an exact count at which this occurs cannot be specified because the spoilage threshold will vary with the composition of the microflora and the storage history of the milk (Heeschen, 1996).


Teat cups–a component of machine milking equipment–being applied to the teats of a cow

Streptococcus agalactiae and Staphylococcus aureus are the species of bacteria most commonly implicated in the infection of the mammary gland known as mastitis. However, there are other causative agents, including ***Streptococcus dysagalactiae, Streptococcus uberis*** and ***Escherichia coli*** (Bramley and McKinnon, 1990). Milk from quarters of the udder infected with ***S. aureus*** usually has a bacterial count up to about 1 x 10^4 cfu per mL; however milk from quarters infected with ***Str. agalactiae*** can have bacterial counts in excess of 1 x 10^6 cfu per mL (Heeschen, 1996).

The microflora of raw milk is usually comprised of a diverse range of organisms, which can be divided into the following broad groups:

- **Lactic acid bacteria.** This group includes the streptococci, lactococci and lactobacilli. Milk is the original source of the commercial lactic cultures used in the manufacture of products such as cheese and yoghurt. If milk is not cooled immediately, these organisms can multiply quickly in the milk and produce lactic acid, resulting in a sour taste and eventually coagulation of the milk. These defects can be evident within a few hours under favourable conditions (refer FAQ B5). Cooling of the milk to below 4°C inhibits the growth of the lactic acid bacteria.

- **Thermoduric bacteria.** This group is typically comprised of Gram-positive organisms and includes the vegetative cells of the genera ***Microbacterium*** and ***Micrococcus*** and spores of the genus ***Bacillus***. Thermoduric bacteria are able to survive pasteurisation. These organisms have relatively little impact on the quality of raw milk provided it is cooled to below 4°C. Some of them will contribute to the bacterial count of pasteurised milk and other products, and the spores of ***Bacillus*** can germinate in heat-treated milk and cause quality defects in products such as pasteurised milk and cream and UHT milk.

  A thermoduric count on farm milk is regarded as a good indicator of the standard of hygiene of the milking equipment, and some dairy companies routinely test their farm milk supplies for this purpose. A count of less than 2 x 10^3 per mL is indicative of a high standard of hygiene in the dairy.

  Thermophilic bacteria are a sub-group of the thermoduric bacteria that can cause quality problems in dairy products processed at high temperatures and with long production runs, e.g. milk powder and evaporated milk. These are usually aerobic spore-forming bacteria (***Bacillus*** spp.), which have their origins in raw milk. They are able to survive pasteurisation and form biofilms on the equipment surfaces in the hot section of the plant, where they can grow quickly and contaminate the product (Craven ***et al.***, 2001).

- **Psychrotrophic bacteria.** This group of bacteria can grow in milk at refrigeration temperatures, albeit slowly. They are mostly Gram-negative rods, with ***Pseudomonas*** the most common genus and ***Ps. fluorescens*** the most common species. ***Ps. fluorescens*** has a doubling time of about 10 hours at 4°C. If the initial psychrotrophic count in the milk was 1 x 10^4 cfu per mL, this could increase to about 1 x 10^6 per mL in four days.

  The psychrotrophic bacteria can be very detrimental to milk quality, especially as heat-stable proteases and lipases are produced by many of these bacteria. Thus not only might the quality of the raw milk be affected adversely by these organisms, but the heat-stable proteases in particular will remain active in the processed product and can affect the quality of products such as cheese and UHT milk.

  To avoid the adverse effects of psychrotrophic bacteria on the quality of milk and other dairy products, it is essential that the milk is produced, stored and handled using hygienic equipment and methods, stored below 4°C and pasteurised within three days of first production if possible, otherwise within four days. The psychrotrophic bacteria will eventually become the dominant component of the microflora of raw milk during extended periods of cold-storage.

- **Coliforms.** Coliforms including ***E. coli*** can occur in raw milk. While their presence in pasteurised products is indicative of poor plant hygiene and processing practices, no particular significance is usually attached to their presence in raw milk provided the milk is stored below 4°C and not consumed as raw milk.

- **Pathogens.** There are many pathogenic microorganisms that can occur in raw milk; the more common among these include: ***Salmonella, Listeria monocytogenes, Campylobacter jejuni, Staphylococcus aureus, E. coli, Yersinia enterocolitica, Bacillus cereus and Streptococcus pyogenes.*** All of these organisms are destroyed by pasteurisation. Consumption of unpasteurised milk should be avoided.

  Raw milk can be a vehicle for transmission of the zoonotic bacterial agents ***Mycobacterium bovis*** and ***Brucella abortus***; however both of these organisms have been eliminated from the Australian dairy herd (Bramley and McKinnon, 1990; Frank and Hassan, 2003; Heeschen, 1996; White, 2003).

Cows being milked in a rotary dairy

3.3.2 Somatic Cells

Mastitis is an inflammation of the mammary gland, generally caused by an intra-mammary microbial infection, which results in altered composition of milk. The two main methods used by industry for the detection of mastitis are: (i) visual examination of the raw milk for clinical signs such as clots and flakes, and (ii) the determination of the somatic cell count (SCC) of the milk. Somatic cell counts are white blood cells and their count in the milk increases during inflammation. When clinical signs are observed in milk from a quarter of the udder, the milk by definition is abnormal.

There is no single SCC that can be said to be the dividing line between normal and abnormal milk. Nevertheless, most mastitis research workers agree that the SCC of normal, healthy quarters of first-lactation heifers without any previous history of udder infection should be less than 100,000 cells per mL of milk, with a SCC greater than 200,000 cells per mL indicative of the presence of inflammation and infection, at least in young cows. However, older cows with a previous history of mastitic infection can produce milk with much higher cell counts, e.g. 200,000 – 400,000 cells per mL, without any evidence of clinical mastitis. In cases of severe infection of a quarter, the SCC of the milk from that quarter can exceed 10 million cells per mL (Anon., 2005; Smith, 2002). Sub-clinical mastitis occurs when the level of the infection of the mammary gland is sufficient to cause elevated cell count, but not clinical signs of infection such as clots.

Broadly speaking, the higher the somatic cell count of milk, the lower its quality particularly its manufacturing properties. High cell counts are also indicative of poor practices on the farm especially in relation to the milking process and animal health.

3.3.3 Residues of Antimicrobial Products Used to Treat Infections in the Cow

Antimicrobial drugs and other chemotherapeutic drugs such as sulfonamides are widely administered to individual farm animals for the treatment of bacterial infections or prophylactically to prevent the spread of disease, to augment growth of the animals and increase yield of animal products. In the case of dairy cows, the most commonly used antimicrobials are the antibiotics used to treat mastitis. Other diseases of dairy cows that can be treated with antimicrobials include laminitis, respiratory diseases and metritis.

Numerous antimicrobial products are available for the therapeutic treatment of clinical mastitis during the cow's lactation period, and also for prophylactic use as a preventative treatment of all cow at drying off; this latter use of antimicrobials is known as 'dry cow therapy'. Both types of these antibiotic preparations are usually administered as intra-mammary infusions, though the former can be administered systemically in severe cases.

However, regardless of method of administration to the animal, all antimicrobial drugs used for the treatment or prevention of mastitis (or other diseases) can enter the milk to a certain degree.

The presence of residues of antimicrobial drugs in milk is important for two main reasons:

- **Technological impacts.** Antimicrobial residues lead to partial or complete inhibition of acid production by lactic starter cultures during production of fermented milk products such as cheese and yoghurt, inadequate ripening and ageing of cheese and changes in the flavour and texture of these products.

- **Health impacts.** Some consumers may exhibit allergic reactions to residues of antibiotics and/ or their metabolites present in the food that they consume, mainly the β-lactam antibiotics. Of the various types of antimicrobials used to treat mastitis, the β-lactam antibiotics penicillin and penicillin derivatives are the most widely used for lactating cows, either alone on in combination with other antimicrobial substances. Other antimicrobial groups in common use are the aminoglycosides, macrolides and the sulfa drugs.

  A general concern with the widespread use of antimicrobials in both the animal industries and human medicine is the potential development of antibiotic–resistant pathogens. All antibiotics can select for resistant bacteria and the presence of antibiotic residues in milk provides another avenue for this to occur. It has been also shown that antibiotic-resistant bacteria and resistance genes can be transmitted from animals to humans via the food chain (Fischer ***et al.***, 2002a; Honkanen-Buzaiski and Suhren, 1999).

Management of residues of antimicrobials in milk requires an integrated approach by Government agencies, the dairy companies and the dairy farmers.

In Australia, all agricultural or veterinary chemical products including antimicrobials for administration to dairy cows must be registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) before they can be supplied, distributed or sold anywhere in Australia. Registration ensures that the product is safe to use and will work when used according to the label. As part of the registration process, a withholding period is set for each product. Maximum residue limits (MRLs) for the chemical in milk may also be set if appropriate.
Note. For more information on the APVMA and its role, refer to refer to Section 7.17 in the chapter titled 'An Introduction to the Australian Dairy Industry' in this manual and to the APVMA website http://www.apvma.gov.au/)

Antimicrobials with MRLs for milk include Benzyl G Penicillin (0.0015mg/kg), Streptomycin (0.2mg/kg), various Sulfonamides, e.g. Sulfadiazine (0.1mg/kg) and Tetracycline (0.1mg/kg). In each of these cases, the MRL is set at about the limit of determination. The Australia New Zealand Food Standards Code does not specify MRLs for some registered antimicrobials (Food Standards Australia New Zealand, 2002). Thus, in effect, it is illegal to sell milk in Australia containing any detectable antimicrobial residues.

Dairy companies receiving milk from producers must continually monitor their milk supplies for the presence of antibiotics residues.

Managing the administration of antimicrobials to dairy cows for mastitis treatment or for any other purpose is an important activity for all milk producers.

3.3.4 Chemical Residues (Other Than Antimicrobials)

Chemical residues in milk can be grouped into several broad categories, depending upon their source:

- **Agricultural pesticides.** This group of chemicals includes insecticides, herbicides and fungicides used in the production of the crops and pastures fed to dairy cattle. The chemicals gain entry to the milk via the cow's body, which yields secretory residues of the pesticides that can pass through the blood-milk barrier into the milk.

However, with most of the modern pesticides now in use, usually no more than 5% of the quantity ingested in the feed reaches the milk. The remainder of the chemical is metabolized in the cow's body or excreted in the cow's urine or faeces. With adoption of Good Agricultural Practice, residues of pesticide chemicals should not occur in milk, or if they do, occur at levels well below the prescribed MRL (Bluthgen and Tuinstra, 1997).

Good Agricultural Practice includes using only registered agricultural chemicals in accordance with the directions on the label and observing the Withholding Period for Grazing. Depending on the product and the crop, the Withholding Period for Grazing can range from nil to 28 days. In Australia, a system of Vendor Declarations requires vendors of stock feed to declare if the feed has been treated with an agricultural chemical and, if it has, to provide the name of the chemical used and date of last application.

Several decades ago, organochlorine insecticides such as DDT, dieldrin and chlordane, did create residue problems in dairy products. There were two reasons for this: (i) they were persistent in the environment and (ii) they were lipophilic, which caused them to accumulate in the milk fat. However, the use of this class of chemical has now been banned. Any farms with patches of soil containing high residual levels of these chemicals have now been identified and the use of these areas is under Government supervision to ensure that the residues do not enter the human food chain.

- **Parasiticides.** Parasiticides are chemical agents that are administered to cattle to control either endoparasites such as helminths and liver fluke, or ectoparasites such as ticks and also biting flies. With a few exceptions, most chemicals for the treatment of endoparasites cannot be used on lactating cows in Australia. Chemicals for the treatment of ectoparasites used strictly according to the directions on the product label will not cause any residue problems in the milk.

- **Dairy detergents and sanitisers.** Residues of detergents and sanitisers used to clean milking machines and milk storage equipment on the farm can be introduced into milk, particularly if the cleaning, sanitising, draining and pre-milking rinsing procedures are improperly conducted. Sanitisers in common use include iodophors (organic compounds containing iodine in a micellar form), chlorine-containing compounds such as hypochlorite, surface active agents such as quaternary ammonium compounds and peroxy compounds such as peracetic acid.

  If used according to good hygienic practice, significant levels of residues of detergents and sanitisers should not occur in milk and should not cause any health concerns amongst consumers.

  However, it must be noted that overuse or careless use of iodophors as sanitisers for farm equipment can result in an elevated iodine content in the milk, which can interfere with thyroid function in certain consumers, especially if the level exceeds 500 µg/L (Fischer ***et al.***, 2002a). Use of iodophors in the Australian dairy industry for sanitising of farm equipment has declined in recent years.

Use of iodine-based post-milking teat dips for mastitis control can also lead to slight elevation of the iodine levels in milk.

- **Industrial chemicals.** Accidental contamination of stock feeds with industrial chemicals that have a potent effect on human health, such as dioxins and polychlorinated biphenyls (PCBs), have occurred in some countries. Such contamination has resulted in residues in milk. However, the Australian dairy industry has a good record in relation to such incidents.

3.3.5 Physical Matter

Sediment, such as dirt, animal manure and feed dust, and foreign matter, such as hair, insects and plant material, can have a detrimental effect on the quality of milk if they are allowed to enter the milk. They can be a source of bacterial contamination and off-flavours. If milk is heavily contaminated with sediment, some of it will settle to the bottom of the milk storage tank and will be evident when the milk is pumped out.

Milk is usually filtered on the farm and clarified when it reaches the processing factory to remove any sediment and foreign matter present.

Farm milks can be tested at the receiving factory for the presence of foreign physical matter by the 'sediment test'; in this test, 100 mL of milk is passed through a standard filter disk and the sample assigned a score by comparing the amount of foreign matter on the disk with a set of reference standards.

3.3.6 Chemical Taints

Milk absorbs taints and odours very readily. Some of these may be harmless, but some adversely affect the organoleptic quality of the milk and some of the products made from it. Some taints may indicate the accidental contamination of milk with dangerous substances. Any milk in a farm vat that exhibits an unacceptable or unusual odour should be rejected by the tanker driver at collection.

Phenolic substances are a particular hazard and should not be used or stored in or near the dairy. If the phenolic substances gain entry to milk, they can react with residues of chlorine sanitisers to form chlorphenols, which have a potent odour even at very low levels of concentration.

3.3.7 Weed and Feed Flavours

Substances capable of causing taints or off-flavours milk can be transmitted directly from the cow's feed into the milk via the cow's digestive tract and blood supply. The presence of these substances in milk at levels in excess of the detectable threshold is regarded as a defect. The defects can manifest themselves as an odour and/or taste and can range in intensity from mild to severe.

Some of these taints originate from common pasture plants and also weeds that cattle can eat. For example, the dimethyl sulphide content of milk increases when cows are fed on a lucerne-based diet. Low concentrations of dimethyl sulphide contribute to the characteristic flavour of raw milk, but higher concentrations can give a 'cowy' or 'malty' flavour.

Taints from pasture species and weeds tend to be more apparent during the spring, when they usually exhibit a flush in growth. The occurrence and intensity of the taints from these sources can be minimised by selection of pasture species, control of weeds and grazing management.

Supplementary feeds can also be a source of taints. For example, cheese made from milk sourced from cows that have been fed on citrus pulp can develop taints during maturation. Also, milk from cows that have been feed supplementary feeds with a high oil content can develop oxidised flavours.

In some cases, the taints can be removed or reduced by directing the milk into a product stream that incorporates a deodorization step. However, some taints, for example those caused by consumption of weeds certain weeds such as Bitter Cress, are very difficult to remove by processing.

The best method for detecting the presence of taints or off-flavours in milk is for a trained person to conduct a sensory evaluation of the milk. However this evaluation should only include tasting of the milk if it has been treated to destroy any pathogenic microorganisms that might be in it (e.g. pasteurised), or is otherwise considered safe to taste.

3.3.8 Toxins of Fungal and Plant Origin

Some fungi and plants can produce toxins that have an adverse effect on human health. Of these, the mycotoxins – secondary metabolites of fungi – are the most important in relation to milk.

Aflatoxin M_1 is a mycotoxin that appears in milk as the direct result of the intake of aflatoxin B1-contaminated feed by dairy cows. Aflatoxin B_1 can be produced in stock feed by the fungi ***Aspergillus flavus, A. parasiticus*** and ***A. nominus*** under warm and humid conditions. The feed materials at greatest risk are peanut hay, maize and oilseeds and also the residue (press meal) remaining after extraction of the oil from oilseeds. The aflatoxins are produced pre-harvest but their production in stored grain also can be very high if the grains are not kept dry. Bakery waste can also be a major source of aflatoxin if it is not kept dry. Between 0.3 and 6.3% of aflatoxin B_1 in the feed intake is transformed by the cow into aflatoxin M_1 in milk.

Aflatoxins are acutely toxic to humans when they are consumed in relatively large quantities and may cause liver cancer if they are consumed in smaller doses over a longer period. Hence the feeding of mouldy feeds and press meal of oilseeds to milking cows must be avoided.

The Australia New Zealand Food Standards Code does not set a maximum limit for aflatoxins in milk or dairy products; hence their presence in milk at levels exceeding the limit of detection (about 5 µg per kg) is not permitted. Aflatoxin M_1 is included in the on-going AMRA survey conducted by the Australian dairy industry. Commercial test kits enable dairy companies to carry out their own screening of milk if required.
Note. For more information on the AMRA survey, refer to Section 7.1.5 in the chapter titled 'An Introduction to the Australian Dairy Industry' in this manual.

Carryover of other mycotoxins, e.g. ochratoxin A, into milk is not significant and hence they are not regarded as a heath issue in milk (Heggum C, 2004; Fischer ***et al.***, 2002b; van Egmond ***et al.***, 1997).

Plants can also produce toxins that affect the health of the consuming animal, e.g. pyrrolidizine alkaloids produced by the pasture weeds Paterson's curse, heliotrope and ragwort, and ptaquiloside produced by several species of bracken fern (Fischer ***et al.***, 2002b). These are weeds are managed by Good Agricultural Practice and there is no evidence to indicate that plant toxins are an issue in Australian milk supplies.

3.4 Milk Spoilage Caused by Natural Milk Constituents

Raw milk contains a number of indigenous enzymes, including lipases and esterases, plasmin (a proteinase), phosphatase, lactoperoxidase and xanthine oxidase. Of these, lipoprotein lipase (LPL) is the most important in terms of their effects on milk quality.

LPL accounts for most, if not all, of the lipolytic activity of raw milk. The total amount of LPL present in raw milk is sufficient to cause rapid hydrolysis of a large proportion of the milk fat. Fortunately, this does not happen under good production conditions, because the LPL is prevented from accessing the fat by the milk fat globule membrane. However, physical damage to the milk fat globule membrane in raw milk or, in some cases, simply cooling certain individual milks soon after secretion, can initiate lipolysis. Lipolysis in milk and milk products releases free fatty acids and partial triglycerides, resulting in rancid off-flavours and technological problems. For these reasons, lipolysis is a constant concern in the dairy industry.

The lipolysis in milk caused by LPL can be broadly categorized into two types: spontaneous and induced. Spontaneous lipolysis is initiated by the simple act of cooling raw milk to 10°C soon after it is taken from the cow. It only occurs at the farm and is associated with predisposing factors such as late lactation, poor quality feed and mastitis. In contrast, induced lipolysis is initiated by physical damage to the milk fat globule membrane, which allows the lipase access to the fat substrate. It can occur on the farm, during transport and in the factory. Physical actions causing induced lipolysis include agitation and pumping (especially with excessive air incorporation or high shear), homogenization, mixing of raw and homogenised milk and freezing/thawing. Both spontaneous and induced lipolysis progress during subsequent storage of the raw milk, with most of it usually occurring during the first 24 hours of refrigerated storage after milking (Deeth, 2006).

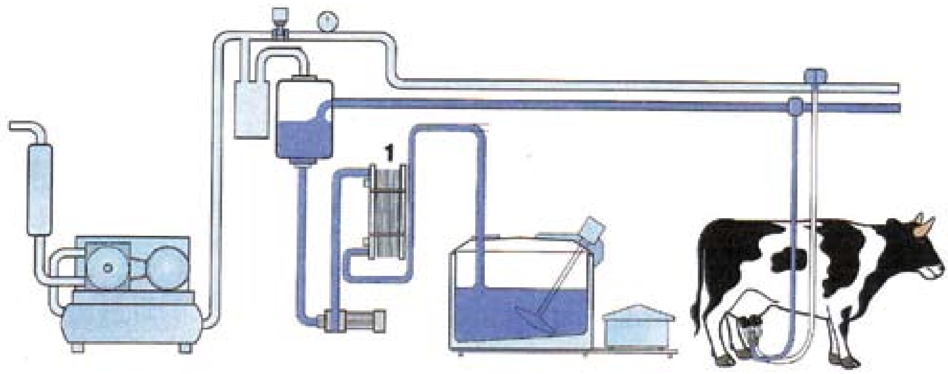
3.5 Storage and Transport of Raw Milk (Cold Chain)

Maintenance of the cold chain for raw milk from first production on the farm through to pasteurisation in the processing factory, together with time limits, is essential to prevent spoilage of the milk and the production of toxins by bacteria and other microorganisms.

All milk in Australia is stored in stainless steel bulk milk tanks (which may also be known as vats or silos) on the farm. These tanks must comply with Australian Standard 1187-1996: ***Farm milk cooling and storage systems*** (refer to website http://www.saiglobal.com/shop/Script/Details.asp?DocN=stds000014437).

This Standard requires that the milk is cooled to less than 4°C within 3.5 hours of the commencement of milking and maintained at that temperature during storage. The milk passes from the cow via the milking machine either directly into the tank where it is fully cooled by a direct expansion 'cold-wall' system (see diagram in Section 1.2 above) or more commonly through a plate cooler where the milk is pre-cooled to 18-25°C before it enters the storage tank, where final cooling also takes place via a 'cold-wall' system (see diagram below). The refrigeration equipment attached to each milk tank or silo is fitted with thermostatic controls to ensure that the temperature of the milk remains below 4°C but above freezing during storage.

The milk is collected from the farm at regular intervals in an insulated stainless steel road tanker designed especially for the collection of milk from farms (see diagram and photograph below). It is then transported to a processing factory, where it is pumped – with further cooling if necessary – into an insulated stainless steel silo for storage until it is pasteurised.



General design features of a farm dairy with a pipeline milking machine and a plate heat exchanger (1) to pre-cool the milk from 37°C to 18-25°C before it enters the storage tank, where final cooling to less than 4°C occurs

Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

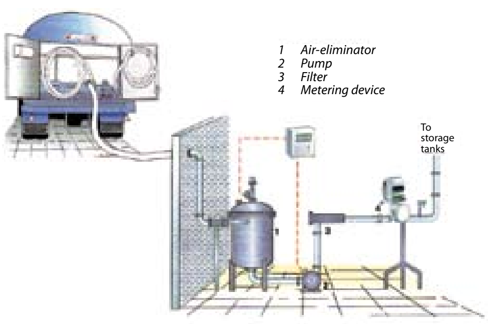
Bulk milk collection at a farm dairy

Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

Milk being pumped from a farm storage tank into a collection tanker

A profile of the cold chain for raw milk typical of that used throughout the Australian dairy industry is summarised below. There might be some minor variations in the profile depending on company policy and the requirements of the State food safety regulatory agencies.

Step	Milk temperature and storage period	Comments
1. Milk taken from cow and stored in farm tank	Milk cooled to less than 4°C within 3.5 hours of the commencement of milking, as required by AS 1197-1996.	Cooling rate and temperature profile will vary, depending on the capacity and configuration of the cooling system.
2. On-farm storage	Temperature on the milk maintained at less than 4°C during storage. A pickup interval of every second day is the most common, though pickup can be daily mainly in cases where the capacity of the storage tank is insufficient to hold 2 days production.	Due to the practicalities of collecting milk from the farm soon after completion of the last milking in the pickup period, when the temperature of the milk might have yet fallen below 4°C, most dairy companies have a policy that allows pickup of milk during an 'exclusion period' of about 2 hours after the normal completion time for milking, e.g. after 8 AM or 6 PM, during which milk can be picked up at temperatures up to 8 or 10°C.
3. Transport to processing factory	Temperature of milk during transport will be the average temperature of the commingled milk. Period of transport is mostly in the range 4-8 hours, but can be as short as about 2 hours or as long as about 12 hours, occasionally longer.	The period of time required to complete a milk collection run reflects the proximity of the farms to each other and to the processing plant, and the number of farms on the run.
4. Receival at processing factory	Milk generally cooled on receival to less than 4°C if it is above 4°C and the milk is not to be processed that day or is to be trans-shipped to anther factory.	If milk is above 4°C and the milk is to be processed that day, it may or may not be cooled to less than 4°C on receival, depending on company policy and assessments of risk to quality.
5. Storage at processing factory pending pasteurisation	Milk is generally held at the processing factory for 12-24 hours before it is pasteurised; maximum period is 48 hours.	Period of storage at the factory will reflect product mix, processing cycles and volume of milk intake.



Reception of raw milk from a farm collection tanker into the processing factory

Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

Milk being pumped from a farm collection tanker at the processing factory

Silo for storage of raw milk at a processing factory, with mechanical agitation of the milk

Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

Silos for storage of raw milk at a processing factory

3.6 Testing of Raw Milk: Standards, Methodologies and Interpretation of Results

All dairy companies carry out a series of quality checks on their raw milk supplies for acceptance and payment purposes. There is a set of basic quality checks that all companies carry out, and some additional checks that only some companies carry out to help them meet their particular quality objectives. An outline of a typical testing program, which commences with a sensory assessment of the quality of the milk in the farm storage tank by the driver of the milk collection tanker before it is pumped into the tanker, is set out below.

Samples of farm tanker milks are also taken monthly for analysis under the Australian Milk Residue Analysis (AMRA) Survey for a range of chemical residues.

Examining culture plates in a dairy company's microbiology laboratory

Step	Basic quality checks and procedures	Comments
On-farm quality checks	• At every pickup, milk is checked by the tanker driver for visual appearance and smell (odour) to ensure it is of acceptable quality before it is pumped into the tanker. • At every pickup, temperature of milk in farm storage tank is checked and recorded on both farm records and tanker collection log.	• Most companies do not permit their tanker drivers to taste the milk, as it represents an unacceptable health risk to them. For example, in some regions, drivers can contract the infectious disease Q Fever by tasting the milk. • In some cases temperature is also recorded automatically by a data logger on the tanker as the milk is pumped into the tanker.

Step	Basic quality checks and procedures	Comments
On-farm sampling	• At every pickup, a sample of the milk in the farm storage tank is taken for laboratory analysis using a drip sampler attached to the milk tanker. • An additional sample for microbiological analysis is taken as required direct from the storage tank by the tanker driver using a sanitised stainless steel dipper.	• The drip sample is usually used to determine milk composition for payment purposes, Bulk Milk Cell Count, presence of antibiotic residues and in some cases also Total Bacterial Count by Bactoscan. • Some companies only use the dip sample for determining the Total Bacterial Count (or other microbiological tests if done), while others use the dip sample to confirm a high count detected by the Bactoscan. • Samples are stored at 0-4°C pending testing at the laboratory.
Acceptance/ screening of milk in farm collection tankers on arrival at receival factory	• Every consignment of farm milk is checked for the presence of antimicrobial residues especially β-lactams using a 'Broad Spectrum' commercial test kit. In some cases, the milk is screened using a 'Rapid' test kit before it is pumped out, followed by a confirmatory test using a 'Broad Spectrum' test kit. • Some companies routinely check acidity of tanker milk before pumping out. • Some companies check tanker milk temperature; if it exceeds 5°C, acidity is then checked.	• Other quality tests carried out by some dairy companies on farm tanker milk include: o Milk composition (fat, protein, lactose); o Freezing point (to detect adulteration with water); o Total Bacterial Count of tanker milk by either the Standard Plate Count or the Bactoscan; if the count exceeds 50,000 cfu/mL, samples from individual farms are checked; and/or o Resazurin dye reduction test (a quick test to detect excessive microbial activity).
Quality checks carried out on samples of individual farm milks in the dairy company laboratory	• **Total Bacterial Count:** Determined by Bactoscan once every 10 days; recognised standard is <50,000 cfu/mL.	• Most dairy companies have a milk payment scheme that provides for a scale of adjustments to the base payment rate that reflects the Total Bacterial Count, e.g. a bonus payment if count <20,000 cfu/mL and a deduction (penalty) if count >50,000 cfu/mL. • Some dairy companies also test farm milks for count of thermoduric bacteria as an index of farm hygiene; a count <2,000 cfu/mL is regarded as very good and a count >10,000 cfu/ml as poor.
	• **Bulk Milk Cell Count:** Determined by Fossomatic or similar instrument on every pickup; recognised standard is <400,000 cells/mL.	• Most milk payment schemes also provide for a scale of adjustments to the base payment rate that reflects the Bulk Milk Cell Count, e.g. a bonus payment if count <200,000 cells/mL; deduction (penalty) if count >400,000 cells/mL; suspension from supply if >600,000 cells/mL.
	• **Antimicrobial residues:** Farm milks are checked once per month using a 'Broad Spectrum' commercial test kit; recognised standard is 'Not Detectable'.	• Some companies test individual farm milks once per month in addition to every farm tanker, whereas other companies rely on the testing of every farm tanker with trace back to individual farms if positive.
	• **Milk composition:** The fat and protein content of a sample taken from the farm storage tank at every pickup is determined by a Foss Milkoscan or similar instrument.	• Most payment systems in Australia are based on the mass of milk protein and milk fat in the milk. • In Australia, the protein content of farm milks for payment purposes is measured as true protein (see FAQ A6). Also, the composition of farm milks for payment purposes is expressed on a mass/ volume basis (see FAQ A7). • The standards generally adopted by the Australian dairy industry for the composition of farm milks are a minimum of 33 g/L for milk fat and 30 g/L for true protein.
Pasteuriser balance tank	• Some companies test milk from every silo every day for Total Bacterial Count; recognised standard is <150,000 cfu/mL.	• Determination of Total Bacterial Count of the raw milk at the balance tank provides a check on the plant hygiene and temperature at all points in the milk handling chain.

3.7 Restrictions on the Sale of Raw Milk and Products Made from Raw Milk

In Australia, the sale of raw cow's milk for human consumption, or the manufacture of products from raw milk for human consumption, is not permitted. This is because of the risk of transmitting foodborne illness through raw milk.

3.8 Regulation of Raw Milk Quality

The food safety aspects of raw milk quality are regulated via Standard 4.2.4, ***Primary Production and Processing Standards for Dairy Products,*** of the Australia New Zealand Food Standards Code. This Standard states, in part, that a dairy farm production business must control the potential food safety hazards in the milk it produces by implementing a documented food safety program. In most States, the food safety program must be HACCP-based. The food safety programs are subject to audit at regular intervals, usually 12-months, by auditors employed by or contracted to the relevant State food safety agency.

The implementation of Standard 4.2.4 and other relevant Sections of the Food Standards Code in relation to raw milk is the responsibility of State food safety agencies:

- Victoria – Dairy Food Safety Victoria, www.dairysafe.vic.gov.au
- NSW – New South Wales Food Authority, www.foodauthority.nsw.gov.au/
- Queensland – Safe Food Queensland, www.safefood.qld.gov.au
- Tasmania – Tasmanian Dairy Industry Authority, www.dpiw.tas.gov.au/inter.nsf/WebPages/EGIL-5HTVZ9?open#GovernmentInputandIn
- South Australia – Dairy Authority of South Australia, www.sa.gov.au/site/page.cfm?u=36
- Western Australia – Health Department of Western Australia, www.population.health.wa.gov.au/Environmental/dairy_safety.cfm

Aspects of raw milk quality that do not fall within the scope of food safety are managed by the dairy companies through their quality assurance programs.

3.9 Dairy Company Programs for the Management of Raw Milk Quality

The dairy companies have documented programs for the management of raw milk quality as a component of their company quality assurance programs. Some of the companies have also developed their own generic on-farm quality assurance and food safety manuals in conjunction with the State dairy food safety agencies. These manuals, which are designed to ensure the company's quality needs are met, are made available to each of the company's milk producers and form the basis of the on-farm quality assurance programs. Company field staff assist the farmers with the implementation of the programs.

3.10 Recent Developments in Testing Methodologies

The basic elements of testing programs for assessment and management of raw milk quality have changed little in recent decades. The main changes that have occurred are:

- The introduction of automated laboratory equipment – with varying levels of automation and software support for sample identification and reporting, depending on brand and model – for the determination of fat, protein and lactose content (e.g. Foss Milkoscan range, Bentley MIR range and Delta Instruments Lactoscope range), somatic cell count (e.g. Foss Fossomatic range, Bentley Somacount range and Delta Instruments Somascope range) and total bacterial count (e.g. Foss BactoScan). These instruments can be used separately or, in the case of the Foss MilkoScan and Fossomatic, combined into an integrated unit, the CombiFoss. Integrated units are also available from other equipment manufacturers, e.g. the Bentley Combi series and the Delta Instruments Combiscope range.

  This equipment allows a test result to be obtained quickly and with a high throughput of samples, e.g. the Foss BactoScan FC can provide a bacterial count in less than nine minutes, with a throughput of 150 samplers per hour, while some models of the Milkoscan and Fossomatic can handle 500 samples per hour.

Foss CombiFoss showing milk samples progressing through the automatic sampling device
Source: Foss, Denmark, www.foss.dk

Close-up of the sample conveyor and automatic sampling device used on automated Foss milk testing equipment
Source: Foss, Denmark, www.foss.dk

  For more information on Foss milk testing instruments, refer to website:
  http://www.foss.dk/Solutions/BusinessAreas/MilkAndDairy.aspx
  For more information on Bentley milk testing equipment, refer to website:
  http://www.bentleyinstruments.com/products.html
  For more information on Delta Instruments milk testing equipment, refer to website:
  http://www.aicompanies.com/DeltaCD/index.htm

- A trend towards centralised laboratories, either within the company or operated by an external contractor. This trend has been largely driven by the need to maximise the throughput of samples through expensive laboratory equipment, such as that referred to above, and other cost considerations. In some cases the use of a centralised laboratory requires transport of samples over long distances by road or air.

- The availability from commercial suppliers of ELISA test kits for the detection of antimicrobial substances in milk, e.g. antibiotics used to treat mastitis. Kits are also available for the detection of other contaminants such as aflatoxins. These kits allow testing to be done rapidly, e.g. within 30 minutes. In the case of antibiotic residues, they can also provide a greater level of specificity for the type of residue present compared with the longer 'Broad Spectrum' kit or standard disk assay methods.
- Same-day reporting of test results to the farmer is now widely used by the dairy companies. This has been facilitated by the use of laboratory equipment and tests kits that allow more rapid testing, a capacity to test samples from every pick-up and the transmission of the results to the farmer by fax or email. The farmer is thus in a better position to take prompt corrective action on any quality defects. Some companies telephone test results through to the farmer if they indicate a serious quality problem. Paper copies of test results are also delivered to the farmer by the tanker driver at the next milk pick-up.

3.11 Conclusions

Milk quality is a complex topic, with many facets, components, variables and indices. To ensure that raw milk is always of the highest quality when it is processed, an integrated and informed approach is required by the dairy farmer, the dairy processor and the regulatory authorities.

The milk production system must result in raw milk that meets the following criteria:

- It is safe to consume after it has been pasteurised, i.e. it must be free of harmful chemical residues and toxins;
- It is free of adulterants, for example added water;
- It is free of unpleasant flavours, taints and odours and is of normal appearance;
- It meets the nutritional needs of the consumers; and
- It can be processed into high quality dairy products, such as cheese and yoghurt, with high yield of product.

Good quality dairy products can only be made from good quality raw milk.

FAQ

A. Composition of milk

A1. Does breed of cattle affect the composition of milk?

Effect of breed of cattle on the average composition of herd milks (after Webb *et al.*, 1974).

Breed	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)	Nonfat Solids (%)	Total Solids (%)
Guernsey	85.35	5.05	3.90	4.96	0.74	9.60	14.65
Jersey	85.47	5.05	3.78	5.00	0.70	9.48	14.53
Brown Swiss	86.87	3.85	3.48	5.08	0.72	9.28	13.13
Holstein	87.72	3.41	3.32	4.87	0.68	8.87	12.28

Breed of cattle has a marked effect on the composition of milk, particularly on the fat and protein content. This is illustrated by the typical milk compositions in the table below. Breed can thus impact on a range of processing factors such as product yield and processing characteristics of the milk. Note, however, that breed is just one of a range of factors that influence the composition of milk.

A2. Does composition of milk change during the lactation period of the cow?

The main changes in the composition of milk during the lactation period occur within the first few days after parturition. The transition in the composition of colostrum to that of normal milk is illustrated in the table below.

Typical changes in the gross composition of cows milk after calving: the transition from colostrum to normal milk (after Marnila and Korhonen, 2003).

Days after calving	Total protein (%)	Fat (%)	Lactose (%)	Ash (%)
0.5	14.6	5.3	2.6	1.16
1	9.4	5.4	3.6	1.03
1.5	5.5	4.4.	4.3	0.92
2	4.5	4.5	4.6	0.87
3	4.2	4.5	4.8	0.85
4	4.1	4.8	4.9	0.85
8	3.6	4.8	4.9	0.81
14	3.3	4.6	5.1	0.78

The proportion of whey proteins in colostrum is substantially higher than in normal milk. The main protein fraction present in colostrum is the immunoglobulins. The transition from colostrum to normal milk is largely complete within 4-5 days after parturition, though slight changes in composition will continue to occur for some time.

The amount of solids-not-fat in the milk will usually drop to a lactation low at 2-3 months, increase slowly to six months and then increase rapidly to the end of lactation (10 months). Lactose percentage drops slightly towards the end of lactation. Fat content of the milk can vary widely during the lactation period.

Other important influences on the composition of milk are cow nutrition and diseases especially udder health (mastitis).

A3. For how long should colostrum be excluded from the milk supply?

Colostrum has a strong odour, a bitter taste, a slight reddish-yellow colour and contains a large percentage of immunoglobulins. Inclusion of colostrum in the milk supply can have a deleterious effect on the quality of the milk and cause problems during processing. It should be excluded from the milk supply for at least four days after parturition (calving).

A new-born calf fully-dependent on colostrum suckled direct from its mother

A4. *What is a MilkoScan?*

A MilkoScan is a laboratory instrument manufactured by Foss for the determination of milk composition. There are various models, but all utilise the principle of absorption of different wavelengths of infrared light by the components of milk. MilkoScan instruments based on mid-infrared technology allow the fat, protein, lactose, total solids and solids-non-fat content of milk and in some case also the freezing point depression to be determined.

Foss MilkoScan FT120, a non-automated model of a MilkoScan widely used by the dairy industry in China for process control purposes

Source: Foss, Denmark, www.foss.dk

Advanced models of the MilkoScan that use the FTIR (Fourier Transform InfraRed) Technology allow other parameters of milk quality to be measured, including casein, free fatty acids (FFA) and pH.

MilkoScans are widely used in the Australian dairy industry for testing farm milks for payment purposes.

Similar instruments available from other equipment manufacturers are the Bentley mid-infrared range (widely used in herd improvement laboratories in Australia) and the Delta Instruments Lactoscope range incorporating both mid-infrared and FTIR models.
For more information on the MilkoScans and equivalent instruments, refer to Section 10 above.

A5. *How can adulteration of milk with water be detected?*

The freezing point of pure water is 0°C. If solutes, e.g. salts, are added to water, its freezing point is lowered below 0°C; the greater the amount of salts added, the lower the freezing point of the solution. The solutes in milk, principally lactose and dissolved mineral salts, depress its freezing point to about 0.5°C below that of water.
The osmotic pressure of cows' blood remains fairly constant. The cow's biological system has to balance the osmotic pressure of the milk in the udder with that of the blood circulating through the udder. Hence the freezing point of milk is also maintained at a fairly constant level.

The freezing point of genuine milk from individual cows varies with the breed of cow, its feed, the season, time of lactation and the climate. However as milk is pooled in a farm storage tank, then into tankers and silos, these variations tend to be averaged out.

In the United States, the Association of Official Analytical Chemists recommends that milk with a freezing point below -0.525°C may be presumed to be free of added water. Thus, for each 1% addition of water, the freezing point between -0.525°C and 0°C will rise by 1%. However, the presence of added water needs to be confirmed by tests on authentic milk samples from a similar source.

In Australia, there is currently no legal standard for the freezing point of milk specified. However, a freezing point of -0.517°C is generally regarded as the upper limit for genuine milk. Some of the dairy companies use higher levels for quality control purposes, e.g. -0.512°C for tanker milk and -0.500°C for farm milk. This provides for a margin of error and for natural variation, especially in periods of drought when cattle might be under nutritional stress. Thus operational standards for freezing point need to be set locally, taking into account the local industry conditions and circumstances.

The freezing point test has been used for estimation of water in milk for almost 100 years. The early reference test (Hortvet method) has now been replaced by the thermistor cryoscope, which is now the internationally-recognised standard method [ISO 5764:2002. ***Milk. Determination of freezing point. Thermistor cryoscope method (Reference method)***]. Some models of the Foss MilkoScan and similar instruments made by other manufacturers allow the freezing of point of milk samples to be determined in-line together with the composition of milk.

A6. What is the difference between the crude protein and true protein content of milk?

Crude protein, sometimes called total protein, is estimated by measuring the total nitrogen content of milk and multiplying it by a standard factor to express the results on a protein equivalent basis. The total amount of nitrogen in milk, however, comes from both protein and non-protein sources. True protein reflects only the nitrogen associated with protein and does not include the nitrogen from non-protein sources.

Non-protein nitrogen is a normal component of milk. The non-protein nitrogen (NPN) fraction is composed of urea and other low molecular weight nitrogen-containing compounds such as creatine and creatinine. About 50% of the NPN in milk is urea, and variation in NPN is attributed primarily to variation in urea content. Non-protein nitrogen has little nutritional value and does not contribute to cheese yield. The amount of NPN in milk varies naturally, just like any other milk component. On average, NPN accounts for about 0.19% of the protein content of milk when it is expressed it is as a crude protein value, but may range from 0.12% to 0.25%.

Kjeldahl nitrogen analysis forms the basis for the reference tests for both crude and true protein. In both cases, nitrogen is multiplied by 6.38 to express the results on a protein equivalent basis.

The modern infrared milk analysers detect a signal generated from the protein molecules, but cannot detect the NPN substances. Thus, while the infrared analysers can be calibrated to take account of the NPN component, errors in protein measurement due to variation in the NPN content of milk can occur. Measurement of true protein eliminates these errors (Barbano and Lynch, 2007).

A7. What does the composition of milk expressed on a mass/mass basis differ from that expressed on a mass/volume basis?

Milk has a specific gravity of 1.032; thus 1 L of milk weighs 1.032 kg. Assume, for example, that 1 L of milk contains 33 g of milk fat: the fat content of this milk can be expressed as either 33 g/L (or 3.3% m/v, where m/v = mass/volume), or 32 g/kg (or 3.2% m/m, where m/m = mass/mass).

Thus one method of expressing milk composition can be converted to the other simply by applying 1.032 as a conversion factor.

In Australia, where farm milk production is measured in litres, the composition of farm milks for payment purposes is usually expressed on a mass/volume basis. However the composition of processed products is usually expressed on a mass/mass basis.

B. Microbial contaminants of milk

B1. What is the Total Bacterial Count of milk and how is it determined?

The Total Bacterial Count is a measure of the numbers of the bacteria in milk that are able to form colonies on a suitable growth medium (Plate Count Agar) when incubated aerobically at 30°C for 72 hours. Usually 1 mL of a serial dilution of the milk, e.g. 1/100 or 1/1000, or a small aliquot of milk dispensed with a micropipette, e.g. 10 µL (1/100), is mixed with 12-15 mL of the molten agar medium. Because colonies are counted, the count is correctly expressed as 'colony-forming units' (cfu) per mL; in some cases, a colony will be derived from a single bacterial cell, while in other cases a colony might be derived from a clump of cells.

The Total Bacterial Count (also known as the Standard or Total Plate Count) is recognised world-wide as the best overall indicator of the microbiological status of milk in terms of its hygienic production and storage history.

The Australian Standard Method for the standard plate count on milk and other foods has been published by SAI-Global (2004). The plate count method has been discussed by Brazis (1991). Faster and less costly variations of the standard plate count method that were widely used by the Australian dairy industry for routine determinations of the total bacterial count of farms milks before the introduction of automated bacteria counting equipment (see FAQ on 'Bactoscan' below) are the plate loop method (Hill, 1991) and the roll tube method (Slaghuis, 1991); both of these continue to be valid techniques for routine use.

B2. How is the Thermoduric Count of milk determined?

A sample of the milk is laboratory pasteurised by placing it in a glass tube or bottle and heating it in a water bath at 63°C for 30 minutes, then cooling. The heated sample is then plated out using the standard plate count method as described above. The Bactoscan or similar instruments cannot be used in this case, as they will give an erroneous result.

B3. How is the Psychrotrophic Count of milk determined?

The milk plated out using the standard plate count method as described above; however the plates are incubated at 7°C for 10 days.

B4. What is a BactoScan?

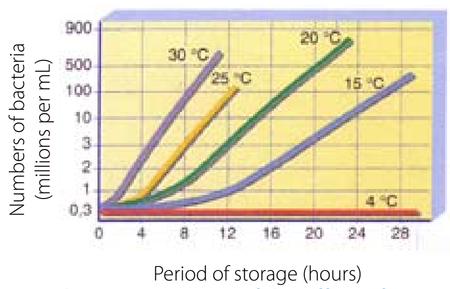
A BactoScan is a laboratory instrument manufactured by Foss for the counting of bacteria in milk. The analytical method is based on flow-cytometry principles and specifically counts single bacteria. It is widely used by Australian dairy companies for determining the total bacterial count of raw milk for quality control and payment purposes. For more information

on the BactoScan equipment, refer to the Foss website:
http://www.foss.dk/Solutions/BusinessAreas/MilkAndDairy.aspx

B5. What factors influence the multiplication of bacteria in milk during storage?

The temperature and duration of storage, the number and types bacteria in the milk and, to a lesser extent, the natural inhibitory systems in the milk, all influence the increase in bacterial numbers that occur in stored milk. Because of the wide variation in the initial microflora, and possibly also in the conditions under which the milk is stored, only generalisations can be can be made about the changes that occur in the microflora during storage and transport.

Foss BactoScan
Source: Foss, Denmark, www.foss.dk



Simple representation of the effect of storage temperature on the growth rate of bacterial contaminants in raw milk

Note. The numbers of bacteria in raw milk stored at 4°C will also increase with further storage, due to growth of psychrotrophic bacteria (see table below).

Source: Modified from the Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

The temperature of storage is probably the most important factor (refer to chart below). If, for some reason, the milk is stored at 25-30°C, e.g. loss of refrigeration due to a failure in the electricity supply, the spoilage organisms that would be most active are the streptococci and the coliforms; acid production would occur and the milk could show evidence of spoilage (souring) within a few hours. The effects of storage at 15-25°C would be similar, but take longer. Below 15°C, the psychrotrophic Gram-negative rods predominate and the nature of the spoilage is different from that at higher temperatures and takes longer to become evident (Bramley and McKinnon, 1990). Acidity becomes progressively less evident as the temperature is reduced and the spoilage is increasingly due to the heat-stable extracellular proteases and lipases that are produced by the psychrotrophs. Spoilage is characterised by unclean, bitter and rancid flavours, protein degradation and protein instability.

The variability in the rate of increase in bacterial numbers that can occur during cold storage of raw milk is illustrated in the table below. The samples A-G were taken from the bulk vats on different farms after two milkings with storage at less than 4°C, then stored for a further four days at 5°C and the total bacterial count determined daily. The data illustrate that the initial total bacterial count is not always a good guide to the increases in bacterial numbers that occur during storage; rather it is the numbers of psychrotrophic bacteria initially present in the milk that is important.

Total bacterial counts of individual farm bulk milks stored at 5°C (after Bramley and McKinnon, 1990).

Farm	Total bacterial counts per mL during storage at 5°C after collection of sample from the farm bulk milk tank			
	0 days	2 days	3 days	4 days
A	5,800	3,300	7,900	14,000
B	14,000	10,000	11,000	70,000
C	14,000	10,000	710,000	15,000,000
D	28,000	83,000	2,800,000	18,000,000
E	62,000	400,000	9,500,000	41,000,000
F	170,000	110,000	110,000	130,000
G	240,000	1,800,000	8,900,000	17,000,000

C. Mastitis and somatic cell count of milk

C1. What effect does mastitis have on the quality of milk?

The inflammation of the udder caused by the mastitic infection affects the circulation of blood through the udder and, as a consequence, volume of milk produced is reduced and the composition of the milk is altered. The changes in milk composition are well documented and can be summarised as follows:

- Decreased production of lactose;
- Increased influx of salts;
- Decreased production of casein;
- Increased influx of blood (hence the increase in somatic cell count);
- Increased influx of enzymes (especially plasmin, a heat–stable proteolytic enzyme);
- Increased influx of immunoglobulins;
- Changes in fat quality; and
- Decreased quality of the milk fat globule membrane.

The reduction in milk quality associated with elevated somatic cell count can lead to less efficient processing and the production of end-products with less favourable properties. Some of these effects, which progressively become more pronounced as the somatic cell count of the milk becomes higher, include:

- Deterioration in milk flavour including development of a rancid taste;
- Lowered cheese yield per 100 L of milk;
- Longer renneting time in cheese production;
- Increased cheese moisture, resulting in weak and pasty texture and flavour defects,
- Longer whipping time for cream; and
- Reduced shelf life for many dairy products (Anon., 2005; Auldist, 2003).

C2. How is the somatic cell count of milk measured?

The oldest method for enumerating the somatic cells in milk is the direct microscopic count, often combined with methylene blue staining. While this method is slow and labour intensive, it is still widely used as a reference method for calibration of the modern analytical instruments.

Instrumental systems, such as the Foss Fossomatic cell counters, are now generally used. The Fossomatic system utilises the principles of flow cytometry: the nuclei of the somatic cells are stained using ethidium bromide and then counted as they pass in a thin film under a high energy light source (Kelly, 2003).

Instrumental cell counters broadly similar to the Fossomatic include the Bentley Somacount range and Delta Instruments Somascope range.

For more information on the Fossomatic, Somacount and Somascope instruments, refer to Section 10 above.

C3. What are the recognised standards for somatic cell count?

There are no legal standards set for somatic cell count in milk in Australia. However the European Communities have set an acceptance standard of less than 400,000 somatic cells per mL for herd milk, calculated as the geometric average over two months with at least two tests per month or over three months with at least one test per month, effective from 1 January 1998 (Council Directive 92/246/EEC of 16 June 1992); this standard is used as the benchmark by the Australian dairy industry.

Most dairy companies in Australia include a graduated scale for somatic cell count in their milk payment systems, with counts less than 200,000 or 250,000 per mL attracting the highest payment.

The Australian dairy industry launched a national mastitis and cell count control program, titled 'Countdown Downunder' in 1998. One of the goals of this program was to work towards having all milk supply below 400,000 cells per mL, and 90% of all milk supply below 250,000 cells per mL. During the period from 2000 to 2004, for example, the percentage of the milk supply with a cell count below 400,000 per mL increased from 90.7% to 94.6%, and the percentage below 250,000 per mL increased from 64.2% to 70.8% (refer www.countdown.org.au).

D. Residues of antimicrobial products

D1. What steps are necessary on the farm to ensure that milk is not contaminated with residues of antimicrobial products?

- Identify the correct cow to be treated;
- If treating a case of clinical mastitis, identify the correct quarter of the udder to be treated;
- Select a suitable antimicrobial (antibiotic) product and ensure it is registered for that use;
- Clearly mark the treated cow and quarter;
- Accurately record the treatment date, cow number, quarter treated, product used and withholding period (WHP);
- Ensure that the milk from treated cows does not enter the milk supply;
- Milk treated cows last;
- Observe WHPs; and
- Store milk from treated cow separately and discard.

D2. What are typical withholding periods (WHPs) for antimicrobial products registered for the treatment of mastitis by intramammary infusion?

WHPs are product specific and the label must be checked. For antimicrobial products registered for use during lactation, the WHP is commonly 3 or 4 days (ie 6 or 8 milkings), but is 7 days (14 milkings) for some products.

For antimicrobial products registered for use as dry cow therapy, the WHP is commonly 30 days, but is 35 days for some products. If the cow calves before the WHP has expired, the milk must be withheld from supply for human consumption for a period specified on the product label; this period can be as long as 10 days.

D3. What are some common reasons for milk in the bulk milk tank on the farm becoming contaminated with antimicrobial residues?

- Treated cows not clearly marked or identified;
- Treatment details not recorded;
- WHP not observed;
- Milk from treated cows accidentally milked as if not treated;
- Products not used as per label or in combination with other veterinary drugs;
- Treated cows not milked last or equipment not cleaned after milking a treated cow;
- Milk from treated cows not clearly segregated from the main milk supply; and
- Cows purchased and new owner not aware of treatment history.

D4. How are residues of antimicrobial products detected in milk?

The standard reference method for detection of residues of antimicrobial chemicals (also widely referred to in Australia as inhibitory substances or antibiotics) in milk is a biological disk assay using ***Bacillus stearothermophilus*** var. ***calidolactis*** as the indicator organism. This organism is particularly sensitive to penicillins (β-lactam compounds), which can be detected at levels exceeding 0.0015 µg/mL. However, the method is also reasonably sensitive to the cephalosporins (also β-lactam compounds) and the sulphonamides. The presence of β-lactam compounds (penicillins and cephalosporins) can be confirmed by additional of penicillinase (β-lactamase) to the sample. The method can be made semi-quantitative for β-lactam compounds by constructing a standard reference curve using a series of dilutions of penicillin G in milk known to be free of inhibitory substances [refer to Australian Standard AS 1766.3.11-1991, *Food microbiology - Examination of specific products - Dairy products - Test for penicillin* (see web site www.saiglobal.com/shop/script/Details.asp?DocN=stds000000994), or method 2.1.1.1, International Dairy Federation, 1991a]. This test is not generally used by industry for daily screening of milk supplies.

Several 'Broad Spectrum' milk residue test kits based on the standard reference method with ***B. stearothermophilus*** var. ***calidolactis*** as the indicator organism have been developed by commercial companies, and these are widely used by Australian dairy companies to screen both milk tankers and individual farm supplies for the presences of antimicrobial residues. Brands of these tests include Delvo SP-NT, Copan, AIM BRT MRL, Charm II and Eclipse. These tests, which are qualitative and designed to indicate whether or not an antimicrobial substance is present in milk at levels exceeding the MRL, take about 2.75 hours to complete.

Another group of more rapid tests, based on the Enzyme-Linked ImmunoSorbent Assay (ELISA) technique, have been also developed. These have excellent sensitivity and specificity, and can be completed in times as short as 10 minutes. Brands of these tests include SNAP, Charm ROSA and Beta-Star. Delvo SP-NT, Copan, AIM BRT MRL, Charm II and Eclipse. Some Australian dairy companies use these test to do an initial check on the milk in farm tankers as soon as they arrive at the plant, then follow up with one of the 'Broad Spectrum' test kits that use ***B. stearothermophilus*** var. ***calidolactis*** as the indicator organism, as described in the preceding paragraph.

An overview and listing of the antimicrobial screening test kits available in Australia have been prepared by Dairy Food Safety Victoria (2006a). The detection limits of these kits have also been published by Dairy Food Safety Victoria (2006b).

An overview of the 'higher level' chemical-physical confirmation tests for the detection of antimicrobial residues in milk has been prepared by Pedersen and Suhren (2000). These tests, many of which utilise high-pressure liquid chromatography (HPLC), can only be carried out in well equipped analytical laboratories and hence are not routinely used by industry for screening purposes.

D5. What is the incidence of antimicrobial resides in Australian dairy products?

Australian dairy companies test each tanker load of farm milk on receival at their factories for the presence of antimicrobial residues, using one or more of the test kit methods referred to above. Any milk containing residues is rejected for human consumption and trace back to identify the source farm is undertaken.

No inhibitory substances (specifically the antimicrobial chemicals penicillin G, streptomycin and oxytetracycline) were detected in Australian dairy products (whole milk, chocolate milk, cheddar cheese and infant formula) during the 20th Australian Total Diet Survey conducted by Food Standards Australia New Zealand in 2003 (refer to website: http://www.foodstandards.gov.au/newsroom/publications/20thaustraliantotaldietsurveyjanuary2003/index.cfm).

E. Foreign physical matter in milk

E1. How is contamination of milk with sediment and foreign matter during milking minimised?

- Apply teat cups only to clean, dry teats;
- Wash and dry dirty teats before applying the teat cups;
- Avoid washing udders;
- Dry wet teats with clean, disposable paper towels only;
- Ensure milkers' hands are clean;
- Keep lanes and gateways free of mud;
- Clip or singe udder hair;
- Trim cows' tails;
- Use a milk filter that can handle the maximum milk flow rate;
- Change filter socks at each milking; and
- Wash and sterilise reusable filter socks before reuse.

F. Weed and feed flavours in milk

F1. What are some common stock feeds and weeds that produce taints or off-flavours in milk?

Feed	Cause	Off-flavour
Beet byproducts	Trimethylamine	Fishy
Common rye and wheat	Trimethylamine	Fishy
Onion pulp	Rumen action	Onion
Gramineae (grasses)		Off-flavour
Legumes or legume hay		Bitterness
Cruciferae	Mustard oil	Sharp radish-like flavour
Residues from processing of fruit and vegetable		Off-flavour
Dry feed	Lack of a-tocopherol	Oxidised
Poor quality silage		Silage flavour
Land Cress		Burnt, unclean, sharp pungent, herb-like

G. Aflatoxins

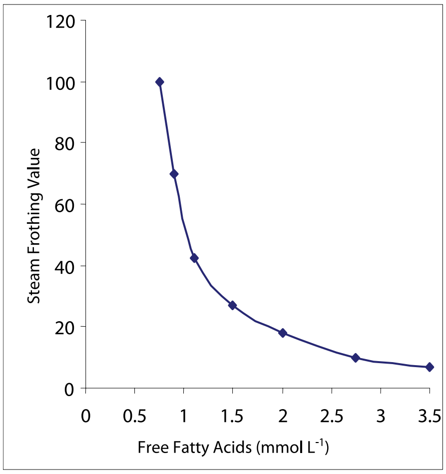
G1. How can the incidence of aflatoxin in milk be avoided?

Because aflatoxins are not produced in pasture, grass hays and silage, the pasture-based dairy production systems that are widely used in Australia present a low risk for the incidence of aflatoxin in milk. The aflatoxin risk is largely confined to feeding of grain-based concentrates, peanut by-product, bakery waste and possibly material containing fruit and vegetable by-products, particularly if they have not been properly dried or allowed to get wet. Dairies purchasing grain and mixed feed should obtain a written assurance from their supplier that it meets local stock food standards for aflatoxin; in Queensland, for example, an upper limit of 0.02 mg aflatoxin B1/kg in stock food for dairy cattle is specified in the Agricultural Standards Regulations 1997 (Blaney ***et al.***, 2006).

H. Milk spoilage caused by natural milk constituents

H1. What is the cause of lack of frothing in cappuccino coffee?

A major functionality effect of lipolysis in milk is depression of its frothing (foaming) ability when injected with steam. This effect is manifested in difficulty in producing acceptable froth when making cappuccino coffee. It is due to the partial glycerides produced during lipolysis, which are surface active and displace the froth-stabilizing proteins at the air–water interface of the foam bubbles. A typical plot of the relationship between the frothing capacity (Steam Frothing Value) and lipolysis (Free Fatty Acid level) of milks



Relationship between the steam frothing value (SFV) and free fatty acid (FFA) level of milks. (SFV = the volume of froth on the milk after stem injection x 100/original volume of milk.)

Source: Deeth (2006), based on data originally published by Deeth and Smith (1983).

is shown below. This plot demonstrates that as the free fatty acid (FFA) level increases as a result of lipolysis, the volume of froth that can be produced by injecting steam into the milk becomes progressively smaller. In this case, the Steam Frothing Value (SFV) of the milk before the onset of lipolysis was 100, corresponding to a FFA level of 0.75 mmol/litre. However, a modest increase in the FFA level to 1.0 mmol/L resulted in a decline in the SFV to 58, while a further increase in the FFA level to 3.0 mmol/L resulted in a decline in the SFV to just 8 (Deeth, 2006).

In practice, milks with an FFA level greater than 1.5 mmol/litre are likely to have impaired frothing properties, while the frothing capacity of milks with a FFA level greater than 2.0 mmol/litre is markedly reduced. A FFA >1.5 is a reasonable threshold value for factory screening of milk from farm storage tanks or farm collection tankers (Deeth and Smith, 1983).
Note. The terms mmol/litre and meq/litre are numerically identical for monovalent acids such as fatty acids.

H2. What are the main differences between milk lipoprotein lipase (LPL) and the bacterial lipases produced by the psychrotrophs growing in cold-stored raw milk?

Milk lipoprotein lipase is a natural constituent of milk. In contrast, the bacterial lipases are not natural constituents of milk, but are produced by the psychrotrophic bacteria that enter the milk from various sources such as contaminated equipment, are able to grow slowly in the cold-stored raw milk and can produce extracellular lipases if their counts are allowed to reach high levels, e.g. more than one million per mL. The main differences between the two types of lipase are summarised in the following table, adapted from Deeth (2006).

Milk lipoprotein lipase (LPL)	Lipases produced by psychrotrophic bacteria
Destroyed by high temperature-short time (HTST) pasteurization	Stable to HTST and even to ultra-high temperature (UHT) treatment
Milk fat globule membrane (MFGM) acts a barrier to lipid substrate	MFGM presents no barrier
Activated by serum lipoproteins	Most not activated by serum lipoproteins
Effect mostly associated with fresh milk and cream	Effect mostly associated with stored products—UHT milk, cheese, butter, milk powders
Effect in cheese/butter obvious at manufacture and does not change during storage	Effect in cheese/butter obvious only after storage and gets progressively worse during storage
High levels in raw milk	Trace levels only in good quality raw milk

H3. How can hydrolytic rancidity caused by milk lipoprotein lipase be prevented?

- Avoid large numbers of cows in late lactation, especially under poor feed conditions;
- Provide a constant balanced diet for the cows;
- Exclude milk from cows with clinical mastitis from the milk supply;
- Design, install and maintain milking equipment correctly;
- Avoid excessive air intake at teat cups;
- Minimize centrifugal pumping, especially of warm milk and with air incorporation;
- Avoid vigorous agitation of raw milk, particularly using air and at higher temperatures;
- Avoid fluctuation in storage temperature;
- Never mix raw and homogenized pasteurised milk; and

- If milk is homogenised during the pasteurisation process, use a processing system that provides for heat treatment of the milk immediately after the homogenisation step (Deeth and Fitz-Gerald, 2006; International Dairy Federation (1991b).

Glossary

Bulk milk cell count (BMCC).

The number of somatic cells (see below) in a consignment of bulk milk from a farm, expressed as cells per mL. Dairy companies usually determine the BMCC on a sample of milk taken from the farm storage tank at every pickup and the results are widely used as a component of the milk payment scheme.

Colostrum.

The secretion from the mammary gland (udder) of the cow for the first few days of the lactation. It differs considerably in composition from the later secretion known from the mammary gland, known as normal milk.

HACCP

Hazard Analysis and Critical Control Points, a system for managing food safety.

Lipolysis

The hydrolysis of triglycerides (triacylglycerols), the major lipid components of milk fat, catalysed by lipase enzymes. The products of the reaction are free (non-esterified) fatty acids, partial glycerides (mono- and di-glycerides) and, in some cases, glycerol. A distinguishing feature of lipases is their ability to act at the lipid–water interface of emulsions of long-chain, insoluble triglycerides.

Organoleptic

Affecting the organs of sense. An organoleptic assessment of quality incorporates sight (visual appearance), smell (odour), taste (if safe) and feel (if applicable).

Mastitis

An inflammation of the mammary gland (udder), generally caused by an intra-mammary microbial infection. Composition of the milk is altered and quality of the milk is impaired.

Maximum Residue Limit (MRL)

The MRL is the maximum permitted limit of an agricultural or veterinary chemical that is permitted to be present in a food, usually expressed in milligrams of the chemical per kilogram of the food (mg/kg). MRLs are published in the Australia New Zealand Food Standards Code. If an MRL is not published in the Code for a chemical in a particular food, there must be no detectable residues of that chemical in that food.

Mesophile

A microorganism that grows best in the temperature range 25-40°C, but cannot grow at 4°C.

Psychrotroph

A microorganism that is capable of growth at 4°C also at 20°C and above (optimum growth temperature often in the range 25-28°C).

Thermoduric

A microorganism that can survive the heat treatment applied to milk when it is pasteurised (72°C for 15 seconds or equivalent, e.g. 63°C for 30 minutes).

Thermophile

A microorganism with an optimum growth temperature in the range 50-60°C.

Somatic cell count

The number of somatic cells in milk, generally expressed as cells per mL. The count is an indicator of udder health.

Somatic cells

The cells present in milk that originate in the mammary gland. They are mostly white blood cells, with a small percentage of epithelial cells also present. The number of cells in the milk can increase dramatically during periods of inflammation of the mammary gland.

Withholding Period (WHP)

In the case of milk, the withholding period is the minimum period that must elapse between the last administration or application of a registered veterinary chemical product to a cow, for example treatment of mastitis with an antibiotic or the feeding of treated stock food, and the collection of milk from that cow for human consumption. In Australia, the WHP if applicable must be stated on the label of every registered veterinary chemical product.

Withholding Period for Grazing

In the case of milk, the withholding period for grazing is the minimum period that must elapse between the last treatment of a crop or pasture with a registered agricultural chemical with a stated withholding period for milking cows and the collection of milk from those cows for human consumption.

References

Anon. (2005). Costs Associated with Mastitis. In: Economic Consequences of Mastitis. International Dairy Federation, Brussels, Bulletin No. 394, pp 6-12.

Auldist M (2003). Milk Quality and Udder Health: Effect on Processing Characteristics. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 2002-2007.

Barbano DM and Lynch JM (2007). Fact Sheet - Milk Protein Testing – FAQ'S: Changing from Crude Protein to True Protein (Cornell University, Ithaca, New York). Federal Milk Market Administrator's Office, Pacific Northwest and Arizona Federal Milk Orders, http://www.fmmaseattle.com/lab/FAQ.htm

Blaney B, Cowles G, Mills G, McKenzie R, Webster R, Were S and Wright G (2006). Avoid aflatoxin poisoning of livestock, and the potential for residues in milk and meat. Department of Primary

Industries and Fisheries' Note, http://www2.dpi.qld.gov.au/health/18460.html

Bluthgen A and Tuinstra LGM (1997). Pesticides. In: Hopkin E (Ed.) Monograph on Residues and Contaminants in Milk and Milk Products. International Dairy Federation, Brussels, Chapter 7, pp 54-64.

Bramley AJ and McKinnon CH (1990). The Microbiology of Raw Milk. In: Robinson RK (Ed.) Dairy Microbiology, Volume 1, Second Edition. Elsevier Applied Science, London, Chapter 5, pp 163-208.

Brazis AR (1991). Methods for Estimating Colony Forming Units. Plate Count Method. In: Heeschen W (Coordinator) Methods for Assessing the Bacteriological Quality of Raw Milk from the Farm. International Dairy Federation, Brussels, Bulletin No. 256, pp 4-8.

Codex Alimentarius Commission (1999). Codex General Standard for the Use of Dairy Terms, Codex Stan 206-1999. www.codexalimentarius.net/download/standards/332/CXS_206e.pdf

Codex Alimentarius Commission (2004). The Code of Hygienic Practice for Milk and Milk Products CAC/RCP 57–2004. http://www.codexalimentarius.net/download/standards/10087/CXC_057_2004e.pdf

Craven HM, Broome MC, Chandler, RE and Jensen N (2001). Dairy Products. In: Moir CJ (Editor in Chief) Spoilage of Processed Foods: Causes and Diagnosis. AIFST Inc. (NSW Branch), Food Microbiology Group, Sydney, pp 147-164.

Dairy Australia (2006). Australian Dairy Industry in Focus 2006. http://www.dairyaustralia.com.au/component/option,com_remository/Itemid,26/func,select/id,8/

Dairy Food Safety Victoria (2006a). Antibiotic Residue Screening Test Methods. Website: http://www.dairysafe.vic.gov.au/pdf/DFSNote1_v2_AntibioticResidueScreeningTestMethods_Jun06.pdf

Dairy Food Safety Victoria (2006b). Detection Limits of Antibiotic Residue Screening Test Kits. Website: http://www.dairysafe.vic.gov.au/pdf/DFSNote2_v2_AntibioticDetectionLimitsOfAntibioticResidueScreeningTestKits_Jun06.pdf

Deeth HC (2006). Review: Lipoprotein lipase and lipolysis in milk. International Dairy Journal 16, 555–562.

Deeth HC and Fitz-Gerald CH (2006). Lipolytic enzymes and hydrolytic rancidity. In Fox PF and McSweeney P (Eds.) Advanced Dairy Chemistry, 2 Lipids. Springer, New York, Chapter 15, pp 481-556.

Deeth HC and Smith, RAD (1983). Lipolysis and other factors affecting the steam frothing capacity of milk. Australian Journal of Dairy Technology, Volume 38, pp 14–19.

Delahunty CM (2003). Analysis: Sensory Evaluation. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 106-110.

Fischer WJ, Tritscher AM, Schilter B and Stadler RH (2002a). Contaminants of Milk and Dairy Products: Contaminants Resulting from Agricultural and Dairy Practices. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 516-525.

Fischer WJ, Tritscher AM, Stadler RH and Schilter B (2002b). Contaminants of Milk and Dairy Products: Environmental Contaminants. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 525-533.

Food Standards Australia New Zealand (2002). Australia New Zealand Food Standards Code. http://www.foodstandards.gov.au/thecode/foodstandardscode.cfm

Fox PF (2003). Milk: Introduction. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 1085-1812.

Frank JF and Hassan AN (2003). Microorganisms Associated with Milk. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 1786-1796.

Heeschen W (1996). Bacteriological Quality of Raw Milk: Legal Requirements and Payment Systems – Situation in the EU and IDF Member Countries. In: Bacteriological Quality of Raw Milk. International Dairy Federation, Brussels, pp 1-18.

Heggum C (2004). Control of Aflatoxin in Cattle Feed – The Danish System. Quality Management at Farm Level. International Dairy Federation, Brussels, Bulletin No. 386, pp 24-27.

Hill BM (1991). Methods for Estimating Colony Forming Units. Plate Loop Method. In: Heeschen W (Coordinator) Methods for Assessing the Bacteriological Quality of Raw Milk from the Farm. International Dairy Federation, Brussels, Bulletin No. 256, pp 9-12.

Honkanen-Buzaiski T and Suhren G (1999). Residues of Antimicrobial Agents in Milk and their Significance to Public Health and Milk Processing. In: Quality and Safety of Raw Milk and its Impact on Milk and Milk Products. International Dairy Federation, Brussels, Bulletin No. 345, pp 11-12.

International Dairy Federation (1991a). Detection and Confirmation of Inhibitors in Milk and Milk Products, 2nd Edition. International Dairy Federation, Brussels, Bulletin No. 258, pp 6-9.

International Dairy Federation (1991b). A Practical Guide to the Control of Lipolysis in the Manufacture of Dairy Products. International Dairy Federation, Brussels, Bulletin No. 264, pp 26-28.

Kelly AL (2003). Milk Quality and Udder Health: Test Methods and Standards. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 1995-2002.

Marnila P and Korhonen H (2003). Colostrum. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 473-478.

Pedersen M and Suhren G (2000). Chemical-Physical Confirmation Tests ('Higher' Validation Level) for the Detection of Residues of Antimicrobials in Milk. International Dairy Federation, Brussels, Bulletin No. 358, pp 29-35.

SAI-Global (2004). AS 5013.1-2004, Food microbiology - Examination for specific organisms - Standard plate count. http://www.saiglobal.com/shop/Script/Details.asp?DocN=AS0733760201AT

Slaghuis B (1991). Methods for Estimating Colony Forming Units. Roll Tube Method. In: Heeschen W (Coordinator) Methods for Assessing the Bacteriological Quality of Raw Milk from the Farm. International Dairy Federation, Brussels, Bulletin No. 256, pp 12-13.

Slaghuis B, Wolters G and Reineman D (2003). Milking and Handling of Milk: Milking Hygiene. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 2016-2021.

Smith KL (2002). A Discussion of Normal and Abnormal Milk Based on Somatic Cell Count and Clinical Mastitis. In: A Fresh Perspective for Managing Milk-Borne Disease. International Dairy Federation, Brussels, Bulletin No. 372, pp 43-45.

van Egmond HP, Svensson UK and Fremy JM (1997). Mycotoxins. In: Hopkin E (Ed.) Monograph on Residues and Contaminants in Milk and Milk Products. International Dairy Federation, Brussels, Chapter 10, pp 79-88.

Webb BH, Johnson AH and Alford JA (1974). Fundamentals of Dairy Chemistry, Second Edition. The AVI Publishing Company, Westport, Connecticut.

White CH (2003). Milking and Handling of Milk: Effects of Storage and Transport on Milk Quality. In: Roginski H, Fuquay J and Fox P (Eds.) Encyclopaedia of Dairy Sciences. Academic Press, London, pp 2021-2028.

DAIRY AUSTRALIA
Delivering for the dairy industry

4

Global Trends and Innovations in Dairy Ingredients, Products and Processing

Content

76 4.1 Introduction

76 4.2 Trends in Milk Production, Consumption and Consumer Attitudes

78 4.3 Trends in Milk Processing

82 4.4 Trends in Processing and Applications of Dairy Ingredients

86 4.5 Trends in Consumer Dairy Products

90 4.6 Conclusion

91 FAQ

95 Glossary

4.1 Introduction

Dairy products and ingredients form an integral part of human diet. Over years, dairy industry has evolved from local production and consumption to value addition and global distribution and consumption. Along the way many technological and logistical challenges have been overcome. Consumer needs and demands have changed with increased wealth in developing countries and health concerns in developed countries. Consumption patterns still vary significantly among developed and developing countries, although in selected developing countries such as China, the consumption is increasing at a rapid rate. In order to keep up with changing consumer trends, the dairy industry has had to reinvent itself and offer new marketable products and ingredients. Since 1980s, many value-added products and ingredients have been developed and are available in the market to meet consumer demands and to address health concerns. Milk has also positioned itself as the preferred delivery vehicle for non-dairy functional/health ingredients. This Chapter summarises some of the recent trends and innovations in global dairy industry.

4.2 Trends in Milk Production, Consumption and Consumer Attitudes

Figure 1 Changes in world milk production from 2001 to 2005

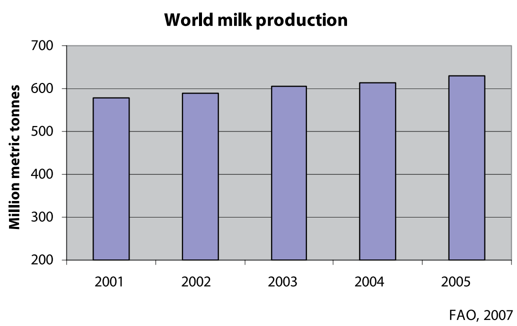


Figure 2 Changes in milk production of selected countries between 2001 and 2005

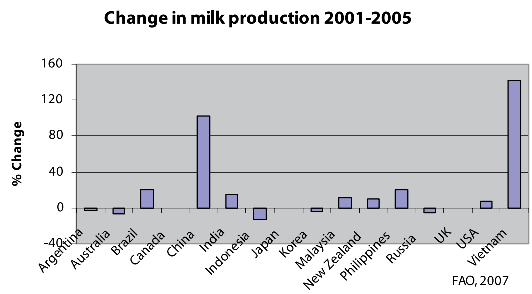


Figure 3 Retail growth trends in dairy products (USDA[1])

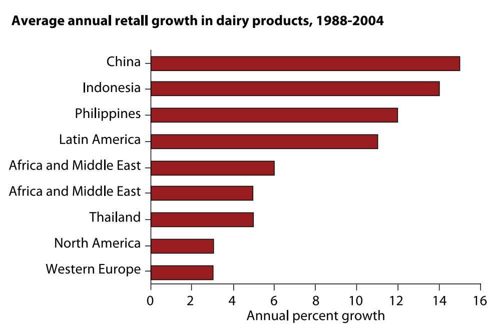
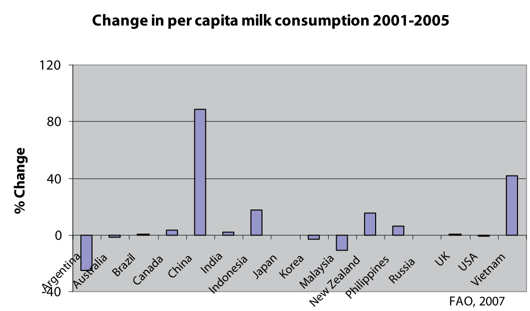


Figure 4 Change in milk consumption (g/capita/day) from 2001 to 2005 in selected Western and Asian countries[2].



According to the FAO, global milk production has increased on average by approximately 2-3% each year reaching about 630 million metric tonnes in 2005 (Figure 1). During this period, most dramatic

[1] *http://www.ers.usda.gov/Publications/ERR28/*
[2] *FAO 2007*

increase in milk production has been in Southeast Asian region, especially in China and Vietnam (Table 1, Figure 2). The reasons for strong growth in this region are the rising costs of imported milk powders, increased demand for fresh milk from an increasingly affluent society and improved breeding through collaborations with leading dairy producer nations such as Australia and New Zealand. So far, relative to traditional milk producing countries, the production volumes in these countries remain low but the growth prospects remain strong.

Table 1 Changes in milk production from 2001 to 2005 in selected countries (FAO, 2007[3])

	Milk production ('000 metric tonnes)				
	2001	2002	2003	2004	2005
Argentina	9769	8793	8197	8100	9491
Australia	10872	10328	10075	10125	10092
Brazil	21284	22453	23079	24337	25468
Canada	8106	7964	8050	8000	8100
China	14515	17335	21871	24273	29403
India	83419	84760	86660	91059	95619
Indonesia	769	785	859	915	664
Japan	8301	8385	8400	8329	8285
Korea, Republic of	2343	2542	2371	2260	2234
Malaysia	36	42	43	41	40
New Zealand	13119	13866	14349	15030	14498
Philippines	11	11	11	12	13
Russian Federation	32905	33504	33373	32173	31144
United Kingdom	14707	14869	15010	14555	14577
USA	74994	77140	77289	77519	80265
Viet Nam	95	109	158	182	229

The rise in production of milk is generally accompanied by the increase in the consumption of dairy products. According to the USDA, Asian countries have shown a strong increase in retails sales of dairy products from 1998 to 2004 with Chinese retail leading the market with a growth of over 15% (Figure 3). Similar trends have been noticed in recent years.

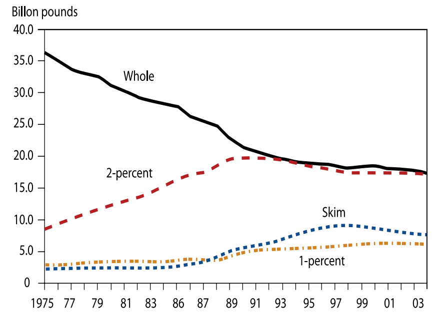
The rise in consumption of dairy products in Asian countries is also reflected in the increase in per capita milk consumption[4]. In past, global consumption patterns have suggested that as the income increases, the consumption of animal protein (fish, meat and dairy) in diet increases. Because many Asian countries have been growing rapidly in recent years, they fit these global consumption patterns. Recent data from FAO show that China and Vietnam are leading the growth in per capita milk consumption (Figure 4). Although the per capita consumption in Asian countries is rapidly rising, it remains significantly low in comparison to Western countries. For example, per capita milk consumption in Australia in 2005 was 101 kg compared with only 4.5 kg for China and 1.8 kg for Indonesia, the two most populous countries in the region. This also means that there is a strong potential for growth in Asian dairy consumption.

Over years, the consumption patterns for milk have considerably changed in developed Western dairy markets. For example, in US the milk consumption patterns over the past 25 years apparently

[3] *http://faostat.fao.org/site/346/DesktopDefault.aspx?PageID=346*
[4] *www.fapri.org*

reflect a growing concern regarding obesity and fat intake (Figure 5). The primary trend over this time has been a steady decrease in per capita consumption of standard milk (milk with 3.5% fat) over this period. Some of this consumption has shifted to skim and low fat (2%) milk through the 1980s. Such consumption trends are not yet evident in Asian countries.

Figure 5 Trends in fluid milk consumption in US[5]



Over years, Western countries have tried to stop declining milk consumption through analysis of consumer attitudes towards milk and offering products meeting consumer requirements. In Australia, a study found that consumers perceived whole milk more negatively than soymilk or reduced fat milk[6]. Milk was perceived to have health benefits related to bone health, weight control, and prevention of certain diseases. Another study[7] examined the effects of diet information on whole and low fat milk choices and found that "women's diet-health attitudes and their food label use contributed to reduced whole milk consumption and increased low-fat milk consumption. According to an AP-Ipsos survey conducted in 2006, of the 79% of surveyed Americans who read the Nutrition Facts panel on food and beverage packages, 26% said they looked for first fat and calorie content[8]. Sugars came in third on the list, with 10% of the 1,003 respondents checking for these first, followed by 8% who check for sodium and 6% for carbohydrates. The survey also revealed that younger people are more likely to look for calories on labels, with almost 40% of people aged between 18 and 29 saying they looked at calories first. This age group is also more likely to believe what it says on the front of a package than other age groups, while almost three quarters of total survey respondents said they check "low-fat" or "reduced-fat" product claims against the nutrition label.

4.3 Trends in Milk Processing

4.3.1 Shelf Life Extension of Pasteurised Chilled Milk

Although high-temperature-short-time (HTST) pasteurization is typically used commercially to process milk, the product shelf life is only approximately 2 weeks at refrigeration temperatures provided the quality of incoming raw milk is good. Meanwhile ultrahigh high temperature (UHT) processing allows milk to be stored at room temperature for six months -- but also leaves a "cooked" flavour. UHT treatment also causes some loss of the nutritional components of milk.

New technologies are being developed to process milk to extend its shelf life without compromising on flavour. Several processing technologies have been explored to achieve microbial safety and minimize off-flavour formation. These technologies include

- Extended shelf life (ESL) milk through heat treatment and aseptic (clean) packaging
- Extended shelf life (ESL) milk through microfiltration
- High hydrostatic pressure processing (HPP)
- Pulsed electric field (PEF) processing
- Ultrasonication (US) of milk

5 *Miller JJ and Blayney DP (2006) Dairy Backgrounder. USDA Economic Research Service*
6 *Bus, A. E. M., and A. Worsley (2003) Consumers' health perceptions of three types of milk: a survey in Australia. Appetite 40: 93-100.*
7 *Kim, S., and R. A. Douthitt (2004) The role of dietary information in women's whole milk and low-fat milk intakes. International Journal of Consumer Studies 28(3): 245-54.*
8 *Barry D (2006) Dairy case offers more products for calorie counters. Dairy Foods, August 11, 2006*

4.3.2 Extended Shelf Life (ESL) Milk through Pasteurisation and Aseptic (Clean) Packaging

Extended shelf life (ESL) is an imprecise umbrella term referring to solutions that extend the shelf life of dairy and other chilled products beyond the shelf life of pasteurised products. In the US, the market for ESL products is growing at about 20 per cent a year, driven mainly by soy and organic milk markets.

Even a few extra days of shelf life for chilled milk can be a significant benefit to dairy companies, allowing them to consolidate operations and extend their distribution chain. Extending the shelf life beyond that -by 30 or even 90 days - opens up new opportunities for marketing milk products to consumers demanding quality and safety.

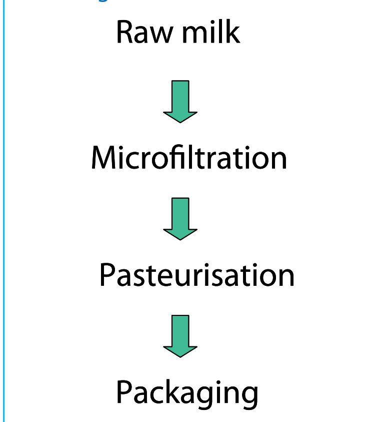
One of the easiest processing changes that some companies have adopted to enhance the shelf of chilled milk is by having clean and aseptic filling associated with a higher processing temperature than pasteurisation. The key to ESL technology is hygiene from start to finish of processing operations. The technology for extending the shelf life of products is used to increase microbial reduction during processing, avoid re-contamination during filling and maintain a reduced distribution temperature. In some instances, a high temperature (90-95°C for few 2-3 sec) combined with aseptic (clean) filling and chilled storage has achieved extension of up to 2 weeks for milk. ESL processing and packaging systems are being used in the production of white and flavoured milks, fortified, enriched and fermented products, cream and dairy desserts. Large dairy equipment suppliers such as Tetra Pak and GEA have adopted new strategies in selling their processing and packaging systems to dairy companies looking to extend the shelf life of their products.

4.3.3 Extended Shelf Life (ESL) Milk through Microfiltration

The current methods used commercially for producing ESL milk are microfiltration in combination with low temperature pasteurization, direct heat treatment such as injection or infusion, or indirect heat treatment for instance using plated heat exchangers. A flow chart showing the use of microfiltration for ESL milk is shown in Figure 6.

The process involves selection of good quality milk, filtration through a microfiltration membrane of pore size 0.5-2 um to remove bacteria and pasteurisation using HTST.

Figure 6: Process flow diagram for ESL using microfiltration



Microfiltration using cross-flow membrane separation has shown promising results in eliminating bacteria from milk and increasing shelf life without the development of off-flavours. It has been reported that the levels of micro-organisms and aerobic spores in raw milk are reduced by 99.3 – 99.9% and 99.1 – 99.9%, respectively. However, high levels of milk fat could foul the membrane and place some restrictions on the use of microfiltration as an alternative technique for milk processing. Many dairy companies have adopted microfiltration for production of ESL milk. In the UK, premium microfiltered ESL milk has captured 11 per cent of the market. In the past 12 months volume share has increased by 29 per cent, while the value of sales has increased by 34 percent. The product has a 23 days shelf life.

4.3.4 High Hydrostatic Pressure Processing (HPP)

HPP is a batch process that involves subjecting moisture-containing products to very high isostatic pressures. High hydrostatic pressure processing can destroy microorganisms by interfering with their cellular metabolism. The technology has been gaining commercial acceptance in the manufacture of food products with "fresh" flavour that is not possible with other preservation technologies. HPP has been successfully implemented for shelf life extension of meat products, seafoods, fruit juices and ready meals in US and Europe. One of the advantages of the technology is that food products can be processed post packaging thereby eliminating the fear of post processing contamination. Figure 7 shows an HPP machine from Spanish company NC Hyperbaric and examples of fruit juices available in US.

Figure 7 HPP machine from NC Hyperbaric and HPP treated fruit juices in US

There is currently no large-scale commercial processing of milk and dairy products using HPP. Research has shown that milk processed using high hydrostatic pressure (HPP) (pressure of up to 87,000 pounds per square inch or 600 MPa) for 5 min, and lower temperatures than those used in commercial pasteurization, cause minimal production of chemical compounds responsible for the cooked flavour. However, some changes have been noted in milk such as alteration in casein micelle size, slight reduction in the whiteness of milk and increase in the viscosity of milk. Another noticeable change has been in the crystallization properties of milk fat which may impact on further processing. The crystallization behaviour of milk fat is altered because high pressure shifts the phase transition temperature.

HPP has been evaluated for inactivation of spoilage bacteria and extension of the shelf life of chilled milk. Some studies have claimed that HPP does not introduce any off-flavours in the milk and could provide manufacturers with a substitute technique for thermal processing, the main method used by processors to achieve microbial safety and shelf-life stability of milk. HPP also avoids destruction of heat labile vitamins and bioactive components thus providing opportunity to maintain the nutritional quality of milk.

Two major suppliers of HPP equipment are Avure Technologies, USA and NC Hyperbaric, Spain. Although for dairy, HPP technology currently remains at a development stage, major dairy companies are showing considerable interest in it.

4.3.5 Pulse Electric Field (PEF) and Ultrasonication (US)

PEF and US are non-thermal technologies that are being assessed for suitability as a replacement or part-replacement of heat for the processing of milk. High intensity pulsed electric field (PEF) processing involves the application of pulses of high voltage (typically 20 - 80 kV/cm) to foods placed between 2 electrodes[9]. PEF treatment is conducted at ambient, sub-ambient, or slightly above ambient temperature for less than 1s, and energy loss due to heating of foods is minimized. Ultrasonic cavitation creates shear forces that can break cell walls mechanically and inactivate spoilage organisms in food.

Of the above technologies, many dairy companies have successfully implemented ESL in a number of forms including microfiltration and HPP is being actively pursued for commercialisation. The remaining two processing technologies (i.e. PEF and US) remain at academic research level and may require another 5-10 years of research and development work before they are considered for possible applications up by the dairy industry.

4.3.6 Organic Milk Processing

In recent years many dairy processors have followed on consumer trends and demands for organic milk processing. Large companies such as Fonterra, Danone and Dean Foods have either acquired small organic processors or developed their own pool of organic milk suppliers. The global market for organic products reached a value of €30 billion in 2006, with the vast majority of products being consumed in North America and Europe[10]. According to the USDA Economic Research Service, health-conscious consumers are driving increased sales of organic and natural food products. Organic food sales in US reached nearly US$14 billion in 2005. Of that, organic dairy products accounted for US$2.14 billion in sales, according to the Organic Trade Association's Manufacturer Survey. Organic dairy products are being marketed through mainstream supermarket channels and natural foods stores. World demand for organic products has risen dramatically over the last ten years and is currently growing at a rate of 15-30% per year and healthy growth rates are expected to continue in the coming years.

Claims made for organic milk include better flavour, taste and nutritional quality. Production of organic milk is also linked to favourable environmental impacts because of elimination of the use of chemical fertilisers, insecticides and pesticides in cows feed.

The United States and European Union are by far the largest markets for organic products at the present time—accounting for 97% of global expenditure. However, as yet, organic milk in US accounts for less than 1 percent of the milk market[11]. As of 2003, 74,435 milk cows were certified organic in US. The number of certified organic milk cows increased by 477 percent from 1997 to 2003. Some 745,273 acres of pasture and rangeland are certified organic. In Australia, it is estimated that there are over 1,500 certified organic farms, however this figure does not include those farms that are in the pre-certification or in-conversion phase of organic certification.

Overall, the trend for organic milk processing is likely to continue as long as consumers can afford to pay a premium but the segment is likely to remain small (less than 5%) in the short term.

Chap - 04

---

[9] *http://ohioline.osu.edu/fse-fact/0002.html*
[10] *http://www.ifoam.org/press/press/Statistics_2007.html*
[11] *Schultz (2006). Organic Dairy Profile*
http://www.agmrc.org/agmrc/commodity/livestock/dairy/organicdairyprofile.htm

4.4 Trends in Processing and Applications of Dairy Ingredients

Although milk powder, cheese and milk protein products such as caseinates, milk and whey protein concentrates, isolates and hydrolysates form the bulk of dairy ingredients in the market, recently, a number of new and novel ingredients have been launched. The main drivers for development and commercialisation for these new ingredients are the health, weight management, sports and nutritional requirements of consumers. Table 2 summarises the key trends in dairy ingredients and their applications.

Table 2 Key trends in processing and applications of dairy ingredients

Dairy ingredient	Key functional properties	Examples of applications
Colostrum	Immune enhancing properties due to high immunoglobulin contentRich source of natural growth factors and antimicrobial factors – lactoperoxidase, lactoferrin and lysozyme	Sports nutrition and body buildingHealth care products, such as Lozenges and tablets from Fonterra and Synertek colostrumHealth supplements in combination with probiotic bacteria such as tablets from Inner healthInfant formula for non-breast-fed babies
Lactoferrin	Antimicrobial activityAntiviral activityAnti-tumour activityAnti-inflammatory activityImmunomodulating activity	Infant formulasAdult nutritional powders and drinksYoghurts and drinking yoghurtsSports formulationsMeat preservative
Peptides	Reduction in blood pressure	Dairy drinks such as Flora Pro Active drink from Unilever containing Ameal Peptide from Calpis
Glycomacropeptides	SatietyPrevention of dental cavitiesControlling blood clottingAntibacterial and anti viral properties	Sports drinksInfant formulasNutrition barsProbiotic dairy products
Milk calcium	Bone and teeth maintenance Hypertension	Powdered beveragesNutritional drinksDairy products Bakery productWeight loss products
α-lactalbumin	Sleep enhancement	Drinks and beverages
Micellar casein	Slow release of amino acidsRich source of protein and calcium	Sports nutritionWeight loss products
Prebiotic rich whey powder	Stimulating growth and activity of beneficial intestinal flora	Probiotic drinks and beverages
Milk protein crisps	High nutrition value with crunchy textured proteins	Sports barsSnack foodsBreakfast cereals
High selenium milk protein concentrate	Source of selenium	Food products and drinks needing selenium fortification
Osteopontins	Immune functions	Infant formula

4.4.1 Colostrum Powders

Colostrum is the first milk secreted after parturition. Colostrum is taken from the first four milkings (48 hours) after calf birth. The composition of colostrum and its physical properties are significantly different from that of mature milk. Colostrum is a good source of nutrients, but in addition it contains enhanced levels of many biologically active components, such as immunoglobulins. More recently, colostrum has been investigated as an immunological agent for its ability to reduce the effects of gastrointestinal infection, especially in individuals who are immuno-compromised. Colostrum has also gained recent popularity as a sports supplement for improving muscle gain, performance and recovery time.

4.4.2 Lactoferrin

Lactoferrin has been shown to have several bioactive effects such as antimicrobial activity or as a bactericidal agent. Lactoferrin controls microbial activity of organisms such as E. coli, Salmonella, Staphylococcus, Listeria, and Candida. In 2003, FDA and USDA approved the use of lactoferrin as meat preservative. Due to food safety concerns in the meat industry and lactoferrin's positioning as a natural antimicrobial agent, a significant opportunity has been created in the market. Analysis of market activities indicates that at least 5 major dairy companies are offering lactoferrin-enhanced dairy ingredients. Lactoferrin is also suitable for a number of application areas including infant formulas, health supplements, functional foods and drinks, cosmetics and oral care and veterinary/ feed products.

4.4.3 Milk-Derived Peptides

Milk protein peptides are made by hydrolysis of milk proteins. Research has shown that they have many physiological benefits including helping to control blood pressure by working with the body's natural mechanism for controlling blood pressure. Dairy peptides only lower blood pressure when it is above normal and are intended for use by people who have been given diet and lifestyle advice to control their blood pressure. They are not intended as a replacement for blood pressure medication. They are found naturally in some cheeses such as Dutch Gouda and mature cheddar, but the amounts are too small to be useful.

Research studies have identified several bioactive peptides from milk proteins, however, only a handful companies have commercialised milk-derived peptides. One of the leading companies in this area is DMV International (http://www.dmv-international.com). Another company, Calpis has been selling milk peptides under the brand name Ameal™ that are available as food supplements. AmealPeptide™ are special dairy peptides that are added to some dairy drinks, such as Flora Pro Activ blood pressure daily dose drink, which when taken daily can help to control blood pressure as part of a healthy diet.

One of the main hurdles in commercialisation of milk-derived peptides remains the high cost of extraction and the inability to make health claims under most regulatory environments. More innovation and commercialisation of milk peptides is anticipated in the near future as companies look for value-added, high return dairy ingredients and health claims regulations are simplified.

4.4.4 Glycomarcopeptides

Glycomacropeptide (GMP) is a casein-derived peptide left in whey after cheese making. When milk is treated with chymosin during cheese making, the milk protein (κ-casein) is hydrolysed into two peptides. The larger peptide containing amino acid residues 1-105 is called para-κ-casein, which becomes part of the cheese curd, while the smaller peptide containing amino acid residues 106-169 becomes soluble and part of the whey. The peptide is relatively small, with a molecular weight of 8000 Daltons. There are two major variants of GMP, variant A and variant B, which differ in two amino acids. Different abbreviations are used to identify GMP, but all refer to the same molecule found in whey: CMP is caseinmacropeptide; CGMP is casein-glycomacropeptide; CDP is casein-derived peptide and CGP is caseinglycopeptide.

Commercially, GMP has been marketed for its nutritional and health benefits. GMP may help prevent dental cavities, influence blood clotting, interact with antibodies, and protect against viruses and bacteria. GMP is the only naturally occurring whey protein without phenylalanine, and may be useful in the treatment of phenylketonuria. Phenylketonuria, or PKU is a rare, hereditary, metabolic disorder. PKU is inherited as an autosomal recessive trait. Studies have shown that GMP stimulates the body to produce the protein released after eating that gives one a sense of satiety. For infants, the inclusion of GMP in the diet helps to inhibit growth of pathogenic bacteria in the GI tract and helps to protect infants from gastrointestinal diseases.

4.4.5 Milk Calcium

Several dairy companies have recently started offering milk calcium made from either whey or milk permeate after ultrafiltration. Milk calcium is becoming an increasingly important source of calcium supplementation in the food industry. Recognized for its numerous health benefits, dietary calcium has proven to have positive effects in osteoporosis, healthy bones and teeth, hypertension and even certain cancers. The gap between calcium intake and recommended daily intake is much wider than previously thought. Milk calcium is generally sold in the form of milk minerals with approximately 24% calcium has an advantage over other sources of calcium as it is considered natural, has a neutral taste and bland odour. Milk calcium helps manufacturers design products with a "clean label" and natural image. Some calcium suppliers offer different granulations for varied applications Main applications of milk calcium include fortification of beverages and drinks.

One of the major applications of dairy calcium is now in weight control and management market. Success in this market could be very profitable for the dairy industry, as this market is likely to grow considerably in the near future.

4.4.6 Alpha Lactalbumin

Some dairy companies have isolated α-lactalbumin from cheese whey using an ion-exchange technology and developed ingredients rich in α-lactalbumin. Davisco Foods (http://www.daviscofoods.com) in US has been marketing tryptophan-rich α-lactalbumin based on its ability to improve sleep and early morning performance by increased alertness. A study carried out by Markus et al (2005)[12] showed a 130% increase in plasma tryptophan after the evening intake of a α-lactalbumin– enriched standard diet as compared with a placebo diet. This was accompanied by reduced sleepiness and higher task-related brain activity the following morning, which suggests improved alertness due to better sleep.

4.4.7 Micellar Casein

Keeping high concentrations of casein in micellar form can help create new opportunities for dairy proteins that exploit colloidal behaviour and the naturally high calcium content. Kerry Ingredients has recently launched micellar casein under the brand name Micellnor™ that is specifically developed for use in sports nutrition and weight loss applications. According to Kerry, Micellnor™ generates a positive nitrogen balance in the body and promotes satiety. Slow amino acid release promotes muscle growth and recovery, thus preventing muscle breakdown. The slow release principle ensures that casein coagulates and aggregates in the stomach. This results in slow and prolonged digestion of proteins. Kerry Ingredients Micellnor™ is claimed as a native micellar casein product, produced from skim milk using a proprietary combination of membrane filtration technologies.

[12] *Markus, CM, Lisa M Jonkman, Jan HCM Lammers, Nicolaas EP Deutz, Marielle H Messer, and Nienke Rigtering (2005). Evening intake of a-lactalbumin increases plasma tryptophan availability and improves morning alertness and brain measures of attention. Am J Clin Nutr 2005;81:1026 –33.*

4.4.8 Prebiotic Rich Whey Powders

Prebiotics are loosely defined as non-digestible food constituents, largely carbohydrate-derived, which benefit the host by selectively stimulating the growth and/or activity of beneficial intestinal flora. Many studies have demonstrated that oligosaccharides promote the growth of beneficial bacteria such as Lactobacilli and Bifidobacteria and reduce the number of pathogens such as Clostridia, Bacteriocides, Enterococci and E. coli. The primary benefits associated with the growth of beneficial bacteria and reduction of pathogens is the decrease in the incidence of diarrhoea as well as increased mineral absorption. Further studies also propose its beneficial role in reducing cholesterol levels and in the prevention of colon cancer.

Kerry Ingredients (http://www.kerrydairy.com/) have launched a galacto-oligosaccharide enriched whey powder. The galacto-oligosaccharide is derived from bovine milk lactose. The powder is marketed as a prebiotic soluble fibre for applications in probiotic drinks and beverages.

4.4.9 Milk Protein Crisps

Building on the functional properties of milk proteins, extruded forms called milk protein crisps have been commercialised recently. Such products are available with a protein content ranging from 40 to 70% with different crisp sizes. The ingredient's crunchy texture has made it suitable for use in cereals, snacks, granola, trail mixes, protein and nutrition bars, salad toppings, frozen dessert toppings/coatings, yogurt toppings, or as a crunchy flavoured snack on its own.

Milk protein crisps, as the ones shown here and marketed as Powercrisp™ by Fonterra are innovations that are competing with the existing extruded snacks markets and offering nutritional and functional alternatives

Milk protein crisps provide ideal vehicles for the delivery of high protein and are easier to use than dairy protein powders in certain applications. For example, in sports bars, snack foods, and breakfast cereals, there are benefits in an easy-to-use dairy protein source for providing structure, crunchiness and nutrition.

4.4.10 High Selenium Milk Protein Concentrate

Selenium in diet is reported to have beneficial effects on immune system, heart diseases and certain cancers. Therefore, selenium is an essential mineral required for human health, however there are many regions in the world where selenium intake is not sufficient due to its low levels in foods. Recently, Tatura Milk Industries (www.tatmilk.com.au) in Australia have developed a high selenium milk powder, TATURA-BIO®SE, through feeding cows with selenium enriched diets. TATURA-BIO®SE contains approximately 5 mg selenium per kilogram powder. According to Tatura Milk Industries, its high selenium milk powder can be used in a range of food applications for enrichment of selenium.

4.4.11 Osteopontin

Osteopontin is a heavily phosphorylated and acidic glycoprotein with strong calcium-binding properties. Although its exact function is not yet known, the ubiquitous presence of osteopontin in the human body has led many academic researchers to focus on investigating the glycoprotein in a variety of physiological functions[13].

[13] *Arla Food Ingredients (www.arlafoodingredients.com)*

Preliminary tests suggest that osteopontin plays a role in the development of infant immune function. In infant nutrition products, it is thought to help non-breast fed infants achieve immune modulation comparable to that of breastfed infants. The whey protein osteopontin was identified in human milk only a few years after being discovered in the human body. Small quantities have since been identified in bovine milk and are now available from Arla Foods Ingredients (http://www.arlafoodsingredients.com/) in a 95% pure form LACPRODAN OPN-10 is the first commercially available osteopontin product on the market. The target application for osteopontin is infant formula.

4.5 Trends in Consumer Dairy Products

In the past 5 years, innovation and growth in the dairy industry has been driven by consumer health concerns such as obesity, heart diseases and diabetes. Apart from the reduction in fat, one of the most exciting opportunities for the dairy industry in recent times has been the growth of functional dairy products containing non-dairy bioactive ingredients such as omega-3 fatty acids and plant sterols. A summary of trends in consumer dairy products is shown in Table 3. Milk and milk products are conveniently positioned as vehicles for the delivery of dairy and non-dairy food ingredients due to their superior flavour, nutritional and compositional profiles. Leading players in consumer dairy products manufacturing and marketing are Danone, Muller, Unilever, Parmalat, Emmi, Nestle and General Mills.

Table 3 Key trends in consumer dairy products

Major modification and/or key functional ingredient	Consumer milk product	Proposed benefits
Reduced fat, sodium or carbohydrate, low calories	Liquid milk, yogurt, cheese with nutritional claims	General health and wellness, weight management
Probiotic bacteria	Yogurt, drinking yogurt, yogurt smoothie, cheese	Digestive health, immune support (or "natural defence") and maintain optimal health and wellness
Prebiotic fibre	Yogurt, drinking yogurt	Act as soluble fibre in the colon for the growth of probiotic bacteria
Omega-3 fatty acid	Milk, Cheese, yogurt, drinking yogurt, cheese	Heart health and brain function
Plant sterols	Milk, yogurt	Cholesterol reduction
Antioxidants	Milk, drinking yogurt	Breast, colon and prostate cancers
Dietary fibre	Milk, drinking yogurt	Able to enhance gut function and may act as prebiotics

Recent product development and innovation trends in consumer dairy products include

- Nutrition claims
- Probiotics and prebiotics
- Omega-3 fatty acids
- Plant sterols
- Dietary fibre

4.5.1 Nutrition Claims

Nutrition claims in foods include, "low fat", low "saturated fat", "low sodium", "low carbohydrate", "low calories". In the past 5 years products with "low" claims have grown significantly, often taking a large market share of regular products. For the dairy industry, the main focus for "low" claims has been related to the reduction of fat, including cholesterol. Some companies also market low or no lactose milk products. Milk and other dairy products such as cheese and yogurt are routinely available in low-fat versions.

At the end of 2005 and in 2006 considerable interest was shown in low carbohydrate products as promoted by the Atkins diet. Many dairy companies including Hood in the US followed the trend but soon had to re-brand their products as the trend faded away.

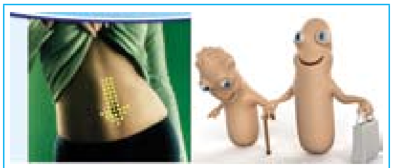
In 2006, some dairy companies followed the trend for low carbohydrate that was driven by popularity of the Atkins diet. As the consumer focus moved away from low-carb, dairy companies were quick to re-brand their products as in the example above showing milk from Hood Company in the US

4.5.2 Probiotic Bacteria

Probiotic bacteria are naturally occurring live bacteria, such as Lactobacillus sp, Bifidobacterium sp and Lactococcus sp. These bacteria are often known as "good bacteria", and it is thought that they help to maintain a healthy digestive system and may also help to strengthen the immune system. The most common food based delivery systems for probiotic bacteria are yogurt and fermented milk drinks such as Yakult, Actimel, Müller Vitality and Healthy Balance, Petit Filous Plus and Danone Activia®. These probiotic foods can be eaten at anytime of the day and many people take them as part of their breakfast routine. At present, there is only limited scientific evidence to suggest that healthy people will benefit from a regular intake of probiotics, however there is strong growth of probiotics in dairy due to the preferred taste profile and convenient delivery format (such as single serve bottles and drinks). Europe is by far the leading market for consumption of probiotics dairy products due to the long history of fermented milk in the region. However, US consumers are becoming increasingly aware of the benefits of probiotics because of the influential marketing and consumer awareness efforts of companies like Danone (known as Dannon in US), Yakult and General Mills (Yoplait).

Using probiotic bacteria L. casei Immunitas, Dannon in US has claimed that the yogurt improves immune systems. According to Dannon, each serving of DanActive contains 10 billion active lactic acid bacteria

One of the fastest growing segments of probiotic dairy products is drinking yogurt. Drinking yogurt is essentially stirred yogurt which has a lower total solids content than a normal yogurt and which also has undergone homogenization to further reduce the viscosity. Fruits, flavouring and colouring are also added to drinking yogurt. Drinking yogurt has also become a preferred system for delivery of functional/health food ingredients because of its convenient format.



Probiotic yogurts such as Activia by Danone and Yakult have successfully communicated the role of friendly probiotic bacteria to consumers worldwide through simple illustrations

Although yogurt and yogurt drinks are the preferred vehicle for delivery of probiotic bacteria because of the flavour, taste and healthy image, other dairy products such as cheese and milk have also been used. Recently, Kraft Foods Canada launched probiotic cheddar and cottage cheese under the brand name "LiveActive". As probiotic bacteria are predominantly lactic acid bacteria and prefer lactose as source of nutrition, milk and its derivatives will remain at the forefront of probiotics delivery market.

The dairy industry has managed to maintain an upper hand in delivery of probiotic bacteria through yogurt and yogurt drinks, although other delivery vehicles such as supplements, juices and drinks have also been used recently.

4.5.3 Prebiotic Fibre

Prebiotics are carbohydrates that cannot be broken down by the human digestive system. The main types are inulin and fructooligosaccharides (FOS). They occur naturally in some foods such as chicory, artichoke, leeks, onions and asparagus. Prebiotics help feed the good bacteria already in digestive system, which can improve the health of the digestive system and may help in strengthening the immune system. There is a growing body of evidence on the health benefits of prebiotics, however further research is required to confirm the actual amounts that are needed for optimal health.

4.5.4 Omega-3 Fatty Acid

In recent years, there has been a trend towards addition of omega-3 fatty acids to dairy products. Omega-3s are essential fatty acids that the human body is unable to produce on its own, and must be incorporated into the diet. Fish is the usual source of Omega-3 but it is well recognised that most consumers are not consuming sufficient quantities of Omega-3. The benefits of Omega-3s include the reduction of blood cholesterol, prevention of certain illnesses, such as cardiovascular disease, improved immune reactions against allergies and a reduction in the threat of blood clots.

Globally, milk and yogurts have become the most popular consumer food products for delivery of omega 3 fatty acids.

Since 2004, the FDA has allowed a limited health claim for reduced risk of coronary heart disease (CHD) on conventional foods that contain eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) omega-3 fatty acids. The role of omega-3 fatty acids in growth and development as well as in health and disease, particularly coronary heart diseases, is currently one of the fastest growing research areas in nutritional science. Commercially, fish oil, algae and flaxseed oil are the most commonly available sources of omega-3 fatty acids. Leading companies marketing omega-3 fatty acids are Martek Bioscience (algal source), Ocean Nutrition (fish oil) and Denomega (fish oil). Dairy products, such as milk and yogurt offer convenient delivery system for omega-3 fatty acids. However, the delivery of omega-3 fatty acids in dairy products remains a challenge as these fatty acids have a strong

In US, a small dairy company, Omega Farms, has become the first dairy company to launch a complete range of dairy products containing omega-3 fatty acids odour, poor oxidative stability and tend to deteriorate during homogenisation and pasteurisation. Consequently, fish oil, algae or flaxseed oil are normally pre-emulsified and admixed with antioxidant blends using a technology called microencapsulation that helps protect omega-3 during milk processing. Milk proteins have successfully been used as encapsulants for omega-3 fatty acids due to their ability to emulsify and protect fat from oxidation. Recent trends suggest that one of the fastest growing markets for omega-3 fatty acids is the infants and kids dairy market where manufacturers are promoting the health benefits of omega-3 on the brain. Dairy products, especially milk and yogurt drinks will remain important delivery vehicles for omega-3 fatty acids and more innovation in this area is anticipated.

With the approval of phytosterol for low-fat milk and yogurt, National Foods become the first dairy company in Australia to launch cholesterol lowering milk and yogurt. Pura Low Fat Heart ActiveTM is suggested to lower cholesterol by up to 15% when taken as a part of a balanced diet, low in saturated fat and full of fruits and vegetables. One serve (250 mL) of Pura Low Fat Heart ActiveTM provides 0.8 g of plant sterols and the manufacturer recommends 2 to 3 serves per day.

4.5.5 Plant Sterols (phytosterols)

Plant sterols (also called phytosterols) are plant materials chemically similar to cholesterol but not found in any significant abundance in the human body. Plant sterols are clinically proven to reduce the absorption of cholesterol from the gut, resulting in a lowering of bad (LDL) cholesterol. Lowering bad (LDL) cholesterol can help maintain a healthy heart. Plant sterols are found naturally in very small amounts in fruits, vegetables, vegetable oils, grains, nuts and seeds. Benecol, Danone Danacol, Minicol and Flora Pro.activ are some of the many dairy products available with plant sterols.

As rates of heart disease continue to soar worldwide, makers of plant sterols are optimistic of significant growth of products in this market segment. While scientists laboured for much of the 1990s to find ways to blend these natural cholesterol-lowering compounds, which are hydrophobic, into beverages and other non-oil-based formulas, such formulation challenges are now a thing of the past.

In the UK, phytosterol containing yogurt drinks are marketed with soft health claims such as this from Benecol: "By drinking one bottle of Benecol Yogurt Drink with a main meal, every day, you can reduce cholesterol to help maintain a healthy heart because each bottle contains just the right amount of the special Benecol cholesterol lowering ingredient, plant stanol ester, which is clinically proven to reduce LDL (bad) cholesterol, as part of a healthy diet and lifestyle

The health benefits of phytosterols on the heart have been recognised by the FDA since 2003 and claims on a broad range of food products are allowed when formulated with 0.65 grams of phytosterol esters or 0.4 grams free phytosterols per serving. Companies active in marketing plant sterols to dairy industry are Forbes MediTech, Raisio, Cognis and Cargill. Forbes MediTech, the maker of Reducol, reported sales of $14.16 million in 2004, up from $11.58 million in 2003. Benecol from Finnish company Raisio Life Sciences reported sales growth of its stanol ester product by almost 40 per cent during in 2004 over 2003. Cognis Nutrition & Health, one of the leading producers of sterols and sterol esters, sold under the brand name Vegapure, reports its sales have grown steadily since entering the market in 2002. Cargill's plant sterol, CoroWise has appeared in the first sterols-fortified yoghurt available on the American market. With strong interest in heart health, and approval by regulatory authorities, more dairy companies are likely to introduce milk products with phytosterol. However, challenges still remain for dairy companies to convince consumers that dairy products can be as effective as cholesterol lowering margarines, which are leading the cholesterol lowering markets around the world.

4.5.6 Antioxidants and Plant Extracts

Dairy products especially yogurts have seen addition of antioxidants in the form of so-called "super fruits" or plant extracts. Antioxidants are promoted for their role in protecting human cells from free radical damage that occurs during aging and infections etc. Free radicals are formed from cellular reactions in the human body, and they are cited as an important cause of most chronic diseases. Antioxidants, by scavenging the free radicals have been suggested to protect body cells. Examples of popular plant extracts that have been added to yogurt drinks are green tea extract, berries, blackcurrant extract and grape seed extract.

In US, many new dairy products containing fruits are being marketed under the banner "superfruits"

4.5.7 Dietary Fibre

Dietary fibre, found mainly in fruits, vegetables, whole grains and legumes, is recognised for health benefits such as lowering the risk of diabetes and heart disease. The American Dietetic Association recommends an intake of 20 to 35 g for adults; 25 g daily for girls aged 9 to 18 years and 31 to 38 g for boys aged 9 to 18[14]. The American Heart Association recommends 25 to 30 g daily. On average, consumers in Western countries consume less than 50% of the dietary fibre levels required for good health. Recognizing the growing scientific evidence for the physiological benefits of increased fibre intake, the FDA has given approval to health claims for fibre. Although dairy products are not generally associated with fibre, recently some milk products have been launched with added fibre. Parmalat introduced low fat milk with fibre, TRIM healthplus, in Australia in 2006. It contains 1.2% inulin from chicory fibre. Opportunities exist for incorporating the soluble fibre beta glucan (from oats and barleys), as beta glucan has cholesterol-lowering function in humans and this is an approved health claim in the US.

Recognising the health benefits of fibre in dairy, Singapore company Marigold has introduced milk with multigrains, a product normally associated with breakfast cereals.

4.6 Conclusion

Over the past 10 years, production and consumption patterns for milk have changed dramatically. Affluent countries have seen a decrease in production and consumption of milk and milk products while developing countries; especially those in South East Asian region have seen an increase in

[14] *ADA (American Dietetic Association). www.eatright.org*

production and consumption. As the economies in this region grow further, this trend is likely to continue in the near future. Due to the increased scientific knowledge and a desire to add value to milk, several bioactive dairy ingredients have been commercialised recently. Increase competition has led to the development of innovative dairy ingredients such as milk protein crisps and colostrum powder by some dairy companies. Further developments in extracting and commercialising bioactive peptide from milk are anticipated in the near future.

Beside the development of new dairy ingredients, milk and yogurt have also been used to deliver newly recognised bioactive or functional food ingredients such as omega 3 and phytosterols. Food regulations around the world are changing to allow addition of new bioactive ingredients that address the health concerns such as obesity, diabetes and heart diseases. Due to the wider acceptability and superior flavour, dairy beverages, such as milk and yogurt will remain at the forefront for delivery of such ingredients.

FAQ

1. *Are there any shelf life and food safety issues with ESL milk?*

   ESL milk keeps longer but poses greater challenges than ordinary pasteurized milk. In pasteurized milk, spoilage organisms limit the shelf life. As a result, pasteurized milk spoils before becoming unsafe. With ESL milk, the thermal process of ultra-pasteurization destroys spoilage organisms along with pathogens. If the milk is contaminated after ultra-pasteurization, there is the potential that the product could develop high levels of pathogens without the usual signs of spoilage. Thus, companies need to take extra precautions for avoiding post past pasteurisation contamination for ESL milk.

2. *What are the main hurdles for successful commercialisation of HPP by the dairy industry?*

   HPP offers an alternative to pasteurisation of milks and drinks however, the capital cost and economies of scale remain the main hurdles for large-scale commercialisation of this technology. As HPP is a batch process and the current HPP processing involves narrow diameter, high strength cylinders large volumes processing is not economically feasible. However, HPP is being considered for commercialisation of liquid colostrum that can be marketed as a premium ingredient to the food industry. HPP may also offer alternative for heat pasteurisation for heat-sensitive bioactive ingredients such as milk peptides.

3. *How does a-lactalbumin enhance sleep quality and alertness?*

   The effects of poor sleep on performance may be partly mediated by a biochemical imbalance of brain serotonin (5- hydroxytryptamine, or 5-HT). Brain 5-HT seems to be involved in the regulation of sleep and cognitive processes, and sleep abnormalities and cognitive decline in clinical populations are partly attributable to deficient brain 5-HT activity. Accordingly, reduced 5-HT concentrations resulting from the exhaustion of its plasma precursor tryptophan has been found to provoke sleep abnormalities seen in depression, whereas increases in available plasma tryptophan for uptake into the brain improved sleep in different subjects. These sleep promoting effects of tryptophan may be stronger in subjects with sleep complaints, because they are vulnerable to the sleep reducing effects of tryptophan depletion. Sleep enhancing attributes of α -lactalbumin are attributed to its enhanced levels of tryptophan.

4. *How can a diet rich in GMP help patients with PKU?*

Phenylketonuria, or PKU is a rare, hereditary, metabolic disorder. For a person with normal metabolism, phenylalanine is an essential amino acid that must be provided in the diet. However, in a phenylketonuric, dietary phenylalanine cannot be metabolized in a normal fashion because of a missing enzyme. As a result, a person with PKU consuming a normal diet would accumulate high levels of phenylalanine and its derivatives, causing toxicity to the central nervous system and possible brain damage. Special low-phenylalanine diets that provide adequate protein are essential for phenylketonurics. Purified GMP is an ideal ingredient in such diets since it does not contribute phenylalanine

5. *How does GMP provide a satiety effect?*

Studies showed that GMP induced secretion of cholecystokinin (CCK), a group of neuropeptides known to regulate short-term control of food intake by acting as a satiety signal. The efficacy of GMP is dependent on glycosylation (i.e. amount of carbohydtare). Non-glycosylated GMP had no effect on the basal levels of CCK. Presence of terminal saccharide chains containing sialic acid is also important for the activity of GMP. The genetic variants of GMP seem to have different effects on the CCK production, with A variant having the greatest effect.

6. *How does GMP help in reducing dental plaque?*

Plaque and dental caries are a result of microbial adhesion and activity on the dental surface. GMP has been shown to have a protective effect by reducing the binding of bacteria, such as the Streptococcus species, on a saliva-covered tooth model and the inner lining of the cheek. Scientists believe that by inhibiting the cariogenic bacteria, GMP reduces dental plaque and caries

7. *What is the difference between probiotics and prebiotics?*

Probiotics are beneficial bacteria that live in the digestive system. Certain probiotic cultures are added to foods like yogurts and yogurt drinks, as they are beneficial in helping to maintain a healthy digestive system.

In a healthy individual the numbers of good (healthy) bacteria in the gut outweigh the bad (pathogenic) bacteria. Probiotic cultures help to promote the growth of "good"bacteria, shifting the balance away from the bad. Examples of probiotic bacteria classes are Acidophilus, Bifidobacteria and Casei. Prebiotics are a form of insoluble fibre that help feed the good bacteria already in the digestive system, which can improve the health of the digestive system and may help to strengthen the immune system. The main types of prebiotics are inulin and fructooligosaccharides (FOS). Where pre- and pro-biotics are added together, the product is sometimes referred to as "synbiotic".

8. *What are the important factors affecting the development of probiotic milk products?*

Yogurt companies need to be aware of the effects of processing factors during the manufacture of probiotic dairy products. Probiotic bacteria are damaged by heat, moisture, light and exposure to air. Minimizing these four factors is the key to keeping probiotic bacteria alive both during and after manufacturing. The required amount of probiotics must be present at the time eating the product (i.e. during the entire shelf life of yogurt) —not just when the product was manufactured.

9. *Is there a relationship between the viability of probiotic bacteria and health benefits?*
The bacteria's ability to survive the stomach and bile acid is important. Not all strains can withstand the acid environment to the same extent, so it is important that each strain is tested for survival throughout the gastrointestinal tract. Studies have shown that unprotected probiotic forms can suffer significantly from exposure to stomach acids, losing as much as 99% of their viability before reaching optimal locations in the intestines. Freeze dried probiotic organisms, like those in supplements, are activated when hydrated and, unless in a fertile environment, will quickly expire. Yogurt and yogurt drinks are ideal nutritional environments for growth and viability of probiotic bacteria.

10. *What are the different types of omega-3 fatty acids?*
Omega-3 fatty acids are long-chain, polyunsaturated fatty acids. Fatty acids are the building blocks of triglycerides and other lipids. They are usually composed of a long chain of unbranched carbon atoms with a carboxyl group at one end. Most fatty acids contain between 4 and 24 carbon atoms in the backbone.

The major omega-3 fatty acids are: alpha linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). ALA is the only essential omega-3 fatty acid because our bodies can convert ALA into others such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The main sources of ALA are plant and algal oils (e.g. flaxseed oil, canola, microalgae) while the main sources of DHA and EPA are oil from fatty fish. The conversion of ALA to EPA and DHA is poor (4-15%) and in some cases conversion is inefficient to non-existent. For example, infants and people with certain enzyme deficiencies cannot efficiently convert ALA to EPA. For this reason, EPA and DHA are sometimes considered as conditionally essential fatty acids. US FDA has approved a qualified health claim for omega 3 that relates to reduction of coronary heart disease.

11. *What are the desired levels of omega 3 that can be added to dairy products?*
The dietary requirements of essential fatty acids are approximately 2% of caloric intake for adults and 3% for children. In Canada, in order to claim a source of Omega 3, the food must contain 300 mg/serving. According to USDA, the acceptable limit for an adult male is 1600 mg/day and for an adult female is 1100 mg/day. The Heart Foundation in Australia recommends 200 mg of omega 3 (including ALA) per day. A number of dairy beverages containing omega 3 fatty acids from plant and marine sources have been launched in the US, Canada, Europe and Australia. The levels of omega 3 in these products vary from 150 to 300 mg per serve of 250 mL.

12. *How do phytosterols provide health benefits?*
Phytosterols are plant fats similar in structure as the animal fat cholesterol, except they have an extra ethyl group on the side chain. They are commercially extracted from vegetable oils (corn, soy, rapeseed, etc) and tall oil (wood). Since phytosterols have a similar chemical structure to cholesterol, the human body cannot chemically distinguish between them. During digestion, the phytosterols compete with cholesterol for absorption in the small intestine. As a result, the amount of cholesterol absorbed into the body is reduced, resulting in a reduction in overall cholesterol levels. Depending on the individual country regulations, phytosterols are permitted for use in selected foods. US FDA has permitted the following claim for foods

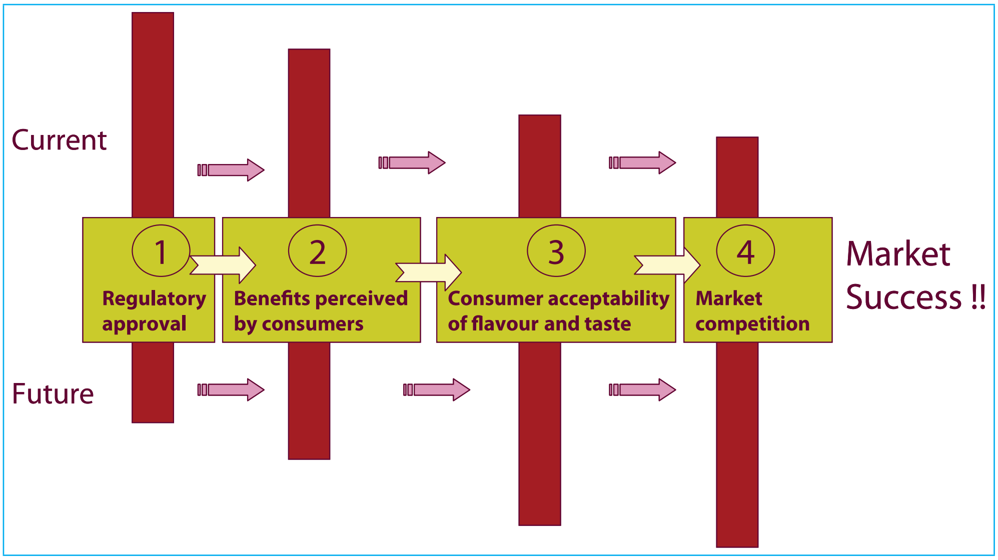
containing phytosterols: "Foods or beverages containing at least 0.4 grams per serving of plant sterols, eaten twice a day with meals for a daily intake of at least 0.8 grams, as part of a diet low in saturated fat and cholesterol, may reduce the risk of coronary heart disease."

13. *What are the technological challenges and precautions for incorporation of dairy and non-dairy bioactive ingredients in consumer dairy products?*
Some of the formulation challenges and precautions for bioactive ingredients are shown in Table 4 below

Table 4 Formulation challenges and precautions required for incorporation of bioactive ingredients

Bioactive ingredient	Potential formulation challenge	Precautions needed
Probiotic bacteria	Exposure to heat, oxygen, low pH, moisture and direct light can reduce activity. Ensuring enough live probiotic bacteria reach the gut	Selection of appropriate species of bacteria, providing sterile environment for growth and avoiding inactivation post processing
Omega 3 fatty acids	Undesirable flavour, sensitivity to heat, light and air	Selection of protected (encapsulated) omega 3 fatty acids, avoiding excessive heating and homogenisation during processing
Phytosterol	Insolubility and difficulty in incorporation into low or no-fat beverages	Dispersion of phytosterols in small amounts of fat, continuous shearing and temperature control
Bioactive peptides from milk	Bitterness, stability towards processing, poor emulsifying properties and flavour	Avoiding excessive heating and high pressure homogenisation; use of emulsifier to enhance emulsification
Milk calcium	Insolubility, sedimentation and grittiness and protein instability	Using micronised (finely milled) milk calcium, use of stabiliser such as carboxymethyl cellulose (CMC) and microcrystalline cellulose (MCC)
Antioxidant and isoflavones	Bitterness, beany taste, poor solubility in water	Avoiding extreme heat, pH and shearing cycles during processing
Dietary fibre	Poor suspension and sedimentation	Use of finely milled powder and addition of stabilisers such as starch, guar gum and acacia gum

14. *Looking at global trends in new consumer products, what points need to be considered to ensure the success of the products?*
Commercial success of dairy products containing bioactive ingredients is influenced by a number of factors. At present, one of the major challenges for companies to market functional dairy products is the approval from regulatory authorities. Educating consumers regarding health benefits of bioactive ingredients remains another challenge for food companies. To a lesser extent the present challenges include consumer acceptability for flavour and taste and the market competition. Direct health claims with added bioactive ingredients are not yet permitted in most countries however, new regulations are being introduced in US, Australia and EU that would make it easier to incorporate bioactive ingredients and streamline the process for health claims. So, in future, as the consumers become aware to health benefits of foods, companies will face further challenges of getting the consumer acceptability and there will be an increased competition in the market.



Glossary

ALA	alpha linolenic acid
CCK	Cholecystokinin
CDP	Casein derived peptide
CHD	Coronary heart disease
CGP	Casein glycopeptide
CMP	Casein macropeptide
DHA	docosahexaenoic acid
EPA	eicosapentaenoic acid
ESL	Extended Shelf Life
FAO	Food and Agricultural Organisation of the United Nation
FOS	Fructo-oligosaccharide
GMP	Glycomacropeptide (another name for caseinomacropeptide, CMP)
HPP	High pressure processing (or pasteurisation)
HTST	High temperature short time
LDL	Low density lipoprotein
PEF	Pulse electric field
PKU	Phenyketourea
UHT	Ultrahigh temperature pasteurisation
US	Ultrasonication
USDA	United States Department of Agriculture

DAIRY AUSTRALIA
Delivering for the dairy industry

5

Milk Powders

Content

97 5.1 Introduction

98 5.2 Brief Overview Of Manufacturing Principles

100 5.3 Functionality

111 5.4 Applications

115 5.5 Product Development

116 5.6 Product Handling

119 5.7 Product Specifications

119 FAQ

128 Glossary

132 References

Abbreviations

ADMI	American Dried Milk Institute (Now the ADPI (American Dairy Products Institute)
AIC	Australian Ingredient Centre (Now DIGA Dairy Ingredients Group of Australia)
AMF	anhydrous milk fat
BD	bulk density
BMP	butter milk powder
CSIRO	Commonwealth Scientific & Industrial Research Organisation
FCMP	full cream milk powder
HTST	high temperature short time
IDF	International Dairy Federation
PV	peroxide value
PSD	particle size distribution
REM	recombined evaporated milk
RSCM	recombined sweetened condensed milk
SMP	skim milk powder
UDWPN	un-denatured whey protein nitrogen
UHT	Ultra high temperature
WPNI	whey protein nitrogen index
WFN	white fleck number

5.1 Introduction

Milk powders are used by end users including consumers and food manufacturers as a substitute for fresh milk and fresh milk products and as ingredients for the manufacture of a range of processed products from traditional dairy products through to confectionery, bakery products, health drinks and nutraceuticals. The quality of these milk powders determines the effectiveness of their use to product manufacturers and the acceptability of the end products to consumers.

All milk powders are manufactured to certain specifications which define their composition and physical, chemical and microbiological standards. Equally important are specifications relating to the functionality of the powders with respect to their ability to perform as required by the end users in specific applications. That is, powders can have the same composition, physical and microbiological attributes, but they will perform very differently if used for the same application. These attributes are not always set out in the standards and specifications or agreements but they must be considered, and all must be acceptable to the end user and perform to the end user's requirements.

There is a very broad range of milk powders available today. This chapter concentrates on:

- Full cream milk powder (FCMP); also known as whole milk powder (often abbreviated to WMP): typically produced by the removal of water from whole milk, resulting in a dried product with a maximum of 5% moisture (more typically 4%) and a minimum of 26% milk fat, with all other constituents, lactose, minerals and proteins, in approximately the same ratio as the original milk from which it was manufactured.
- Skim milk powder (SMP) which is non-fat dried milk (sometimes abbreviated to NFDM): typically produced by the removal of water and fat from milk, resulting in a dried product with a maximum of 5% moisture and a maximum of 1.5% milk fat, with all other constituents,

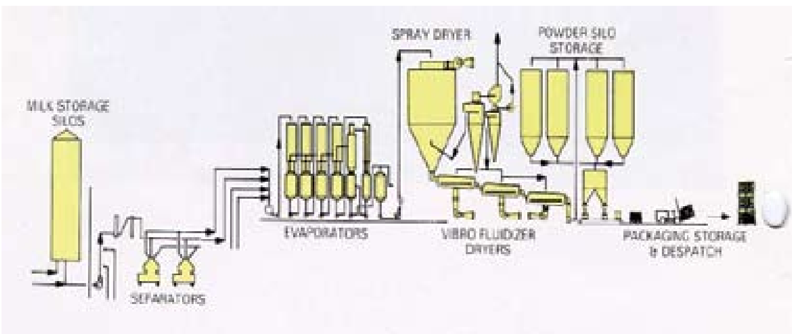
lactose, minerals and proteins, in approximately the same ratio as the original milk from which it was manufactured and

- Buttermilk powder (BMP): typically the product resulting from the removal of water from buttermilk, resulting in a dried product with a maximum of 5% moisture and a minimum of 4.5% milk fat and 30% protein.
- Some reference is given to blends and to some specialised powders and the development of these. This chapter considers the manufacture, specifications, functionality, applications and nutritional aspects as they relate to these powders and then considers a range of frequently asked questions regarding these powders.

5.2 Brief Overview Of Manufacturing Principles

The basic aim in the manufacture of milk powders is to convert a liquid to a powder, thus extending shelf life and reducing transport and handling costs. The process must be such that there is minimal loss of nutritive value and functional properties. The powder must be easy to handle and any deterioration during storage must be kept to a minimum. It must be easily reconstituted or repacked for a range of applications and must be able to display all the functional attributes of the original milk and in many cases demonstrate enhanced functionality which has been induced during processing.

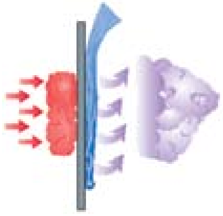
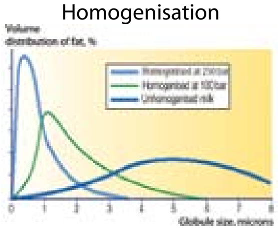
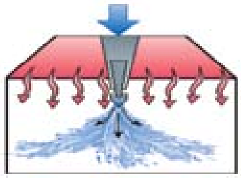
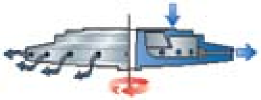
Figure 1 Typical flow diagram for the manufacture of milk powder



The method of manufacture of conventional milk powders, SMP, FCMP and BMP all employ some common unit processes. Additional processes may be required specific to their individual manufacturing requirements.

Figure 1 shows a typical flow sheet for milk powder manufacture. The raw material for SMP and FCMP is fresh milk whereas, for BMP it is the buttermilk, by-product of butter manufacture. Each of the following unit processes plays an important role in the manufacture of a stable, consistent and functional milk powder fit for each end application.

Starting material	For SMP and FCMP the starting milk needs to be standardised to give the desired final powder composition. This entails the separation of whole milk to produce a skim milk stream, which typically contains less than 0.1% fat for SMP manufacture and a cream stream. For FCMP the skim and cream streams are remixed at a specific ratio to give the desired fat to protein ratio, this may also require addition of cream or skim to the full cream milk stream.

Preheating	The standardised milks are then subject to a preheat treatment. A range of time / temperature regimes are applied typically with a minimum of pasteurisation at 72 °C / 15 sec. Depending on the type of powder required with respect to functionality (see Table 4) higher time / temperature regimes are imposed, particularly for SMP, to impart or improve specific functional properties.
Concentration  General principle of evaporation. Apartition is heated by hot steam and vapour evaporates from the liquid on the other side.	The milk is then concentrated to higher solids by the removal of water in a thermal evaporator. The configuration of this is usually of multiple effects with a host of tubes bundled together with product flowing down the tube inner and heat being applied on the outer. These units operate under a vacuum to decrease the temperature of evaporation and are thus very economic, removing up to 30 kg of water for every 1 kg of steam used. This efficiency is obtained by reusing the heat of the removed vapour, and by the use of mechanical or thermal recompression to boost the temperature of the vapour after removal from the milk, prior to reuse. Because of the overall low temperatures used (~45 - 68 °C), there is very little thermal damage done to the milk and the total solids of the concentrate can be increased to over 45% and often over 50%, depending on the viscosity of the concentrate.
Homogenisation  From Tetra Pak Dairy Processing Handbook	Following evaporation the concentrate for SMP is introduced to the spray dryer. However, for FCMP and BMP the concentrate is homogenised (at 50 to 75 °C at total pressures up to 90 bar usually with two stage configuration) prior to drying to create a stable emulsion of much smaller fat droplets protected by encasing them in a film of milk protein.
Atomisation  From Tetra Pak Dairy Processing Handbook  Rotating disc for atomising milk in the spray drying chamber.	The concentrate is then introduced into the spray dryer. There is a range of configurations for spray dryers. These include different shapes, atomisers, single and multi stage, different air exits, internal and external fluid beds and different agglomeration systems. Each design is often used for a specific product but many are multi functional. After the initial drying the powder is often instantised by the application of lecithin to fat containing powders to enhance dispersibility.
From Tetra Pak Dairy Processing Handbook	 

5.3 Functionality

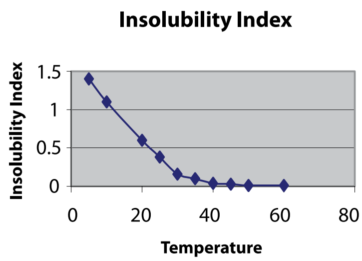
Milk powders contribute three different forms of functionality – physical, nutritional and physiological. Physical properties refer to the structural and chemical attributes that the powder has in itself or which it brings to its use as an ingredient in a food system. This includes such attributes as the ability to bind, form a gel or a stable foam. These are largely determined after reconstitution and also impact the sensory properties of resulting products. Nutritional functionality refers to the ability of a powder to be a source of nutrients. This is a direct result of the milk's composition, but it can be enhanced or diminished by the environment of the final application. Physiological functionality refers to the milk powders ability to facilitate a biomodulating response because it contains bioactive substances that the body uses for improved physiological function such as improved gut function. This can be due to the milk's natural composition (e.g. colostrum or milk peptides) or because the powder can be used as a carrier of additional health giving substances such as probiotics or prebiotics.

5.3.1 Physical Functionality

Solubility

Solubility is a fundamental functional property that is a prerequisite for most other desired physical functionalities. If a powder is not able to completely dissolve, it will not become a homogeneous component of the intermediate or final product, leading to losses of solids and problems in processing. The insoluble material is usually denatured proteins or combinations of casein/whey proteins and lactose. Whole milk powder often exhibits more insolubility than skim milk powder. The solubility of powders can deteriorate during storage depending on conditions

Figure 2 Insolubility index as a function of the temperature of reconstitution at high solids (Personal observations)



There are several factors, which influence the inherent solubility of powders. These include; seasonal variations in the composition and quality of the milk, preheat treatment used during manufacture (the higher the temperature the more susceptible to insolubility), the type of dryer used (roller drying being particularly detrimental), the configuration of the spray dryer (the atomisation system and single versus multi stage dryers), the conditions of manufacture including in particular the time /temperature relationship and the degree of homogenisation carried out before drying. The temperature of reconstitution also plays a major role in determining the degree of insolubility of powders particularly at high solids as shown in Figure 2 which shows how the insolubility index of the premix for RSCM can rise dramatically if the reconstitution water temperature is decreased. Milk powder reconstituted at single strength total solids demonstrates similar behaviour but not to the same extent as at high solids.

Instant Properties

This is the ability of a powder to quickly reconstitute and is an essential attribute for many applications. The process of redissolving the powders is far from straight forward and is influenced by many factors which at times are counter productive to other functionalities. The instant properties of powders are still subject to on-going studies but are known to be influenced by several factors:

Dispersibility
Dispersibility is the ability of powder to dissolve without forming dry lumps and with instantaneous disintegration of agglomerates into single particles ready for dissolution. The agglomeration process is of primary importance for good dispersibility and should be optimised to produce few agglomerates >250 micron, few compact agglomerates and little if any fines.

Flowability
Flowability is an important property of powders in respect to transport, weight measurement, packaging and handling, both as a powder and in subsequent applications. It is influenced by particle morphology (size, shape and structure) and distribution of the powder particle sizes. Good flowability is usually obtained from larger particles, or agglomerates with a minimal number of smaller particles. However, this particle size distribution may have an adverse effect on bulk density (BD). Lower "loose" BD improves flowability but the relationship is not as strong with tapped BD. Uniformity of particle size also improves flowability.

The fat content plays an important role in the flowability of powders; in particular the degree to which the fat is in the "free" form or more particularly the amount on the surface. Any increase in free fat will reduce flowability. The addition of agents to assist free flow (e.g. silicates) and/or the application of an instantising operation can be used to assist the flowability of powders.

Sinkability
A powder must be able to penetrate the surface of the water to be able to make intimate contact with the water. This is influenced by high particle density, which is determined by the composition of the powder and is greatly influenced by the amount of occluded air present in the powder particle.

Wettability
Wettability is a measure of the ability of a powder to be wetted and in particular for water to penetrate the surface of the powder at a given temperature. If a powder fails to wet properly lumps form. The degree of agglomeration, the amount of wettable surface and its nature (the presence of free fat is an inhibitor) and the amount of interstitial air influence wettability. Another factor of importance is the structure of the powder particle surface. If, for example the surface has been hardened ("case-hardening") then the ability of water to readily penetrate is diminished.

Emulsion and Foaming Capacity
Milk powders can be used in applications where foaming and emulsifying properties are required, eg. ice cream, mousse, and baked goods. These roles are performed by the milk fat having a variety of physical interactions at the surface of air bubbles and by clumping of the fat globules. Milk proteins (both casein and whey) because of the presence of hydrophilic and hydrophobic groups are also involved in this role through their surface-active properties, stabilising the air/water interface of air bubbles and the oil/water interface of fat globules. The factors that effect the foaming capacity of milk include pH and mineral balance, the state of the fat, temperature, the degree of denaturation of the whey proteins (the greater the denaturation the lower the foaming capacity) and the presence

of low molecular weight surfactants. Another way to enhance the foaming capacity of powders is to have a high occluded air content where the air is released upon reconstitution. Injecting air into the concentrate in the atomiser during drying of the powder can do this.

Heat Stability

Heat stability is an extremely important property in most applications as the use of heat is a universally accepted and applied manufacturing process. In essence, heat stability is the ability of milk, either single strength or concentrated, alone or in combination with other ingredients, to be heat processed without unduly thickening, coagulating or precipitating. Concentrated milks are more susceptible to heat instability than single strength milks. The whey proteins are denatured when heat in excess of 65°C is applied, whereas the major protein in milk, casein, is stable up to temperatures of 140°C. Milk proteins are destabilised by heat-induced changes including a decrease in pH, denaturation of whey proteins and the shift of calcium and phosphate from the serum into the colloidal phase. Once the whey proteins have been denatured their state cannot be reversed whereas the effect on minerals, particularly calcium and phosphates, can be reversed where relatively low heat treatments have been used. The inherent heat stability of milk varies across the season of production in pasture based countries such as Australia, and is related to shifts in mineral balance and pH. This mineral balance phenomena is used by industry to manipulate the heat stability of milk and produce powders suitable for particular end use applications. (See testing methods)

Water Binding Capacity

Both the proteins and lactose in milk powders can bind or entrap water with proteins being the major contributors. Casein can bind approximately 3.3 g of water per gram of protein whereas whey proteins in their undenatured state bind ~0.4 g/g but when denatured can hold up to 2.5 g/g or more than 6 times their undenatured counterpart. Examples of applications where water binding is important include confectionery, bakery and meats.

Viscosity Development

The proteins in milk powders can be used to modify rheological properties in a range of applications. This ability is dependent on their state of dispersion, the concentration of solids and temperature and the degree of denaturation of the whey proteins. This property predominantly occurs because of protein-protein interactions similar to those for gelation. Viscosity development is particularly important in RSCM and in yoghurt.

Hydration

This is the process of full dissolution of a milk powder to establish the original milk protein and mineral equilibria balance. The majority of this occurs quite quickly i.e. in a matter of 10 – 20 minutes at temperatures above 25°C. There are small changes after this period, in pH for example but this process is negligible in its effect on end product usage. Therefore, ideally hydration times for powders need not exceed 15-20 minutes at normal processing conditions of 40 - 55°C with a longer time only being implemented for high solids solutions. Where a powder displays high levels of insolubility the hydration time will be effected adversely i.e. it will take longer to reconstitute.

Colour

The ability of milk powders to influence colour is often over looked. The powders themselves must meet certain criteria regarding their colour as set out in their specifications but their ability to enhance colour through browning when heated due to the Maillard reaction is often used in applications such as bakery and confectionery.

Gelation

The proteins in dairy powders have the ability to form gels which can hold water and fat and assist in structure as well as aid in mouthfeel. The whey proteins are capable of forming heat induced gels and the caseins together with the whey proteins have the ability to form gel networks by rennet action (cheese manufacture) or by acidification, as in some dairy desserts.

Flavour

All milk powders must be free of any foreign flavours or taints. Their natural bland flavour enables their use in a wide range of products. Flavour development of both proteins and fat during processing, especially by heat, results in a range of different flavours. Fat also has the ability to act as a carrier of flavours that are fat soluble. Developed flavours through high heat may assist some manufacturers (e.g. confectionery).

5.3.2 Nutritional and Physiological Functionality

Milk and milk powders are a rich source of a range of essential nutrients, necessary for good health. Milk is an important part of any balanced diet from infancy throughout childhood, adolescence, adulthood and old age. Therefore the incorporation of dairy products into a well balanced diet is recommended. From data presented in Miller (2000) it can be seen that although the total amount of energy provided by milk in a typical USA diet at 9.3% which is relatively low, it is a nutrient dense food which can supply a large percentage of the required daily intake of a number of micronutrients e.g. calcium at 73%. This natural ability is often enhanced by the fortification of dairy powders during manufacture, (e.g. iron) and this fortification further enhances the health benefits of dairy based products.

Milk powders contain proteins, carbohydrates, fat, vitamins and minerals.

- Proteins: the main protein in milk is casein, which represents approximately 80% of total proteins, with whey proteins making up the remaining 20%. Milk provides a range of essential amino acids including lysine, which is limited in most other foods. Individual proteins have been shown to exhibit a range of functions beneficial to humans including reducing blood pressure, preventing dental caries, assisting in the prevention of some cancers, assisting the immune system and helping to develop bone strength. Both of the predominant proteins in milk, casein and whey, have high protein efficiency ratios which is their ability to support growth.
- Carbohydrates: the main carbohydrate in milk is lactose; others include glucose, galactose and some oligosaccharides. Some people are intolerant of lactose but this number is decreasing and lactose can be hydrolysed into its two sugars, glucose and galactose, by enzymatic action. It has nutritional benefits because of its slow digestion rate, often with some reaching the colon intact enabling it to act as a nutritive for the natural gut flora to grow.
- Vitamins and minerals: milk is a good source of all the vitamins required for human health. These include the fat soluble vitamins A, D, E and K as well as others including B1, B2 and B12. Milk powders are often fortified with vitamins, especially SMP which naturally lacks the oil-soluble vitamins. Milk is also a good source of minerals, particularly calcium which is an

essential role player in cell membrane functions, hormonal regulation and bone health; others include magnesium, potassium, phosphorus, sodium, zinc and iron.
- Fat: milk fat has a unique composition containing more than 400 fatty acids. It is essential for the delivery of fat-soluble vitamins and is now considered by way of such components as conjugated linoleic acid, butyric acid, sphingomyelin and others components to have many health benefits.

Milk is now known to assist, or evidence is fast being accumulated supporting the involvement of milk in particular, in the following:
- Cancer – increased calcium and vitamin D reduce cancer promoting effects in particular in Western style diets, and that calcium, vitamin D, bacterial cultures, conjugated linoleic acid and sphingolipids protect against colon cancer.
- Hypertension – there is an increasing amount of medical evidence that three components found in relatively large amounts in milk, namely calcium, magnesium and potassium, can lower blood pressure and hence reduce hypertension risk in humans.
- Osteoporosis – prevention or reduction in this disease are seen to be influenced by the bone mass at maturity at some 30 years of age. This is influenced by the intake of calcium and vitamin D both in the growing stages and post skeletal maturity. This is particularly of interest to post-menopausal women and to both men and women in later life.

5.3.3 Measurement of Functionality and Physical Characteristics of Powders

There are a vast number of methods undertaken for the measurement of functional properties and physical characteristics of powders. Many of these are accepted worldwide as standard methods (e.g. AS 2300, IDF, ADPI Bulletin 916), others are proprietary or are used by individuals as a guide for purchase or for assessing the usefulness of particular powders for specific applications.

Bulk Density (BD)

Typically a prescribed amount of powder (usually 100g) is weighed and transferred to a 250ml measuring cylinder. The surface is levelled and the volume measured (poured BD), the cylinder is then tapped 100 times (loose BD), the volume recorded and then tapped a further 525 times for a total of 625 (BD) and the final volume recorded. The volume measured after each of these operations is termed the poured, tapped and bulk density. There are several variations of this method (e.g. up to 1250 taps and the use of specialised equipment such as the Stampfvolumeter) and the method used must be quoted when a result is being given. Factors that can influence the BD include the interstitial air, the occluded air, the particle density and the PSD.

Typical analysis: loose BD

FCMP, non agglomerated	0.56 – 0.66 g/mL
FCMP, agglomerated	0.45 – 0.52 g/mL
FCMP, instant	0.45 – 0.52 g/mL
Regular SMP	0.58 – 0.68 g/mL

(References: AS 2300.4.3, IDF

Colour

Colour can be measured against a set of standard colour discs. Another more defined method of measuring the colour /whiteness of milk powder is with the use of a chromameter such as the Minolta colour meter which measures by tristimulus colorimetry three colour parameters; a value measurement of the redness, b value is a measure of yellowness and the L value which is a measure of the lightness. An even spread of powder on a Petri dish is measured using the L, a, b scale at an illuminat of D65.

Typical results:

	L	a	b	Whiteness
SMP	101.33	-5.52	16.49	****
FCMP agglomerated	98.22	-6.05	28.01	***
FCMP instant	100.34	-5.86	22.67	****
FCMP non agglomerated	100.72	-6.12	22.39	****
BMP	98.58	-6.83	22.35	***

(Reference: AIC Powder Functionality Manual)

Viscosity

The inherent viscosity of milk powders can be measured in a number of ways depending on the application it is to be used for. Simple dispersion at a set total solids and measurement at a specified temperature by a viscometer will give you a base measurement for many applications. However, specific measurement techniques are required to test suitability for some applications e.g. recombined sweetened condensed milk (RSCM). For this application the viscosity contribution of specific milk powders can be measured in two basic ways:

- using a laboratory assessment method such as Kieseker et al or Weerstra et al
- undertaking pilot scale manufacture of RSCM.

Heat Stability

The heat stability of milk and hence milk powders is one of the most important functional properties as heat treatment is used in nearly all processing applications. The diversity of use of milk powders means that tests developed and used must assure that the milk powders can be used for that specific application. The measurement of heat stability of a milk powder is often undertaken and reported with no reference to the application. This is a fundamental mistake and methods being developed and used for heat stability measurement need to be relevant to the intended application.

Most of the common methods used revolve around a heat coagulation time where a sample of milk or reconstituted milk powder in a sealed tube is subjected to a certain heat treatment (typically 120°C to 140°C) in a bath and the time taken for the sample t°Coagulate is noted. The longer the coagulation time, the more heat stable a milk or milk powder is considered to be. Little, if any, attempt is made to determine thickening which can also be a precursor to heat instability. Other methods using time coagulation criteria include mixtures of reconstituted milk with various amounts of ethanol (the ethanol stability test – Horne 1980).

Figure 3 Equipment used in the CSIRO heat stability test. (Kieseker & Aitken 1988)

However, these types of tests can only give consistent results on milk samples alone i.e. they can predict the heat stability of the milk itself under the conditions of the test, but they do not consistently predict the behaviour of milk powders in applications This is particularly the case with concentrated milk applications such as REM. One way around this is to undertake pilot scale manufacture of the product in question and thus identify the ability of a powder to meet the end application's heat stability requirements. Obviously this is a rather costly and time consuming exercise.

The Australian dairy industry has access to an improved method to that of Kieseker & Aitken (1988) developed by CSIRO in which a laboratory scale analysis (See Figure 3) of a recombined powder and milk fat are subjected to a regime equivalent to that of the commercial manufacture of REM. A range of stabilizing salts such as phosphates are added in a prescribed way to assist in identifying the maximum heat stability point. This test can also be carried out during the manufacture of the powder to enable pre-phosphating of the powder at the point of manufacture.

Emulsion Stability

Determinations concerning emulsion measurements are reported in several ways including volume index, capacity, activity index and stability. The range of tests and reporting scenario indicates the complexity of this measure and the way it is affected by application and environment. So many of these tests are indicative and all must be taken with the specifics of the test method kept in mind.

The ***emulsion capacity*** of a milk powder solution can be determined by the principle of pumping oil into a protein solution with homogenisation while monitoring the electrical resistance of the solution. When the capacity of the powder solution to emulsify oil is exceeded, the solution changes from continuous water (oil in water) to continuous oil (water in oil). At this point a rapid increase in electrical resistance occurs. A typical example of this approach is the method of Vuillemarde et al (1990) which has been adopted and modified by many researchers e.g. Williams (Personal communication, 2005).

For the measurement of the emulsion volume index a model emulsion is prepared and allowed to age overnight at 4 °C and then its emulsion stability is determined using a hematocrit centrifuge. A typical example of this method is that of DeCastro-Morel and Harper (2002) and McDermott et al (1981). Again there are modifications of these methods (Personal communications, Williams, 2005).

Because of the lack of comparability of most methods for emulsion characteristics attempts have been made to try to standardise the reporting. An example of this is the work of Bennett et al. (Internal communication, 2005).

Typical results (simple method)

FCMP, non agglomerated	0.9g
FCMP, agglomerated	1.7g
FCMP, instant	1.3g
Regular SMP	1.0 to 2.0g
BMP	1.7g

As well as these rather sophisticated methods there are some quite simple methods which give a guide to emulsification capacity. An example of this is to simply add milk powder (in 0.1 g increments) to a mixture of water and oil (1.0g oil to 99.0g water). The oil droplets on the surface will appear as large droplets prior to powder addition. High speed mixing is applied and the powder is added. The oil is satisfactorily emulsified when the droplet sizes on the surface reduce to <0.5mm in diameter. When this droplet size is reached the amount of powder added is recorded. The more powder required equates to lesser emulsification capacity.

Foaming/Whipping

The foaming and whipping of milk powders is important in many product applications, (e.g. the manufacture of ice cream). There are many methods for determining foaming and whipping capacity, some sophisticated and others quite simple. Many are in house adaptations of published methods.

Figure 4 Apparatus used in determining foam stability and over run. (Ward et al 1997)

An example of this is the method of Phillips et al (1987). Researchers in Australia have adopted this method (Ward et al 1997) as a reference for work in enhancing the foaming capacity of milk powders. This method enables an initial visual comparison (see Figure 4) between two powders with subsequent measurement of over run or foam expansion (calculated by weight of the unwhipped solution minus the weight of the same volume of foam divided by the weight of the same volume of foam multiplied by 100) and foam stability (calculated by the difference between the weight of 100ml of foam and the weight of the liquid drained, divided by the weight of 100 ml of foam multiplied by 100) using formulations relating to foam volume initially and on standing.

$$\%\ \text{Overrun} = \frac{(\text{Weight of unwhipped solution}) - (\text{Weight of same volume of foam})}{\text{Weight of same volume of foam}} \times 100$$

$$\%\ \text{Stability} = \frac{(\text{Weight of 100 ml foam}) - (\text{Weight of liquid drained})}{\text{Weight of 100ml foam}} \times 100$$

A *simple method* to estimate foaming capacity and foam stability is to make up a 10% (w/w) powder in water (at 20°C) foam with a suitable domestic mixer (eg ultra turrax), and then to pour the foam into a cylinder and measure the volume for foam capacity. The volume is then measured again after a further 15 min standing. The reduction in foam is recorded as the foam collapse or foam stability.

Typical results (for this simple test)

	Foaming	Foam Collapse
FCMP, non agglomerated	102 ml	2 ml
FCMP, agglomerated	106 ml	6 ml
FCMP, instant	100 ml (no foam)	N/A
Regular SMP	130 – 170 ml	37 – 60 ml

(Reference: AIC Powder Functionality Manual)

Wettability

Wettability is measured by systematically placing a weighed amount of powder (typically 10g) onto the surface of a set amount of water (250 ml at 25°C) and noting the time for all the powder to become wet i.e. to fall below the water line.
(References: IDF 87, Pisecky)

Dispersibility

The methods for measuring the dispersibility of powders are typically undertaken by systematically placing a weighed amount of powder (typically 10g) onto the surface of a set amount of water (250 ml at 25°C), stirring the solution for a set time and rotational pattern, sieving the contents and after drying weighing the residue and reporting the dispersibility in terms of the mass of the test portion and the values for water content and total solids.
(References: IDF 87, Pisecky)

Flowability

The development of a method for the measurement of flowability of a range of powders is a particularly difficult assignment. There are several sophisticated analytical instruments on the market (eg. Hosokawa micron powder tester, Aeroflow powder flowability analyser – see Figures 5 & 6). The Hosokawa instrument can measure a range of other characteristics including BD, compressibility, angle of repose, angle of spatula, angle of fall, cohesion and dispersibility.

A typically simple way is to measure flow through a funnel or the measurement of the amount of powder to flow down an incline. These methods include one where 6g of powder is placed at the top of an inclined plane (50mm long at 45 °C) and all the powder that flows to the bottom is collected and weighed and expressed as a % of the 6g original sample.

Other methods developed include the use of a specially designed stainless steel rotating drum operating at a set rpm (usually 30) into which a weighed sample of powder is introduced and the time taken for all the powder to be spun out of the drum is recorded.

Figure 5 and 6 The Aeroflow and HosowakaPowder analysers

Typical analysis (using simple method as above);

FCMP, non agglomerated	35 – 95%
FCMP, agglomerated	92 – 93%
FCMP, instant	90 – 97%

(Reference AIC, Powder Functionality Manual)

Typical analysis:

FCMP, non agglomerated	200 – 300 s
FCMP, agglomerated	50 – 100 s
FCMP, instant	40 – 60 s
Regular SMPAgglomerated skim	50 s10 – 20 s

(Reference, Pisecky)

Particle Size Distribution (PSD)

PSD affects functional properties including flavour release, flowability, ease of dispersibility and solubility and (in the liquid phase) emulsion stability. PSD of milk powders and liquids can be measured in a variety of ways, from simply putting them through a sieve rack of different sizes (powders only), using a microscope for visual analysis through to sophisticated counting techniques using laser diffraction.

Sieving methods can only be used as a guide given that the mechanical movement can cause changes to the powder morphology e.g. break down of agglomerates. The capacity of powders to flow freely is a prerequisite for best results and often requires the addition of a free flowing agent.

Microscopic examination is time consuming and operator dependent in many instances. It has the obvious advantage of being able to visually examine the powders for other structural features while undertaking the counting and sizing.

The majority of PSD is now done by equipment such as the Malvern Mastersizer (Figures 7 & 8) which can measure PSD under either wet or dry conditions by maintaining the particles in a stream of air or suspended in a solution of isobutanol or a similar medium, for particles in the range from 50nm to 2mm.

Figure 7 Malvern Mastersizer 2000 particle size analysis system

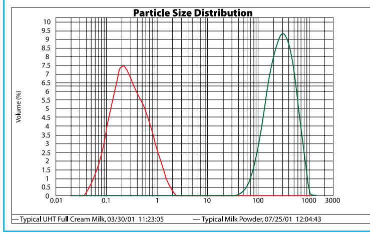


Figure 8 Typical PSD for UHT milk and FCMP

Coffee Stability or Coffee Test

The practical aspect of adding milk powder to coffee forms the basis of the coffee test which is basically a measure of the proteins resistance to instability in the coffee environment. Powders with a whey protein nitrogen index (WPNI – see section on Specifications and Analysis - part c for detailed explanation of WPNI) of less than 3 tend to give better results.

There are several variations of the coffee test, but basically a coffee solution is made up (usually about 1%) and brought to a set temperature (75 - 85°C), a weighed amount of powder is added and stirred in a predetermined manner. The amount of undissolved material on the surface (often referred to as "floaters or feathering") and the sediment are either visually noted or quantitatively assessed and the results expressed individually or in combination. Care must be taken in the selection of the coffee used in the analysis as the pH is lowered to ~4.9 which is quite close to the isoelectric point of the proteins and any further lowering of the pH will have a dramatic effect on the results. A typical test measures sediment when powder is dispersed into a coffee solution; an acceptable powder ranges between 0.2 - 0.3 ml. When the result >1.0 ml the powder is considered to be unacceptable.

Sludge Test

The sludge test is very similar to the coffee test in that a weighed amount of powder (usually 2g) is dissolved in water (at 25°C for the cold sludge for instant powder, 45°C for the cold sludge for agglomerated powder and 85°C for both instant and agglomerated for hot sludge), mixed in a prescribed manner, poured through a filter and the sediment is collected, dried and weighed. The result reported is the weight of dried sludge.

Typical analysis:

FCMP, non agglomerated	0.3g
FCMP, agglomerated	0.1g
FCMP, instant	0.0g
Regular SMP	0.0 – 1.3g
BMP	0.1g

(Reference, Pisecky)

Solubility

The test for solubility of powders is termed the insolubility test as it measures the amount of powder that is insoluble under standard conditions. A typical test consists of adding a prescribed amount of powder (13g for FCMP and 10g for SMP and BMP) to 100ml of water (at 24°C or 50°C) which is, mixed in a specially designed apparatus, decanted into special centrifuge tubes, centrifuged and the sediment is measured.

Typical analysis;

FCMP, non agglomerated	Max 1.0 typically 0.5 ml
FCMP, agglomerated	Max 1.0 typically 0.5 ml
FCMP, instant	Max 1.0 typically 0.5 ml
Regular SMP	Max 1.25 typically 0.5 ml
BMP	Max 1.25 typically 0.5 ml

(References: AS 2300.4.4, IDF 129A, ADPI Bulletin 916)

Care must be taken to maintain the temperature as it is the single most determinant factor for insolubility.

Gelation

The ability of milk powders to form gels is influenced by the environment in which the application takes place. However, it is often required, and an analysis of the milk powder in a simple reconstituted form can give some indication of the potential gelling strength. One such method is to reconstitute a solution of powder in water (up to 50% w/w), heat the solution to a relatively high temperatures (eg 80°C) with stirring, refrigerate the solution for 10 to 12 hrs and then measure the gel strength using a suitable analysis (eg Instron, TA.XT2).

Browning

Weigh a prescribed amount of powder (e.g. 25g) into a cookie/muffin tray and bake the powder in an oven at ~200°C for a set time (10 – 15 minutes). After allowing the powder to cool to room temperature measure the colour with a chromometer at L, a and b colour determinants at a setting of D65 illumination. A suitable instrument for this is a Minolta colour meter.

Typical analysis

	L	a	B	Browning
SMP	81.27	2.36	39.30	**
FCMP agglomerated	58.77	12.08	40.77	****
FCMP instant	56.19	15.48	39.30	****
FCMP non agglomerated	82.58	0.17	37.10	**

(Reference: AIC, Powder Functionality Manual)

White Flecks

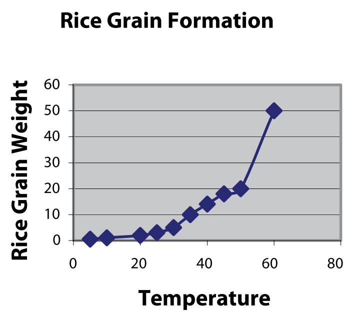
White flecks are undissolved particles, which can be seen when a milk solution is observed in a thin layer. White flecks easily clog a filter or fine mesh because of their soft physical nature and their abundance. This phenomenon is seen to a greater degree when solutions of high total solids are prepared. The initial procedure is the same as in the dispersibility test. However, after the mixing step a further amount (100 ml) of water is added and the stirring process is repeated. This mixture is poured through a sieve and the volume of liquid that passes through in a set time (15s) is recorded. A simple formulation is then applied and the result is reported as the white fleck number (WFN). A simpler method is to reconstitute 50g of powder in 300ml of water at 20°C or 80°C by mixing with a teaspoon for 6 complete clockwise and 6 anti-clockwise motions. Then allow the mix to stand for 5 min, dip a clean teaspoon into the mix, slowly withdraw, then count the number of white flecks deposited on the back of the spoon. Typical results for this technique are shown below.

Typical results

	20 °C	80 °C
FCMP, non agglomerated	clumps	10 - 12
FCMP, agglomerated	clumps	0 - 2
FCMP, instant	0 - 3	0 -2
Regular SMP	clumps	0 - 2

(Reference: AIC, Powder Functionality Manual).

Figure 9 Effect of temperature on rice grain formation at high solids (Personal observations)



When making up solutions with high total solids (e.g. for RSCM) the appearance of the white fleck phenomena is a function of the mixing temperature, with the amount of white fleck material produced increasing as the mixing temperature rises, as shown in Figure 9 where the white flecks are referred to as "rice grain".

Scorched Particles

Scorched particles are usually measured according to the method as set out in ADMI where 25g of SMP/BMP or 32.5g FCMP are mixed at 18 – 27°C for 50 seconds in 250 ml of water with antifoam added. The solution is then filtered through standard discs which are then gently dried and compared to a standard photographic scale.
(Reference: ADPI Bulletin 916)

5.4 Applications

5.4.1 Non Dairy Products

SMP, FCMP and BMP are used as ingredients in a range of non-dairy products. Their functional attributes make them the perfect ingredient for products such as bakery, confectionery, chocolate, sauces and spreads, meat and fish and desserts. As well as providing specific functional properties, all dairy powders used add nutritional value.

- Confectionery: SMP is the most used powder for this application. The SMP contributes to browning and caramelised flavour by the Maillard reaction products produced when heat is applied. SMP also contributes to structure by water binding, reducing fat globule mobility, gelation and creating firmness and chewiness in the final products. FCMP and BMP which are not used as often in this application, assist in emulsification and the creation and maintenance of uniform foams.
- Bakery:
  In bakery applications, such as biscuits, breads, doughnuts and pancakes, both SMP and FCMP are extensively used. Both these enhance browning by Maillard reaction products and impart natural flavour as does BMP when used as the fat component. They also add strongly to texture and structure, particularly in crepes, croissants and muffins, by forming dense foams with finer more uniform bubbles due to their emulsification attributes and water binding abilities. They further add to colour and flavour by Maillard reactions where the amine group of the protein reacts with lactose and other carbohydrates.

- Meat & fish: SMP is used extensively in prepared meat and fish products where its water binding and emulsification capacity are utilised for structure and texture especially in comminuted meat products. It also adds some flavour although this is a minor attribute.
- Sauces & soups:
  SMP, FCMP and BMP all contribute to soups and sauces by enhanced emulsification, water binding and flavour

development. Structure and formation can also be enhanced by the gelation capacity of SMP and FCMP in particular.

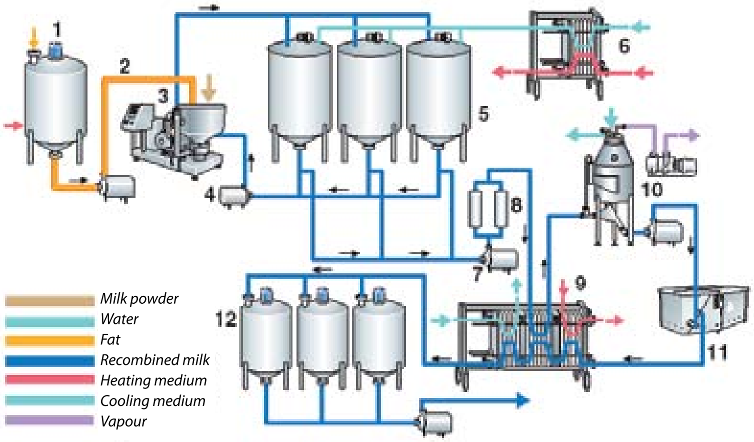
- Desserts: The foaming and emulsification capacity of FCMP and BMP are used to advantage in desserts. The bland flavour enables the natural flavour of products to come through, and Maillard browning products add flavour to custards, puddings and crème caramels.
- Chocolate:
  FCMP is a major component in the manufacture of chocolate, although SMP and BMP are also used. Apart from its nutritional role, milk powder contributes to the gloss, shelf life, flavour, texture and colour of the final chocolate product. FCMP also reduces the cost, as it enables less cocoa butter to be used in the mix by lowering the viscosity.

  Chocolate is traditionally made from roller dried milk powders because of the high degree of free fat they contained (>90%) and because of their enriched flavour due to the heat they were subject to. However, modern methods are now available where spray dried FCMP can be tailor made by being manufactured with relatively high levels of free fat (>40% consistently), enriched caramelised flavour, and other special requirements important for chocolate manufacture such as particular powder morphologies. Care must be taken with these powders as the high amount of free fat makes them susceptible to oxidation and they therefore have a shorter shelf life.
- Beverages: Milk powders are also used in beverages where they enhance mouthfeel by increasing texture and viscosity.
- Infant formula: the use of SMP in infant formula is to provide a sound nutritional base for the addition of a range of other ingredients

5.4.2 Dairy Products

The manufacture of dairy products from several milk ingredients is referred to as recombining (See Figure 10 for typical recombination plant layout) whereas reconstitution is simply the act of mixing one ingredient with water. These processes are carried out in countries which have little or no dairy industry, or where the local industry cannot supply the demands of the population. The ability to manipulate the various functional properties of milk during the manufacture of milk powders enables them to be tailor made for specific end use and applications. The use of the variant compositional changes of the starting milk, unit process manipulation (particularly heat) and the use of additives (e.g. minerals) are the major means of functionality manipulation and control. Skim and full cream milk powders are the predominant ingredients used in recombining and reconstitution. Buttermilk powder is also used as a substitute for these products at levels of up to 20% for various enhancements.

Figure 10 Typical layout for a recombining plant for liquid milk.



Recombination plant with fat supply to mixing vessel.

1 Tank for fat
2 Insulated pipe for fat
3 Mixer with high-shear mixing unit
4 Circulation pump
5 Mixing tanks
6 Water heater
7 Discharge pump
8 Filters
9 Plate heat exchanger
10 Vacuum deaerator
11 Homogeniser
12 Storage tanks

From Tetra Pak Dairy Processing Handbook

Sweetened Condensed Milk

Medium heat powder is generally used for the manufacture of sweetened condensed milk. However, the most important functionality required is for the powder to have the ability to induce a viscosity in the final product within the specific ranges required by manufacturers and consumers. The viscosity optimum at manufacture is in the range of 25 to 40 poise with it increasing during storage to a maximum of between 60 to 100 poise over a storage period of approximately 6 months. This range will change from manufacturer to manufacturer according to plant configuration and the manufacturers ability to manipulate viscosity with unit processes especially heat treatment and homogenisation. There are several methods to measure the inherent viscosity of milk powders (see Measurement of Functionality).

Single Strength Milk

Single strength liquid milk can be manufactured using several technologies. The three main methods are pasteurised, UHT and retorted. Typical processing regimes and shelf life for each of these are 72°C for 15 – 30 sec and 14 days, 135 -140°C for 3 – 5 seconds and 3 – 9 months and 118 - 125°C for 10 to 13 minutes and 12 months.

It is recommended that low or medium heat milk powders are used in the manufacture of UHT recombined single strength milk whether plain or flavoured. The use of high heat powder, particularly manufactured by HTST preheat treatment, is not recommended as it often imparts a cooked flavour to the final product. High heat powder manufactured by UHT preheat treatment is preferred if high heat is to be used. One important aspect of milk powders for UHT applications is that they must not contain enzymes that are resistant to heat. These enzymes, usually heat resistant lipases and proteases, have a detrimental effect on the storage stability of UHT milk as they are responsible for thickening, sedimentation and ultimate coagulation. A guide for selection of powders for UHT milks is that the powders do not contain more than 9 mg/100g of pyruvate (a metabolite of a psychrotropic bacteria) that develops during cold storage of milk prior to the manufacture of powder.

Evaporated Milk

Powders used for the manufacture of evaporated milk must be high heat and must be heat stable as they need to be able to withstand high retort heat treatment without excessive thickening or coagulation. Buttermilk powder is often used because of its high level of milk fat globule membrane which is known for its emulsification and heat stability enhancing properties as well as the rich flavour it naturally imparts. Further improvement of the heat stability during sterilisation can be accomplished by addition of mineral salts (citrates, carbonates, or polyphosphates). Orthophosphates are generally avoided as they promote age gelation in the sterilised concentrated product.

Cheese

The primary consideration in selecting milk powder for use in recombined cheese is that it must be low to extra low with respect to heat classification. If higher heat treated powders are used the resultant cheese will have a soft curd. Low to extra low heat powders will give the best results for cheese making where the whey protein must be in the undenatured state and the milk in general close to fresh milk quality and composition to enhance rennetability and fermentation properties. Adjustments to manufacturing conditions compared to conventional cheese making may need to be made, and these include salt addition and pH change.

Yoghurt

Yoghurt can be manufactured from both high and low heat classified milk powders depending on the manufacturing process, as at some stage a high heat treatment must be implemented. The heat treatment applied should be sufficient to denature the whey proteins as this is necessary for the production of yoghurt with a firm texture and good resistance to syneresis. Both HTST (e.g. 85 °C /30 min) and UHT treatment are used for this purpose. Water holding capacity is also enhanced and required for yoghurt manufacture.

Ice Cream

The ability to form stable foams by the incorporation and holding of air is one of the main attributes sought in milk powders for ice cream manufacture. The proteins in the powder act at the oil/water interface to stabilise emulsions. Low and medium heat powders are used as they enable the flavour of the ice cream to be enhanced and develop without interference as low/medium heat milk powders have a very bland flavour, and possess good emulsification, water binding and texture development properties.

Cream

The manufacture of recombined cream from milk powders is possible with the incorporation of another dairy fat source or with the use of high fat containing powders specifically manufactured to deliver large amounts of fat in a powdered form. Powders containing up to 65% fat are commercially available.

5.5 Product Development

5.5.1 Method

In developing new ingredients or powders with enhanced functional properties for specific end-uses, the Australian dairy industry together with various research groups adopt the following approach. They firstly identify the target functionality required and consider the major factors that can affect this target functionality. The use of compositional change, manufacturing techniques, and addition of other ingredients are then considered and used to produce the desired effect. The effectiveness of the developed ingredient is then tested by the application of functional screening tests which are used to examine the inherent performance. The powder is then finally tested in the specific application for which it was designed. Many factors, especially the local product composition, can dramatically affect the ability of an ingredient to perform its task. All this requires knowledge and understanding of the fundamental aspects of milk components, and their interactions in various food systems, the effects of variation in milk composition and effects of processing and how the various processes, both conventional and innovative can be used to manipulate and control the properties of ingredients and finally the key functional attributes required in target formulations where the dairy ingredients are used.

The process of developing and producing a successful dairy powder ingredient requires the knowledge and understanding of

- the fundamental aspects of milk components
- ingredient interactions in various food systems,
- the effects of variation in milk composition
- the effects of processing on the ingredient properties
- how to manipulate process controls to vary ingredient properties
- key functional attributes required in target formulations

5.5.2 New Powders (On the Market or Under Development)

Cream Powder

As most high fat powders manufactured today contain a mix of many ingredients (special proteins and emulsifiers) to maintain stability, the challenge was to convert a high fat emulsion into a powder with a low level of surface fat to minimise oxidation and to achieve good flowability, all without the need for additives. As a result of meeting this challenge the Australian dairy companies possess a technology to manufacture simplified formulations of powders containing 60 to 70% fat without the need for these expensive additives. This gives a powder that is easy to use, has good shelf life and is heat stable.

Yoghurt Base Powder

This milk based milk ingredient has been developed specifically for the manufacture of recombined yoghurt. It can contain fat if required. It enables the manufacture of yoghurt with reduced milk solids requirements, thus reducing raw material costs while maintaining or enhancing the physical characteristics of yoghurts such as gel strength or viscosity, with reduced syneresis.

Blends

The economic advantages of using cheaper milk based ingredients in formulations have led to the emergence of a range of blends of milk-based ingredients. The main ingredient used for substitution is whey or whey derivatives. Initially substitution was simply a replacement exercise with no thought of functionality. However, recent developments have produced a large range of blends of dairy based ingredients with basic milk powders with enhanced functionality due to the incorporation of these substitutes for a range of end uses, in particular, ice cream, confectionery and bakery. It has also led to the creation of a new range of recombined products e.g. creamers as substitutes for conventional evaporated milk.

Nutritionally Enriched Powders

The need to supply the demands of the modern consumer for healthy foods has led to a range of nutritionally enhanced milk powders. There are many variations of conventional skim and full cream milk powder on the market shelves and they are being used in formulations that now contain enhanced levels of such components as pre and post biotics, added calcium, enriched vitamin levels and omega 3 fatty acids. This trend will continue as dairy products are an extremely convenient way of incorporating various nutritionals into a natural food environment. There is also another group of newer powders on the market with biological functional properties e.g. colostrum powders.

5.6 Product Handling

5.6.1 Packaging, Transport, Storage and Handling

The packing method and the conditions of transport and storage must afford the milk powder protection from contamination from dirt and microorganisms, prevent moisture and oxygen uptake and exclude light, insects and odour. To this end there are several ways to package and transport milk powders.

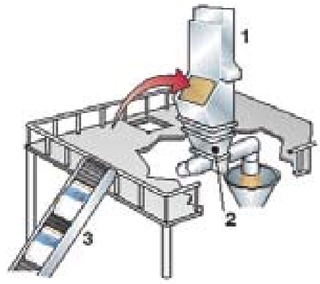
Figure 11 Shows the sealing section of a 25kg bagging line

The majority of milk powder for export is packed into 25kg bags (see Figure 11) with some being packed into 500-1000kg bulk bins usually for re-packing into consumer packs. The bags are multi-wall with a mix of paper and plastic. Powder manufacturers use a mix of 3 and 2 ply paper (90 gsm), with a move to using 2 ply with a polyethylene liner only for environmental reasons, The polyethylene liner for SMP is typically 60 micron whereas for fat containing powders the polyethylene liner is slightly heavier at 65 micron and has gas barrier properties. It is also becoming popular to use barrier bags and liner of co-extruded polymers, for reduced oxygen and water vapour permeability.

The bulk bins are typically a bag-in-box construction with a large polyethylene bag filled with powder and closed by heat sealing, with the outer walls being made of rigid laminated board. Powders containing milk fat such as full cream milk powder and buttermilk powder are flushed with an inert gas (typically CO_2 & N_2 mixture) at the time of packaging to reduce the internal oxygen level and thus enhance the storage stability and shelf life.

The 25kg bags are stacked onto pallets and are shrink wrapped in plastic sheeting with a top and bottom cardboard sheet for added protection during transportation and storage. Powders should be kept at a temperature of <28 °C and a maximum relative humidity of ~65%, during transport and storage.

Figures 12 and 13 showing powder handling apparatus



Equipment for handing powder in sacks.
1 Dust collecting unit
2 Sifter
3 Sack elevator

Tilting rack for powder container.

From Tetra Pak Dairy Processing Handbook

Figures 12 and 13 show two methods of handling powder during the reconstitution phase of product application or for on-packing for domestic use. Retail packs used include bag in a box, plastic bags and metal cans. The latter is almost the complete container for milk powders in that it offers protection from moisture, light and physical damage. However, it is relatively expensive and can be subject to rust.

5.6.2 Deterioration

The most important aspect of milk powder that should be considered when discussing the possible deterioration of powders is moisture level, or more specifically the water activity (aw) of the powder. Whole milk powder has a higher aw than skim milk at the same moisture level because fat does not effect the aw level. The main component that attracts water is the lactose, particularly if it is in the amorphous or non-crystalline form. Therefore powders need to be well packed and because the aw increases with temperature this needs to be kept <28°C because an increase in aw often induces an increase in other deteriorative reactions. There are several deteriorative aspects to consider and be aware of:

- *Microbial and enzymic* deterioration are not often seen in milk powders as the aw is too low. However, enzymic reactions can occur slowly at low aw levels and thus fat-containing powders must be free of lipase. Also powders must be free of all enzymes as these may cause problems in applications where they can subsequently be activated.
- *Caking* is a problem when a powder is too high in moisture or absorbs moisture from the air or surrounds. Water vapour condenses on the surface of the powder particles causing caking which leads to clumping and then ultimately to an overall hardening of the powder. This is caused by lactose content and state, with hydrolysed lactose more susceptible to rapid caking because galactose and glucose are both hygroscopic and attract water. Higher temperatures and humidities in storage both promote caking. Mild caking can have a detrimental effect on dispersability, solubility and flowability. The main method used to determine caking temperature is the turning of a propeller in a sealed vessel containing powder. The vessel is placed in a heated water bath and when there is a sudden increase in the force applied by the electric motor to keep the propeller at a constant speed the temperature is noted as this

corresponds to the caking point (Chuy et al, 1994 and Hennings et al, 2001). Free fat can also cause soft clumping, especially if there is a rise and fall of temperature during storage.

- ***Browning or off flavours*** are generally caused by the development of Maillard reaction products which are formed by the reaction between proteins and carbohydrates (lactose in milk powders). This can also lead to an increase in insolubility index due to protein insolubilisation. Colour changes can also be monitored by use of a Minolta or similar instrument in determining L, a, b values. Maillard reaction extent is measured initially by furosine determination and later by hydroxymethylfurfural analysis and advanced reactions can be measured by non enzymic browning products of low (Amadori compounds) and high (melanoidins) molecular weight.
- ***Oxidation*** of fat in full cream and buttermilk powder can give rise to tallowy off flavours. Unlike other reactions the oxidation of fat increases with a decrease in aw. An aw of around 0.3 provides a minimum reaction rate for auto-oxidation. Therefore, a balance must be struck for the aw to prevent oxidation (but not to promote caking) which together with gas flushing usually gives the powder a good storage life.
- ***A loss of some nutritive components*** and overall digestibility can occur during storage, this is mainly due to the Maillard reaction, as this reaction can impair some essential amino acids by linking them with lactose. The most vulnerable to this reaction is lysine. Vitamin A, a fat-soluble vitamin can also be lost during storage particularly if oxidation of the fat occurs.

Overall, when considering the storage of milk powders a general rule of thumb is to utilise them as follows: 18 - 24 months for SMP, 12 – 18 months for FCMP, preferably with barrier lining and inert gases to exceed 12 months and 10 – 12 months for BMP. Powders containing fat are particularly prone to deterioration and care must be given to initially selecting high quality powders and storing them under ideal conditions.

Table 1 Typical specifications for SMP, FCMP and BMP

Constituent	Skim MilkPowder	Full Cream Milk Powder	Buttermilk Powder
Moisture %	Max 4.0Range 3.0 -3.5	Max 4.5Range 2.5 - 4.0	Max 4.0Range 3.0 – 4.0
Fat %	Max 1.25Range 0.5 – 1.25	Min 26.0Range 26 – 28.5	Typical 6.0Range 4.5 – 7.5
Protein %	Typical 32.5Range 32 – 38	Typical 26.0Range 24.5 – 28.0	Typical 31.0Range 30.0 – 34.0
Ash %	8.2 – 8.5	5.4 – 6.6	8.2 – 8.7
Lactose %	48.5 – 51.5	35.5 – 38.5	46.0 – 49.0
Titratable Acidity %	Max 0.15	Max 0.15	Max 1.25
Insolubility Index	Max 1.25Typically 0.1	Max 1.0Typically 0.5	Max 1.25Typically 0.5
Scorched Particles (ml)	Disc A	Disc A	Disc A
Colour	White to cream	Cream	Cream to yellow
Flavour	Clean	Clean	Sweet and clean
Standard Plate Count cfu/g	<30,000Typically Max. 10,000	<50,000Typically Max. 10,000	<50,000Typically Max. 10,000
Salmonella	NegativeTypically in 375 gm	NegativeTypically in 375 gm	NegativeTypically in 375 gm
Listeria	Negative	Negative	Negative
Coliform	NegativeTypically in 1.0 gm	NegativeTypically in 1.0 gm	NegativeTypically in 1.0 gm
Staphylococci	NegativeTypically in 0.1 gm	NegativeTypically in 0.1 gm	NegativeTypically in 0.1 gm
Yeasts & Moulds	Typical Max. 50 / gm	Typical Max. 50 / gm	Typical Max. 50 / gm

From personal communication with Australian dairy manufacturers

5.7 Product Specifications

Table1 shows typical specifications and ranges of values for SMP, FCMP and BMP. As well as these common specifications the end user can and should consider specifying other aspects particularly those related to functional properties and heat classifications, according to the functional properties required in the application they are planned for e.g. heat stability for REM or viscosity for RSCM. These requirements can be discussed and agreed with the manufacturer during negotiations for supply. Particular specifications or requirements can be determined by reference to many of the functional properties described in Section 2.

FAQ

A. Physical Characteristics and Functionality

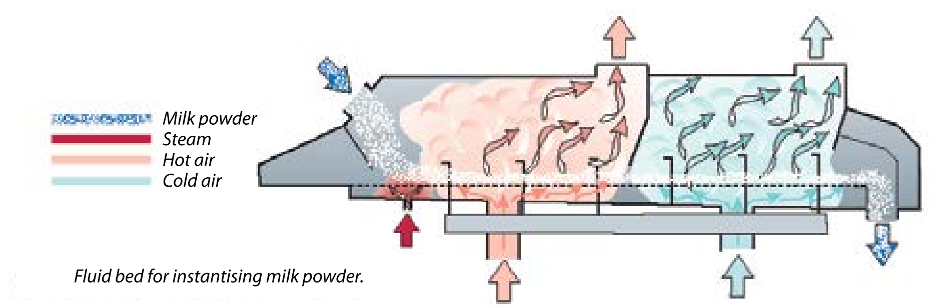
A1. What is the difference between instant and non instant powders?

An instant powder has enhanced reconstitution properties and is readily dissolved in cold water as well as warm. The most important aspect of instantising is the agglomeration process applied during powder manufacture where the amount of air between the powder particles is increased resulting in a coarse, cluster like agglomerate structure. This structure allows more water to come into contact with the powder particles when dispersed in water, preventing the formation of a viscous layer which is common in non instant powders.

The agglomeration process in powder manufacture can be done in a number of ways including:

- Returning fines to the atomiser,
- forcing agglomeration at the time of atomisation,
- rewetting powder after the initial drying and / or
- use of multi stage dryers - most often used for the best results using with gentle final drying by way of fluid beds or rewet agglomeration (see Figure 14) of the moist powders that exit from the primary drying stage.

Figure 14 Schematic of a rewet agglomeration process.



From Tetra Pak Dairy Processing Handbook

Production of instant FCMP requires the addition of a surfactant as normal powder particles are covered with a thin layer of fat making them repellent in cold water. Lecithin (from soya beans) is dissolved in milk fat and applied to the powder as a fine spray during the final drying process in a fluid bed, at a rate between 0.1 and 0.3%. In evaluating instant powders several properties are considered: BD (max 0.48 g/cm^3), scorched particles (disc A), wettability (max

10 sec @ 25 °C), dispersibility (min. 95%), sludge test (max. 0.1 g @ 25°C and 85°C) and free fat (max.1.5%).

A2. What are the indicators of solubility, flowability, and dispersibility in milk powders?

Solubility or rather insolubility is determined for a powder by mixing a prescribed amount of powder (13g for FCMP and 10g for SMP & BMP) with water (100ml) under controlled temperature conditions (usually 24°C but can be at 50°C if the powder is specifically intended for use at a high reconstitution temperature) using a specialised mixing machine (defined mixing vessel and stirrer configuration) with subsequent decanting into prescribed centrifuge tubes where the insolubles are spun down and measured (see section 2.3). Temperature is the single most important determinant in this evaluation where a powder may exhibit some insolubles at 24°C but little at 50°C due to the higher solubility of heat denatured protein and the release of any entrapped fat at these higher temperatures. Therefore it is essential that insolubility index measurements be reported with the temperature being clearly stated.

Flowability is an important property of powders in respect to transport, weight measurement, packaging and handling in subsequent applications. It is influenced by particle morphology (size, shape and structure) and the distribution of the powder particle sizes. Good flowability is usually obtained with larger particles or from agglomerates with a minimal number of smaller particles. However, larger particle size distribution and agglomeration may have an adverse effect on BD. Lower "loose" BD improves flowability but this is less related to tapped BD. The fat content plays an important role in the flowability of powders; in particular the degree to which the fat is in the "free" form or more particularly on the surface. The use of free flowing agents and the application of an instantising operation assist the flowability of powders.

Dispersibility is the ability of powder to dissolve without forming dry lumps and with instantaneous disintegration of agglomerates into single particles ready for dissolution. The agglomeration process is of primary importance for good dispersibility and needs to be optimised to ensure that there are few agglomerates >250 micron, few compact agglomerates and little if any fines.

A3. How do you assess bulk density and what does it mean?

Bulk density (BD) is a measure of the weight of powder that can be contained in a prescribed volume (weight of a volume unit of powder) and is usually expressed as g/cm^3 (or sometimes kg/m^3). It is a very important attribute when considering packaging and transport as most transport is costed on a per volume basis. Bulk density also has effects on other powder properties particularly in applications concerning dispersibility and instantising. The method for determination is quite simple. Typically a prescribed amount of powder (usually 100g) is weighed and transferred to a 250ml measuring cylinder. The surface is levelled and the volume measured (poured BD), the cylinder is then tapped 100 times (loose BD), the volume recorded and then tapped a further 525 times for a total of 625 (BD) and the final volume recorded. The volume measured after each of these operations is termed the poured, tapped and bulk density. There are several variations of this method and the method used must be quoted with the results.

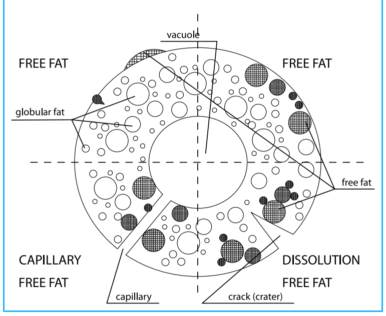
There are many factors that contribute to BD. During the manufacture of the powder the final BD can be influenced by concentrate characteristics, atomisation parameters, drying temperatures and degree of whey protein denaturation (the greater degree of denaturation, generally the higher the BD). The critical measurements that determine the ultimate BD of a powder include the particle size distribution (the greater the spread, the higher the BD), occluded air or the amount of air incorporated within the powder particles, (the more air, the lower the BD), the shape of the powder particles which give rise to the amount of air between them known as interstitial air (the more interstitial air, the lower the BD) and the density of the powder particle which is determined by the composition of the powder. The BD of a powder can increase with storage, due to attrition of the particles with subsequent packing down within the bag or container. This is not beneficial from a visual point of view nor does it assist in dispersibility when too many fines are formed.

One drawback of agglomerated powder is that it has a lower BD than non-agglomerated due to the uniformity and larger nature of the particles in an agglomerated powder.

A4. What is free fat and how does it affect milk powder?

Free fat is that fat which is easily extractable from milk powder particles by a solvent under standard conditions of time, temperature and agitation. As shown in Figure15 the extractable fat is predominantly on or close to the surface but when there are cracks or fissures in the surface of the powder particle then fat that resides within the particle can also be extracted. This free fat can cause both physical and compositional defects. High free fat causes clumping and the hydrophobic nature of the fat causes reduced flowability and dispersibility. Its exposure to air facilitates oxidation which reduces the powder's shelf life and leads to the occurrence of flavour problems. It is therefore very important that during the manufacture of milk powder a good emulsion is formed prior to drying, the conditions of drying minimise cracking and case hardening and that the storage conditions of the powder is optimal to minimise the production of free fat.

Figure 15 Buma's free fat model

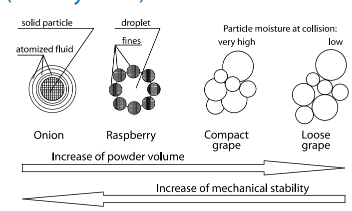


From Buma, 1971

A5. What is agglomeration and how is it undertaken?

Agglomeration is the formation of clusters of powder particles. For milk powders it is used to increase the amount of air between the particles (interstitial air) which is required to assist powder dispersibility. There are essentially four types of agglomerates that can be formed: onion, raspberry, compact grape and loose grape. See Figure 16. The first two types do not assist in dispersibility and are not used in the dairy industry. The latter two occur by collision of particles and fines and depending on the moisture content, a loose or compact formation occurs with the loose being

Figure 16 Types of agglomerates (Pisecky 1997)



Chap - 05

superior for dispersibility. During the spray drying operation agglomeration can occur naturally by interaction or can be forced by the introduction of fines or cross over spray patterns.

A6. What is meant by particle size distribution?

Particle size distribution (PSD) gives a measure of the number of powder particles that exist within a specified range of sizes. There are several ways of measuring PSD including sieving, microscopic counting and automatic counting apparatus. The sieving and microscopic counting are the least accurate as they tend to break down agglomerates and they are also time consuming. Apparatus such as the Malvern and Coulter are fast and very accurate as they use relatively non destructive laser beam methodology. (See section 2.3 for more details). PSD can have an effect on a range of physical characteristics of powders including a decrease in dispersibility with increasing fines, a lowering of interstitial air with a broadening of the PSD particularly with large amounts of fines, an increase in BD with an increase in PSD. The ability of various spray dryers to produce particular PSD ranges is shown in Table 2

Table 2 Mean particle size obtained from dryers of different configuration

Powder Characteristics	Dryer Configuration	Particle Size(micron)
Individual particles	Concurrent with pneumatic conveying	20 – 200
	Tall form - tower	30 - 250
Flakes	Roller dryer	200 - 5000
Loose agglomerates-open structure	Mixed flow with integrated fluid bed	100 – 400
	Concurrent with integrated fluid bed	100 - 200
Compact agglomerate-porous structure	Concurrent spray dryer with integrated belt	300 – 2000
	Mixed flow with integrated fluid bed	100 - 400

Personal Communication (E. Refstrup), Niro A/S, Denmark

A7. What, if any, special characteristics does BMP possess?

BMP as its name implies comes from the milk extracted during butter manufacture. During butter manufacture the natural milk fat globule membrane is ruptured by the processing regime. This membrane which represents approximately 2% of the total fat globule is composed of a mixture of phospholipoproteins (50% protein, 30% phospholipid and 8% other fats) and contains different complex surfactant materials some of which have very desirable functional properties. Buttermilk and hence BMP contains a very high proportion of these materials which have a range of positive effects on subsequent applications including enhanced flavour, improved heat stability, increased emulsification capability and reduction in fouling of liquid milk particularly UHT.

B. Quality and Economics

B1. How can you maintain optimum solution appearance that is an important functional property?

The maintenance of optimum solution appearance depends on a range of issues. Firstly the milk powders used for the application must be of the highest quality (e.g. no scorched particles). This means using powders with the best possible insolubility index and colour measurements and in the case of FCMP and BMP having no sign of fat oxidation. The process that most determines the appearance of the final product is the application of appropriate levels of heat. Therefore optimisation of manufacturing conditions and regular checks of equipment are essential, with indicator gauges regularly checked and monitored. Hygiene regimes should ensure absolute cleanliness of the machines. The storage of the final product can also have a telling effect on the quality of its continuing appearance. Products subjected to heat, moisture, humidity and light will all suffer to some degree.

B2. How to minimise the nutrient loss during processing and storage?

The most important aspect of milk powder that should be considered when discussing the possible deterioration of powders is moisture level or more appropriately the water activity (aw) of the powder. Whole milk powder has a higher aw than skim milk at the same moisture level because fat does not effect the aw level. The main component that attracts water is the lactose particularly if it is in amorphous or non-crystalline form. Therefore powders need to be well packed and because the aw increases with temperature the temperature needs to be kept <28°C because an increase in aw often induces an increase in other deteriorative reactions. There are several deteriorative aspects to consider and be aware of:

- ***Microbial and enzymic deterioration*** are not often seen in milk powders as the aw is too low. However, enzymic reactions can occur slowly at low aw levels and thus fat-containing powders must be free of lipase. Also powders must be free of all enzymes as these may cause problems in applications where they can subsequently be activated.
- ***Caking*** is a problem when a powder is too high in moisture or absorbs moisture from the air or surrounds. Caking leads to clumping and then ultimately to an overall hardening of the powder. The component primarily responsible for caking is lactose and higher temperatures of storage promote caking.
- ***Browning or off flavours*** are generally caused by the development of Maillard reaction products formed by the reaction between proteins and carbohydrates (lactose in milk powders). This can also lead to an increase in insolubility index due to protein insolubilisation.
- ***Oxidation*** of fat in full cream and buttermilk powder can give rise to tallowy off flavours. Unlike other reactions, the oxidation of fat increases with a decrease in aw. An aw of around 0.3 provides a minimum reaction rate for autooxidation. Therefore a balance must be struck for the aw to prevent oxidation (and not promote caking) which together with gas flushing usually gives the powder a good storage life. A loss of some nutritive components can occur during processing and on storage. Loss can be minimised during processing by using staged drying i.e. multi stage. The most vulnerable to this is lysine, which happens as a result of the Maillard reaction. Vitamin A can also be lost during storage particularly if oxidation of the fat, in which the vitamin A is usually dispersed, occurs.

B3. What is oxidation and how to minimise fat oxidized flavour during storage?

Oxidised flavour is a consequence of the reaction between oxygen and radical species formed from unsaturated fat in milk powders. Obviously FCMP and BMP are more susceptible to this reaction but it can still occur in SMP. It can develop quickly if the fat quality prior to separation was poor or the fat globules have been mistreated. There are two stages of oxidation – the first being the formation of hydroperoxides and the second, and more important, is the formation of degradation products which primarily give the off flavours detected in milk powders. Traditionally, tests such as the ferric thiocyanate method were undertaken to determine the peroxide value (PV) as a measure of oxidation but as these hydroperoxides further react in the second stage this is not a good stand alone method and PV values will rise and fall during storage. A better indicator is to test for the secondary products by undertaking analysis such as the thiobarbituric (TBA) determination. Other measures such as the determination of free sulfhydryl groups are also used as indicators of oxidation as they are antioxidants and a decrease usually correlates with an increase in oxidation (Thomas et al, 2004).

In order to minimise oxidised flavour the best possible quality milk powder must be sourced and absence of oxidation included in the specifications. If there is any sign of oxidation then the powder should be rejected as once oxidation starts it can only be controlled to a certain extent but not stopped entirely. Storage conditions are very important – temperature in particular needs to be kept between 20 – 25°C if possible as higher temperatures promote oxidation. Low humidity and minimal light exposure are also recommended. Stacking of powder at heights for extended periods can lead to possible rupture of the encapsulated milk fat droplet leading to free fat and the possibility of exposure to oxygen/air and hence degradation.

Packaging can also assist in minimising oxidation by using modified atmospheric packaging to reduce the O_2 to <1.5% by the use of gas flushing and/or the use of barrier bags and also a preheat treatment of the milk during processing produces natural antioxidants.

B4. How can the bacteriological quality of products be improved?

The bacterial quality of the final product is predetermined by several factors but particularly by the quality of the ingredients used. The powder must be of the highest microbiological quality because once water is introduced for reconstitution the growth of microbial contaminants is almost inevitable if they are present in the powder. Relying on later processes to rid the product of contamination by way of heat treatment is not an acceptable practice. This is particularly pertinent if local raw milk is used to supplement other dry ingredients. If this milk is not of the highest quality the total product will be placed at risk. The next issue to consider is the cleanliness and operation of the processing plant. Proven start up, operating and cleanup processes are essential to producing high quality products and in determining the shelf life and microbiological storage stability of the product. All efforts must be made to comply with the written procedures regarding plant, packaging materials and staff hygiene at all times.

B5. How can ingredient costs be optimised?

Optimisation of ingredient costs can be achieved in several ways. The most important way is to make sure that the ingredient purchased is firstly the best fit for your application i.e., not only does it exhibit all the common compositional and functional properties but it also possesses those compositional and functional properties specific to the end use which will enhance the final product. Making sure that the ingredient purchased is the best for the application will cut back on failures and on product which is not of the best quality and hence difficult to dispose of. Storing the ingredient under the best possible temperature and humidity conditions will assist in the retention and maintenance of quality.

The use of blends is becoming increasingly popular as an economic tool. The most common cheaper ingredient used is whey or permeate powder. The fact that these ingredients do not contain all the components of SMP, FCMP or BMP often means that they will not perform to the same level as these powders. The simple blending or substitution of SMP, FCMP and BMP by whey at the point of application can be fraught with danger. However, there are now appearing a range of blends manufactured specifically for designated use e.g. ice cream blends and bakery blends are now appearing in the market place. These are not only economic but often have enhanced functionality because the composition is based on the selection and blending of appropriate ingredients with enhanced specific functionalities required for specific end uses. However, even with these specialised blends there may be trade off in some attributes, flavour for example. These powders still require the processor to get all the processing conditions correct and to have the flexibility to accommodate changes in formulation and processing conditions with changes in ingredients if required. Above all purchasing the right ingredient for the right application combined with the best quality will save money and prove an economic advantage.

C. Processing and Storage

C1. What is the most suitable packaging temperature for milk powders?

SMP is usually cooled to less than 30°C in the final stage of drying in a fluid bed prior to packaging in order to minimise any clumping and moisture migration. For the fat containing powders (FCMP and BMP) the temperature of packing is usually higher particularly for instantised powders where the temperature is around 45°C to ensure that the lecithin /AMF applied to the powder has sufficient time while still in a relatively molten state to completely migrate and thus to completely coat all the powder particles. Care must be taken though not to maintain this temperature for too long a period as clumping could be encouraged particularly if the free fat level is elevated or in the case of higher fat powders.

D. Specifications and Analysis

D1. How do you test for scorched particles in milk powders?

Scorched particles mainly occur as a result of deposits in the spray dryer or other areas of manufacture and/ or where the deposits or particles have been exposed to high temperatures, usually for some time e.g. deposits can form on the atomiser where they are subjected to very high temperatures. This causes scorching, browning and leads to insolubility. There is also the possibility of burn-on in the evaporator. Scorched particles can also result from sediment not removed from the raw milk but this is of little concern in a modern dairy factory.

The method for the determination of scorched particles is quite simple and relatively fast to undertake:

25g of SMP or 32.5 g of FCMP or BMP is mixed into 250 ml of water at 18 - 27°C for approximately 50 sec using a high shear mixer (the insolubility mixer is typical of that used). The solution is then filtered through a filter pad (often made of cotton with a pore size of 100 micron) of 32 mm diameter. There are several devices available that can hold the filter pad in position or the use of a simple funnel will be adequate. The solution is forced through the pad by either vacuum or pressure (50 kPa is sufficient). The pad is then visually compared to a standard for classification and the scorched particles are recorded as A, B, C or D depending on the intensity of the colour on the pad.

D2. What is Whey Protein Nitrogen Index?

Whey protein nitrogen index (WPNI) is a measure of the amount of undenatured whey protein remaining in milk powder and is expressed as mg of undenatured whey protein per gram of powder. The amount of undenatured whey protein is a measure of the degree of heat treatment the milk has been subjected to during manufacture into powder. The preheat treatment given to the raw milk prior to evaporation and drying is the most dominant determinant of this reduction in undenatured whey protein. During preheating >95% of the total denaturation occurs. Very little denaturation occurs in the evaporation and drying stages even though the temperatures are relatively high the contact time is low and the temperature which the milk or milk droplet reaches is relatively low.

D3. What is the difference between low, medium and high heat powder and what is heat classification of powders?

The degree to which the whey proteins are denatured during the preheat treatment determines many of the functional properties of a powder. Therefore it is a common practice to classify powders according to their degree of whey protein denaturation. One of the most common classification methods is that from the ADMI where the concentration of undenatured milk serum protein nitrogen (UMSPN) is calculated by precipitation and turbidity readings and then ranked as shown in Table 3. Another method of classification is the Heat Number (IDF Standard 114:1982) which is based on the procedure of Rowland (1938a) in which the casein number is determined by multiplying the ratio of casein nitrogen content to total nitrogen and multiplying by 100. The equivalent values for the heat number are also given in Table 4. However, it must be understood that a WPNI or Heat Number alone does not guarantee that a powder will perform or will perform consistently in a functional way e.g. not all high heat powders are heat stable and not all high heat powders with the same WPNI or Heat Number perform the same; factors such as seasonal variation also need to be considered. Specific functional tests must be undertaken to determine the degree of functionality and suitability for application of all powders independent of their WPNI or Heat Number.

Table 3 Heat Classification According to WPNI and Heat Number

Heat Classification	WPNI (mg undenatured WPN/g)	Typical Heat treatment	Equivalent Heat Number (%)
Low heat	>6.0	72-75°C/15-30 sec	<80
Medium heat	1.51 – 5.99	75-95°C/1-2 min	80.1 – 83.0
Medium–high heat	-	75-110°C/1-5 min	83.1 – 88.0
High heat	<1.5	85-120°C/1-5 minor 125-140°C/1-5 min	>88.1

D4. How is WPNI measured?

All the casein in the powder together with the denatured whey protein (which has complexed with the casein) are precipitated from a sample of reconstituted dried milk by saturation with sodium chloride with the precipitate being removed by centrifugation and subsequent filtration. The nitrogen (which is a combination of the undenatured whey protein nitrogen - UDWPN and non protein nitrogen - NPN) is determined in an aliquot of this filtrate by the Kjeldahl method. A second aliquot of the filtrate is acidified with hydrochloric acid to precipitate the UDWPN and the NPN remaining in the filtrate is determined. The UNWPN or WPNI is then calculated by the difference between the two determinations i.e. (UDWPN + NPN) – NPN = UDWPN or WPNI . SMP is often classified by WPNI as a broad classification of heat treatment but end users need to be wary of directly translating this to functional properties.

E. Applications

E1. Is there a simple guide to the use of SMP, FCMP and BMP in applications according to desired functionality?

Table 4 gives a general guide to the use of SMP, FCMP and BMP in applications. The exact attribute required will change from specific product to product but the general principle will apply.

Table 4 General guide to powder usage and functional property.

Application	Powder and Heat Treatment	Desirable Functional Attribute/s
	DAIRY	
Yoghurt	SMP or FCMP and usually high, but low heat can be used if yoghurt milk given high heat treatment during manufacture	Water binding, viscosity and gelation
Ice cream	SMP, FCMP & BMP with low to medium heat	Foaming, whipping and emulsifying
Milk (Pasteurised)	SMP & FCMP with low heat	Lack of cooked flavour
UHT Milk	SMP & FCMP with low to medium heat	Heat stability and Pyruvate <9 mg
REM	SMP, FCMP & BMP with high heat	Heat stability
RSCM	SMP, FCMP & BMP with medium heat	Viscosity
Cheese	SMP & FCMP with low heat	Rennetability
Beverages	SMP & FCMP with low to medium	Nutritional, viscosity & texture
	BAKERY	
In general	SMP, FCMP & BMP with medium to high	Water binding, emulsifying, foaming, whipping and gelling
Bread	SMP with high heat	Water binding, emulsifying, foaming and gelling
	CONFECTIONERY	
In general	SMP & BMP with medium to high heat	Water binding, whipping, foaming, viscosity, colour development and emulsifying
Chocolate	FCMP & BMP with high heat	High "free fat", flavour and viscosity
	SMALLGOODS	
In general	SMP with low to medium heat	Gelation, water binding and emulsifying
	HEALTH FOODS	
In general	SMP, FCMP & BMP with low heat	Nutritional, water binding & emulsifying

Glossary

Age Thickening

The demonstration of an increase in viscosity by a product on storage. Usually associated with REM, RSCM and UHT milks.

Atomisation

This is the formation of a spray or mist of the feed concentrate into the spray dryer to enable intimate contact with the drying air in the main chamber.

Agglomeration

Agglomeration is the formation of clusters of powder particles to assist in the inclusion of more interstitial air and thus to aid dispersibility.

BMP

Butter milk powder is the dried form of the liquid by-product from the manufacture of butter, which is expelled during the churning phase of the process.

Bulk Density

Bulk density (BD) is a measure of the weight of powder that can be contained in a prescribed volume (weight of a volume unit of powder) and is usually expressed as g/cm^3 (or sometimes kg/m^3).

Cakiness

Is the natural propensity of a powder to form a semi or solid lump when exposed to air and or when subjected to pressure. The degree to which this occurs is related to hygroscospicity and free fat.

Coffee Test

Is an observation and quantitative measurement of undissolved particles formed when milk powder is added to a coffee solution.

Cyclone

Is a conical shaped apparatus that by controlling the air flow patterns is able to remove powder particles from the outlet air of a spray dryer.

Dispersibility

Dispersibilty is the overall expression of the instant characteristics of a dried milk. It is affected by wettability, sinkability and solubility.

Emulsifiers

Assist in the formation and maintenance of stable emulsions in many dairy applications. Many dairy ingredients also possess emulsion capability.

Emulsion Capacity

Is a measurement of an ingredient, including dairy based, to exhibit emulsion enhancing characteristics.

Evaporation
The removal of water from a solution. Thermal evaporation is the major way of concentration of milk prior to drying.

Fat Separation
Is a defect in many dairy products that contain fat. It is usually caused by unstable emulsions, which allow fat to rise to the surface.

Fines
Fines are the particles at the lower end of the particle size range of powders. They usually do not separate from the exhaust air in a spray dryer with the bulk of the powder and are removed by cyclones and often returned to the main chamber to facilitate agglomeration.

Flowability
This is the ability of a powder to freely flow when placed on an incline or during transportation within the manufacturing plant or point of application. It is of particular importance in the handling of powders.

Fluid bed
The fluid bed is a secondary drying unit, either external to or within the dryer, which finishes the drying and/or is used for agglomeration and or instantisation of powders.

Foaming
Is the ability of a solution to incorporate air and is of particular importance in the manufacture of ice cream and mousse type products.

Free Fat
Free fat is that fat which is easily extractable from milk powder particles by a solvent under standard conditions of time, temperature and agitation.

Free Moisture
Free moisture is water that is easily extractable when the powder is subjected to a temperature slightly >100 °C at atmospheric pressure. It is moisture not involved in any chemical reaction.

Flowability
This is a measure of the free flow characteristics of powders.

Fluid bed
A fluid bed is a unit used during powder manufacture, which can either, be incorporated into the main body of the dryer or more typically external to the dryer. It has a twofold function in that it acts as a secondary and/or tertiary dryer and is used for instantising action.

Functionality
Is a characteristic of a powder that can be physical in that it imparts physical & sensory properties, nutritional in that it is a source of nutrients and biological value and physiological in that is has a biomodulating response.

Gelation
Gelation is when cross linking occurs between proteins to the extent that a solid or semi solid structure is formed from a liquid. This is accomplished by heat and occurs as a two step process, with heat denaturing the whey protein and unfolding them, and then they aggregate to form a network.

Heat Classification
This is a means to distinguish milk powders that have been subjected to different heat treatments, predominantly preheating of the raw milk prior to evaporation and drying. A typical classification is low, medium and high heat.

Homogenisation
Homogenisation is a process used to reduce the size of fat globules in milk and milk products. The process usually involves passing the product through a small opening under rather high pressures. The process also induces the coating of the fat with protein.

Inlet temperature
The temperature of the air used for drying whether primary for the main chamber or secondary for fluid beds.

Insolubility Index
This is a defect in powders and is a measure of the amount of solids in a powder that are not soluble under specified conditions of temperature and mixing.

Instantisation
This is a process to enhance the reconstitution properties of powders and in particular assists dissolution at cold water temperatures.

Interstitial air
The air that is between the powder particles is designated the interstitial air.

Lactose Crystallisation
In milk lactose crystallisation is the conversion of the beta-lactose, which is hygroscopic into the non hygroscopic alpha-form. Due to the fast water evaporation during spray drying this conversion does not take place to any great extent. In recombined dairy products e.g. sweetened condensed milk, lactose crystallisation occurs as sediment on the bottom of the product due to poor nucleation during processing that results in large crystals that give a grainy mouth feel.

Lecithination
This is the use of lecithin, usually derived from soy, which has both hydrophilic and lipophilic properties and enables the wetting process when powders are reconstituted to be enhanced.

Lipase
Lipases are enzymes that cleave fat both in milk and in milk products often resulting in unpleasant flavour defects

Maillard Reaction
The Maillard reaction takes place when heat is applied to a protein/carbohydrate mixture. The most obvious result of this reaction is the enhancement of browning. A positive outcome is the manufacture of antioxidant agents.

Mechanical Vapour Recompression
Mechanical Vapour Recompression is a method by which the temperature of the condensate removed from a thermal evaporator is increased by applying pressure to the condensate by mechanical means.

Occluded Air
This is the air that is entrapped within the powder particles.

Outlet Temperature
This is the temperature of the air as it exits the spray dryer or fluid bed. It is the dominant determining factor of many functional properties especially powder morphology.

Powder Density
The powder particle density is a measure of the density of the powder solids including the occluded air. Whereas the powder solids density is the density of the solids not including any air and is a determinant of composition.

Preheat
The preheat is the heat treatment given to the raw milk during powder manufacture prior to evaporation and drying. This heat determines many of the resultant powder functionalities.

Scorched Particles
Insoluble particles in the powder that are usually caused by heat damage during powder manufacture.

Sediment
Sediment is the film or individual particles that gather on the bottom of liquid dairy products, usually upon storage.

Thermal Vapour Recompression
Thermal vapour recompression is a method by which the temperature of the condensate removed from a thermal evaporator is increased by injecting a small amount of steam.

Water Binding
Water binding is a functional attribute whereby milk solids, particularly proteins, can bind water to increase texture, viscosity or form gels.

Wettability

Wettability is a measure of the ability of a powder to penetrate the surface of water at a given temperature.

White Flecks

These are very minute insolubles that form a layer on the surface of a reconstituted liquid.

Whey Protein Nitrogen Index

This is a measure of the degree of heat treatment given during powder manufacture and is used to classify powders according to heat treatment as low, medium or high. The classification however, has very limited value as a method for prediction of functional properties.

References

American Dairy Products Institute. Standards for Grades of Dry Milks: Methods of Analysis. rev ed., Chicago: ADPI. (Bulletin 916) (2002)

Buma, T.J. Free fat in spray-dried whole milk: X. A final report with a physical model for free fat in spray dried milk. Neth Milk Dairy J, 25: 159-174 (1971)

Chuy, L.E. and Labuza, T.P. Caking and stickiness of dairy-based food powders as related to glass transition. J Food Sci, 59: 43-46 (1994)

DeCastro-Morel, M. and Harper, W.J. Basic functionality of commercial milk protein concentrates. Milchwissenschaft, 57: 367-370 (2002)

Hennigs, C., Kockel, T.K and Langrish, T.A.G. New measurements of the sticky behaviour of skim milk powder. Drying Technol, 19: 471-484 (2001)

Horne, D. S and Parker, T. G. The pH sensitivity of the ethanol stability of individual cow milk. Neth Milk Dairy J, 34:126-130 (1980)

International Dairy Federation 3rd International Symposium on Recombined Milk and Milk Products. Brussels: IDF (1999)

International Dairy Federation 4th International Symposium on Recombined Milk and Milk Products. Brussels: IDF (2004)

International Dairy Federation Determination of the dispersibility and wettability of instant dried milk. Brussels: IDF (IDF Standard 87) (1979)

International Dairy Federation Dried milk and dried milk products: determination of insolubility index. Brussels: IDF (IDF Standard 129A) (1988)

International Dairy Federation Dried milk: assessment of heat class: heat – number reference method. Brussels: IDF (Standard 114) (1982)

Kieseker, F.G and Southby, P. Studies of recombined sweetened condensed milk. Aust J Dairy Technol, 20: 136-138. (1965)

Kieseker, F.G. and Aitken, B. An objective method for determination of heat stability of milk powders. Aust J Dairy Technol, 43: 26-31 (1988)

McDermott, R.L, Harper, W.J. and Whitley, R. A centrifugal method for characterisation of salad dressing emulsions. Food Tech, 35 (5): 81-87 (1981)

Miller, G.D., Jarvis, J.K. and McBean, L.D. Handbook of Dairy Foods and Nutrition. 2nd ed., Boca Raton: CRC (2000)

Niro Atomizer Dairy Research Group Analytical Methods for Dry Milk Products. 4th ed., Copenhagen: Niro (1978)

Phillips L.G., Haque Z. and Kinsella J.E. A method for the measurement of foam formation and stability. J Food Sci, 52: 1074-1077 (1987)

Pisecky, J. Handbook of Milk Powder Manufacture. Copenhagen: Niro (1997)

Rowland, S.R. The determination of nitrogen distribution in milk. J Dairy Res, 9: 42-57 (1938)

Standards Association of Australia. Standard. Methods of chemical and physical testing for the dairy industry. Melbourne: SAA, (Australian Standard 2300) (1988-1994)

Thomas, M.E.C., Scher, J., Desobry-Banon, S. and Desorbry, S. Milk powders ageing: effect on physical and functional properties. Crit Rev Food Sci Nutr, 44: 297 – 322 (2004)

Vuillemarde, J-C., Gautheir, S.F., Richards, J-P. and Paquin, P. Development of a method for the measurement of the maximum value of emulsifying capacity of milk proteins. Milchwissenschaft, 45: 572-575 (1990)

Ward B.R., Goddard S.J., Augustin M.A. and McKinnon I.R. EDTA – induced dissociation of casein micelles and its effects on foaming properties of milk. J Dairy Res, 64: 495-504 (1997)

Weerstra, R., Sjollema, A. and Tokley, R. Improved viscosity test for the evaluation of skim milk powder for use in recombined sweetened condensed milk. Neth Milk Dairy J, 42: 375-386 (1988)

DAIRY AUSTRALIA
Delivering for the dairy industry

6

Milk Powders in Non-Dairy Applications

Content

135 6.1 Introduction

135 6.2 Confectionery

136 6.3 Chocolate

139 6.4 Bakery

139 6.5 Meat and Fish

140 6.6 Sauces and Soups

140 6.7 Desserts

141 6.8 Beverages

141 6.9 Infant Formula

142 6.10 Conclusion

142 FAQ

144 Glossary

147 References

Abbreviations

ADMI	American Dried Milk Institute (Now the ADPI (American Dried Products Institute)
AMF	Anhydrous Milk Fat
BMP	Butter Milk Powder
FCMP	Full Cream Milk Powder
PV	Peroxide Value
PSD	Particle Size Distribution
SEF	Solvent Extractable Fat
SMP	Skim Milk Powder
USDEC	United States Dairy Export Council

6.1 Introduction

A broad range of milk based powders are used in a variety of non-dairy applications. This chapter will concentrate on the traditional milk powders namely full cream milk powder (FCMP), skim milk powder (SMP) and buttermilk powder (BMP). While there are an ever increasing number of special dairy based ingredients being manufactured for applications, the use of the traditional powders is still prevalent and the ability to manipulate composition and physical functionality continues to add to their acceptability. These traditional powders are used for bakery, confectionery, meat products, prepared mixes, as well as sauces soups, spreads, meat, fish and desserts. SMP's are generally used as an economical source of non-fat dairy solids, a source of physically functional high-heat solids (e.g. important for good loaf volume in breads), a source of physically functional low heat dairy solids for optimising sensory and physical properties in foods and beverages and as an easily and readily transportable dairy ingredient. These powders are usually classified according to the heat treatment they received during manufacture (see Milk Powders Chapter for detail) SMP's are also used extensively in animal milk replacers as a minor or major component. FCMP's are used as an economical source of dairy solids, including milk fat, a convenient form of nutritious milk that is easily reconstituted and does not require refrigeration and also an easily and readily transportable dairy ingredient (USDEC, 2007b) and like SMP can be made functionally serviceable by processing techniques.

All of these milk powders have functional properties that are valuable in formulated and processed food applications. These properties include effects of solubility, emulsification, gelation, water-binding, whipping/foaming, viscosity, heat stability browning/colour and flavour aroma attributes. All of these attributes are contained in the powders and can be further enhanced during application.

6.2 Confectionery

Milk powders are a key ingredient in the formulation of candy, nougats, frosting and creams, and provide flavour and functionality to these products. The proteins in milk powders can act at oil/water interfaces to form and stabilise emulsions, together with lecithin (the natural emulsifier present in the milk fat globule membrane) they prevent oiling off and creaming, and undenatured milk proteins which are able to form rigid, heat-induced, irreversible gels that hold water and fat, and provide structural support to confections. The firm, chewy texture of some confections is related to the binding of water by casein. Milk powders are also important in the formation of foams which is important in confections such as nougat, frosting and various creams, and in contributing a pleasant dairy flavour note and aroma to confections (USDEC, 2007a).

Table 1 Usage of milk powders in confectionery

Dairy powder	Typical usage level (%w/w)
SMP	Caramel candy (4.2), chocolate candy coating (15), fudge icing (2.2), reduced fat icing (4.0), chocolate frosting (0.2), compound coating (8 – 10), fudge (8.5), toffee (2.5)
FCMP	Milk chocolate (~20),

(Reference Chandan and USDEC 2007a)

SMP is the most used powder in confectionery manufacture and contributes to browning and caramelised flavour by Maillard reaction products produced when heat is applied. SMP also contributes to structure by water binding, reducing fat globule mobility, gelation and creating firmness and chewiness in the final products. FCMP and BMP, which are not used as often in this application, assist in emulsification and the creation and maintenance of uniform foams. BMP is used for flavour enhancement and because of its high lecithin content which assists in emulsification.

SMP has also been shown to result in enhanced toffee flavour while other applications include uses in fudge to produce dairy flavours and in hard-candy filling and marshmallows for improved flavour and browning characteristics (Campbell and Pavlasek, 1987).

6.3 Chocolate

Traditionally, FCMP, BMP and SMP have been used in the manufacture of chocolate. For example, FCMP in chocolate applications is used to reduce plastic viscosity, decrease refining time, change chocolate hardness, solid-fat content and surface colour (Walshe, 1994).

The physical characteristics of milk powders used in chocolate can have a significant impact on the processing conditions needed to make chocolate and the physical and sensory properties of the finished product. Aspects of chocolate manufacture and storage such as tempering conditions, melt rheology, hardness and bloom stability are dependent on the level of free fat in the milk powder. However, particle characteristics of the milk powder also influence the physical and sensory properties of the final products (Liang and Hartel, 2004).

Adjustment of lactose content (by ultrafiltration and diafiltration) in FCMP affects the microstructure of spray-dried FCMP. Milk powder particles with ~0% lactose have a more porous matrix with deep dents and wrinkles; lower true and apparent particle densities and larger median diameter, vacuole volume, surface area and free fat content. Higher lactose concentrations produce nearly spherical particles with a less porous matrix, higher true and apparent particle densities, and smaller median diameter, vacuole volume, surface area and free fat content. FCMP with modified lactose content may have potential in the manufacture of milk chocolate (Aguilar and Ziegler, 1994).

Increasing the concentration of amorphous lactose from spray-dried powders in chocolate decreases viscosity, increases particle size of refined chocolate mass and lowers the concentration of surface-active agents. Increasing the concentration of crystalline lactose for milk powders in chocolate increases viscosity, decreases particle size and increased the concentration of surface-active agents. Conditions which affect lactose crystallinity in milk powders, such as improper storage and handling prior to use in chocolate production, could be responsible for variations in chocolate viscosity noted sometimes by processors (Aguilar and Ziegler, 1995).

When used in chocolate processing, spray-dried milk powders (together with an independent fat source), have been shown to produce low viscosities, comparable with those obtained by using roller-dried milk powder (Attaie et al. 2003).

Milk ingredients influence consumer liking of milk chocolate through the quality driving parameters of particle size/sandiness, viscosity/melting mouthfeel and milk flavour. Chocolates made from milk products that contain high amounts of free fat-e.g. SMP plus anhydrous milk fat (AMF), score better than those using bound fat, e.g.FCMP. Milk fat status has more influence than differences between spray and roller-dried powders. High free fat cream powders have been shown to be most suitable for cream chocolates (Bolenz et al. 2003).

A high solvent-extractable fat (SEF) content is a desirable attribute for FCMP intended for chocolate manufacture. FCMP produced by conventional powder manufacturing processes have low SEF contents (<40 g free fat.kg-1 total fat in powder). Full-cream milk powders with high levels of SEF (up to approximately 400 $g.kg^{-1}$ total fat in powder) can be obtained by separating full-cream milk into cream and skim milk fractions, pasteurizing the cream fraction, then, either cooling the cream and recombining it with a skim milk concentrate or homogenizing it at high temperature and pressure prior to combining with a skim milk concentrate. Full-cream milk concentrates produced by either process can then be spray dried without homogenization. In addition to the use of altered processing steps for manufacture of milk powders, the level of SEF in milk powder is also influenced by the total solids of the cream and the milk concentrates used in the production of the milk powders (Clarke and Augustin, 2005).

The favourable flow properties of milk chocolate when roller-dried milk powder is used are generally attributed to the high free fat content. The liberation of fat during the different stages of chocolate manufacture has been investigated in milk powders differing in free fat content. Refining of the chocolate mass discloses a major part of enclosed milk fat. Nevertheless, the flow properties differ depending on the type of powder used. Normal spray-dried whole milk generally has insufficient flow properties for chocolate manufacture. However, replacing roller-dried FCMP by spray-dried SMP combined with AMF seems a possible solution to maintain the necessary flow properties (Dewettinck et al. 1996).

It is possible to alter important properties of chocolates using milk powders of varying fat contents, free-fat contents and particle sizes (Keogh et al. 2003). Shear cell techniques have been used to measure milk powder flow properties for chocolate manufacture. Fat content, free-fat content, particle size, moisture content, lactose content, amorphous lactose content and storage conditions have been evaluated for their effect on flowability of the milk powders. Increased fat content reduces powder flowability especially when comparing 1% (SMP) and 26% (FCMP) fat powders. Varying free-fat content has no effect on flowability. Particle size has a major influence on flowability, as increasing the particle size significantly improves the flowability of powders with 1% and 26% fat content. The concentration of amorphous lactose increases the susceptibility of powders for absorbing moisture, resulting in reduced flowability and caking on storage (Fitzpatrick et al. 2005).

Table 2 Usage of milk powders in chocolate

Dairy Powder	Typical Usage level (%w/w)
FCMP	Milk chocolate (20),
SMP	Milk chocolate (15), compound coatings (8-10),

(Reference Chandan and USDEC 2007a)

Exposing spray-dried FCMP to high shear and elevated temperature in a twin-screw continuous mixer increases the free fat content. Exposure to elevated temperatures and high shear has been shown to: (a) increase the free fat to more than 80%, (b) crystallize the lactose, (c) reduce the average volume-based particle size and (d) broaden the particle size distribution. Processing generally enhances the functional properties of spray-dried FCMP for milk chocolate manufacture (Koc et al. 2003).

Spray-dried milk powders have a median particle size of 30-80 mm. Roller-dried powder particles, which are larger (about 150 mm), are preferred for chocolate making. New processes have been developed resulting in spray-dried powders with median particle size values of 132-162 mm. These values in the chocolates were correlated with higher contents of free-fat and lower vacuole volumes in the powders (Keogh et al. 2004).

The free-fat content and the median particle size of high-fat milk powders has been shown to be affected by the protein content and solid-fat content of the milk but not significantly affected by the lactose content nor the protein: lactose ratio and it is possible to predict the free-fat content of high-fat milk powders, from the protein and solid-fat content of the milk (Twomey et al. 2000).

Spray-dried high-fat milk powders with different properties can be used to make chocolates with a range of viscosities and yield values for different end uses, such as moulding or enrobing (Twomey et al. 2002).

Flavour variability in SMP can carry through into chocolate manufacture and ingredient applications such as hot cocoa mix, chocolate bars, ice-cream and yogurt, and negatively affect consumer acceptability (Caudle et al. 2005).

New research on the role of spray drying, along with other processes in the development of dairy ingredients for applications in chocolate and the preparation of microencapsulated powders has recently been reviewed (Kelly, 2006).

6.4 Bakery

In bakery applications such as biscuits, breads, donuts and pancakes, both SMP and FCMP are extensively used. These enhance browning by Maillard reaction products and impart natural flavour, as does BMP when used as the fat component. They also enhance texture and structure, particularly in crepes, croissants and muffins, by forming dense foams with finer more uniform bubbles due to their emulsification attributes and water binding abilities. Milk powder also increases the water binding capacity of bread dough in direct proportion to the amount added which has a positive effect on texture, flavour and product shelf life (USDEC, 2007c).

Milk powders add to colour and flavour by Maillard reactions where the amine group of the protein reacts with lactose and other carbohydrates. Lactose does not get fermented by baker's yeast in yeast-leavened bakery products and remains available for colour development in the crust. SMP is also used in baking applications to enhance the level of milk solids, for milk flavour and to stabilise cake batter emulsions.

Table 3 Usage of milk powders in bakery

Dairy powder	Typical usage level (%w/w)	Functionality
SMP	Biscuits (4.1), yellow layer cake (2.22), croissants (3.41), donuts (2.00), muffins (2.35), choco chip cookie (1.25), cheese scone (2.05), cookies (2.5), bread dough (1.0 - 4.1), white cake (2.1)	In bread & biscuits – flavour, colour, crust, water absorption and textureIn cakes – browning, water binding, emulsification & texture
FCMP	White bread (0.5), cookies (3.05),crackers (1.6 - 2.52),	Flavour and texture
BMP	Pancakes (4.85)	Flavour and emulsification

(Reference Chandan and USDEC 2007g)

6.5 Meat and Fish

SMP is used in prepared meat and fish products where its water binding and emulsification properties are utilised for structure and texture, especially in comminuted meat products.

Table 4 Usage of milk powders in meat and fish

Dairy Powder	Typical Usage level (%w/w)
SMP	Bologna (4.2), corned beef (12.1), salami (4.5), meat loaf (5.0), roast beef loaf (9.4)

(Reference Chandan and USDEC 2007d)

The proteins in milk powders can act as oil/water interfaces to form and stabilise emulsions. The lecithin present in milkfat also helps in stabilising emulsions. Undenatured milk proteins in the powders are able to form rigid, heat-induced gels that hold water and fat and help to provide structural support to meat products. Milkfat present in some powders can act as a carrier for fat-soluble ingredients, spices and herbs. The low melting point of milkfat also ensures complete flavour release (USDEC, 2007d).

SMP has been used to emulsify fish oil prior to microencapsulation and spray drying into fish-oil containing powders (Augustin et al. 2006). Milk powders have also been used to enhance the textural properties of meat batters (Barbut, 2006), while SMP has been shown to affect the yield and sensory quality of cooked sausages (Ellekjaer et al. 1996). SMP has also been shown to improve the yield, emulsion stability, appearance, colour, flavour, texture and overall acceptability of chicken patties (Girish et al. 2004) and cooked turkey breast meat (Haines, 2004).

6.6 Sauces and Soups

Milk powders contribute to the viscosity of soups and sauces and SMP, FCMP and BMP all contribute to soups and sauces by enhancing emulsification, water binding and flavour development. Structure and formation can be enhanced by the gelation capacity of SMP and FCMP.

SMP, in particular, is often used in sauces to modify viscosity and texture. This increase in viscosity and improvement in texture can be enhanced by increasing the amount of powder in the soup formulation or by using powder with a higher protein content. (Muir et al.1991a). SMP has also been shown to be Suitable for incorporation into cream of tomato soup. In this application, however, the effect of changing powder protein content and heat classification appears to have no effect on the texture and viscosity of cream of tomato soup (Muir et al. 1991b). SMP is also used in soup formulations for the elderly for its nutritional properties (Arhontaki et al. 1991).

Table 5 Usage of milk powders in soups and sauces

Dairy powder	Typical usage level (%w/w)
SMP	Soups (5.5 – 8.0),
FCMP	Sauces (7.6 – 10.0)

(Reference Chandan and USDEC 2007f)

6.7 Desserts

Milk powders are useful for their foaming properties in frozen desserts, whipped toppings, meringues and mousses.

SMP improves the foam structure and texture in cakes (USDEC, 2007c), while the foaming and emulsification capacity of FCMP and BMP are also used to advantage in desserts. The bland flavour of SMP enables the natural flavour of products to come through, and Maillard browning products add flavour to custards, puddings and crème caramels.

The acidification of milk is an integral step in the manufacture of many processed dairy products such as yogurts, acidified dairy desserts and sour creams. As pH is reduced, the milk develops viscosity. Acidification under quiescent conditions yields a set gel. A range of textures in milk products may be obtained depending on the nature of the acidifying agent, the final pH and the milk ingredients used. Generally, the acidifying agent is added to the milk during the manufacture of the dairy product. However, there are opportunities to provide food manufacturers with acidified powders. An example of this is yogurt powders, where cultured milk is dried. The use of a chemical acidulant, glucono-delta-lactone (GDL), for the production of acidified skim milk powders (which thicken or gel upon reconstitution depending upon the amount of heat applied) and the effect on functional properties has been reported (Clarke and Augustin, 2000). Milk powder also contributes to the gel strength of desserts (Verbeken et al. 2006). The rate of incorporation in desserts varies greatly depending on the formulation and can be anywhere from less than 1% to upwards of 10% where the product is closer to a traditional dairy dessert.

6.8 Beverages

Milk powders are used in beverages where they enhance mouthfeel by affecting texture and viscosity. Milk powders are also used in a variety of beverages to enhance nutritional attributes as they are a source of high quality protein, with the amino acids being readily digestible and bioavailable. Milk powders are also high in calcium and soluble vitamins and can therefore be used to fortify beverages.

Milk powders can assist in the formation of foams which is an important attribute in beverages such as nutritional shakes. As dairy protein concentration increases, foams become denser with more uniform air bubbles and a finer texture. Examples of beverages that contain milk powders include, meal-replacement type beverages, chocolate drinks and infant formula mixes (USDEC, 2007e). SMP and FCMP are typically used at levels from 5 – 10% in these applications.

The use of nano technology is now showing very promising signs of enabling the creation of milk based ingredients that can be added to clear beverages. These ingredients enhance the nutritional value of the beverage without causing a deterioration of clarity.

6.9 Infant Formula

In general, infant formulas, in comparison to cow's milk, contain a lower level of sodium, lower protein, increased lactose and vitamin levels and a specific casein: whey protein ratio and calcium: phosphorus ratio and modification of the fat to simulate the fatty acid profile of human milk.

Milk powders provide a sound nutritional base for infant formulas, including providing a good source of nutritional elements such as Ca, Cu, Fe, K, Mg, Mn, Na, P and Zn. In general, the bioavailability of these nutritional elements in milk powders and infant formulas are high. FCMP also contains several water-soluble vitamins (e.g. thiamine, riboflavin, niacinamide, pyridoxal, ascorbic acid, choline. inositol, biotin, pantothenate, folate and vitamin B12) as well as fat-soluble vitamins (e.g. A, E and beta-carotene).

6.10 Conclusion

The traditional milk powders SMP, FCMP and BMP continue to be used in a range of non dairy applications despite the emergence of an ever increasing range of specialised dairy based and non dairy based ingredients. These traditional powders have a strong appeal in the market place and are often preferred because of their traditional and accepted usage in food. The use of SMP, FCMP and BMP and the specific type of each of these is usually dictated by the functionality they are required to perform in the end formulation and application. The functionalities exhibited include water binding, flavour, nutritional enhancement, emulsification, browning and texture modification. Examples of the applications and functionality include bakery (water binding, emulsifying, foaming, whipping and gelling), confectionery (water binding, foaming, viscosity, colour and emulsification) and smallgoods (gelation, water binding and emulsifying). These functionalities are induced and enhanced during the manufacture of the powders and are tailored to the end use with the heat treatment applied to the liquid milk prior to concentration and drying of the powder having the most influence with powders often being classified according to this treatment. With the ability to tailor make and further refine the attributes of these products it is envisaged that SMP, FCMP and BMP will continue to be a favoured ingredient in non dairy applications well into the future.

FAQ

1. *Is there a standardised way of describing the flavour components of skim milk powder?*
   standardized descriptive language for skim milk powder and dried dairy ingredients has been developed. The lexicon was initially identified from a large sample set of dried dairy ingredients. Twenty-one descriptors were identified for dried dairy ingredients. Seventeen flavours and tastes have been identified in SMP's with nine flavours/tastes observed in all SMP's (Drake et al. 2003).

2. *How does the fat component of milk products enhance a confectionery and bakery product?*
   In confectionery the fat component of milk powders helps prevent stickiness in high sugar environments such as caramel & toffee. It also has a unique flavour profile and acts as a carrier for oil soluble flavours especially for cream centres. Fat is highly compatible with cocoa butter and helps to minimises fat bloom in many products. Cream powders are a substitute for fat as a stand alone product.

   Whereas in bakery the fat adds an appealing colour, contributes to a rich flavour, can act as a carrier of fat solubles and enhance the structure to cakes, pie crusts and pastries.

3. *Is there one single factor that determines the suitability of milk powders for chocolate manufacture?*
There is no one single factor that determines the suitability of a milk powder for the manufacture of chocolate. There is a complex interplay between both the composition (fat content in particular) and the physical attributes (particle size, free fat, state of the lactose etc) of the powder.

4. *What is the composition (%) of dried dairy ingredients used in chocolate?*
Table 6 Composition of dairy based ingredients used in chocolate manufacture.

Product	Water	Protein	Fat	Lactose	Mineral
FCMP	2.7	26.5	27.4	37.7	5.7
SMP	3.0	38.2	0.9	49.6	8.2
BMP	3.3	33.2	8.4	48.0	7.2
Cream Powder	2.6	15.4	55.0	23.6	3.5
Caseinate	3.3	91.4	0.9	0.2	4.1
Whey Powder	4.6	13.0	1.1	73.0	8.2
Demin Whey Powder	4.6	14.5	1.0	76.6	3.2
Milk crumb	1.3	7.6	31.0	7.9	1.7

Range of dairy based ingredients are used in the manufacture of chocolate. Their basic composition is shown in Table 6.

5. *What are the main attributes of concentrated and dried milk when used in bakery?*
The main attributes of dried milks when used in bakery include, an increase in nutritive value, enhanced water binding and mach inability, a contribution to browning and colour, the formation of dense / fine air bubbles, a subtle pleasant flavour and formation and stability of emulsions

6. *Water absorption is often a priority in selecting an ingredient – what is the water holding capacity of dried milk products?*
The water absorption capacity of dairy ingredients in applications varies widely mainly depending on the type and amount of the protein present. Table 7 gives an indicative amount of water absorption for several milk powders.

Table 7 Water absorption capacity for various milk ingredients.

Product	g water/g ingredient
Skim Milk Powder	0.96 – 1.28
Sodium Caseinate	2.95
Calcium Caseinate	1.59
Lactic Casein	0.97 – 1.28
Lactalbumin	0.96

7. *What are the foaming properties of milk products dependent on and what factors affect the foaming of milk in applications?*
The foaming properties are dependent on the ability of surfactant (the proteins) to lower the surface tension and then to stabilize the foam after its formation.
Factors affecting foaming of milk include, milk composition (protein and fat level in particular), pH and mineral balance, fat (quality), temperature and others (e.g. low molecular weight surfactants)

8. *Is there a simple guide to the use of SMP, FCMP and BMP in applications according to desired functionality?*

Table 8 General guide to powder use and functional property.

Application	Powder and Heat Treatment	Desirable Functional Attributes
	BAKERY	
In general	SMP, FCMP, & BMP with medium to high heat	Water binding, emulsifying, foaming, whipping and gelling
Bread	SMP with high heat	Water binding, emulsifying, foaming and gelling
	CONFECTIONERY	
In general	SMP & BMP with medium to high heat	Water binding, whipping, foaming, viscosity, colour development and emulsifying
Chocolate	FCMP and BMP with high heat	High "free fat", flavour and viscosity
	SMALLGOODS	
In general	SMP with low to medium heat	Gelation, water binding and emulsifying
	HEALTH FOODS	
In general	SMP, FCMP and BMP with low heat	Nutritional, water binding and emulsifying

Table 8 provides a general guide to the use of SMP, FCMP and BMP in non dairy applications. The exact attribute required will change depending on the product but the general principle will apply.

9. *What is the best method for the manufacture of FCMP for use in chocolate manufacture?*

Chocolate is traditionally made from roller dried milk powders because of the high degree of free fat they contained (>90%) and because of their enriched flavour due to the intense heat they were subject to. However, modern methods are now available where spray dried FCMP can be tailor made by being manufactured with relatively high levels of free fat (>40% consistently), enriched caramelised flavour, and other special requirements important for chocolate manufacture such as particular powder morphologies. Care must be taken with these powders as the high amount of free fat makes them susceptible to oxidation and they therefore have a shorter shelf life.

Glossary

Atomisation

This is the formation of a spray or mist of the feed concentrate into the spray dryer to enable intimate contact with the drying air in the main chamber

BMP

Butter Milk Powder is the dried form of the liquid by-product from the manufacture of butter, which is expelled during the churning phase of the process.

Bulk Density

Bulk Density (BD) is a measure of the weight of powder that can be contained in a prescribed volume (weight of a volume unit of powder) and is usually expressed as g/cm3 (or sometimes kg/m^3).

Dispersibility
Dispersibility is the overall expression of the instant characteristics of dried milk. It is affected by wettability, sinkability and solubility.

Emulsifiers
Assist in the formation and maintenance of stable emulsions in many applications. Many dairy ingredients also possess emulsion capability.

Emulsion Capacity
Is a measurement of an ingredient, including dairy based, to exhibit emulsion enhancing characteristics.

Fat Bloom
It is a defect in chocolate where the surface appears to shine.

Flowability
This is the ability of a powder to freely flow when placed on an incline or during transportation within the manufacturing plant or point of application. It is of particular importance in the handling of powders.

Foaming
Is the ability of a solution to incorporate air hold on to the air in the foam; it is of particular importance in the manufacture of any product which requires air incorporation.

Free Fat
Free fat is that fat which is easily extractable from milk powders particles by a solvent under standard conditions of time, temperature and agitation.

Functionality
Is a characteristic of a powder that can be a) physical - it imparts physical and sensory properties and b) nutritional - as a source of nutrients and biological value and c) physiological - it has a biomodulating response.

Heat Classification
This is a means to distinguish milk powders that have been subjected to different heat treatments, predominantly preheating of the raw milk prior to evaporation and drying. A typical classification is low, medium and high heat.

Homogenisation
Homogenisation is a process used to reduce the size of fat globules in milk and milk products. The process usually involves passing the product through a small opening under rather high pressure. The process also induces the coating of the fat with protein if present.

Lactose Crystallisation
In milk, lactose crystallisation is the conversion of the beta-lactose, which is hygroscopic, into the non

hygroscopic alpha-form. Due to the fast water evaporation during spray drying this conversion does not take place to any great extent. However, this conversion can occur during the storage of milk powder under adverse conditions.

Lecithination

This is the use of lecithin, usually derived from soy, which has both hydrophilic and lipophilic properties and enables the wetting process during reconstitution to be enhanced.

Maillard Reaction

The Maillard reaction takes place when heat is applied to a protein/carbohydrate mixture. The most obvious result of this reaction is the enhancement of browning, both positive and negative depending on the application. Another positive outcome is the forming of Sulphhydryl (SH) groups which act as antioxidants.

Occluded Air

This is the air that is entrapped within the powder particle.

Powder Density

The powder particle density is a measure of the density of the powder solids including the occluded air. Whereas the powder solids density is the density of the solids not including any air and is a determinant of composition.

Preheat

The preheat is the heat treatment given to the raw milk during powder manufacture prior to evaporation and drying. This heat treatment determines many of the resultant powder functionalities.

Scorched Particles

Insoluble particles in the powder that are usually caused by heat damage during powder manufacture.

Sediment

Is the film or individual particles that gather at the bottom of liquid dairy products or container usually upon storage or when first reconstituted for further use.

Water Binding

Water binding is a functional attribute whereby milk solids, particularly proteins, can bind water to increase texture, viscosity or form gels.

Wettability

Wettability is a measurer of the ability of a powder to penetrate the surface of water at a given temperature.

Whey Protein Nitrogen Index

This is a measure of the degree of heat treatment given during powder manufacture and is used to classify powders according to heat treatment as low, medium or high heat. The classification, however, has very limited value as a method for prediction of functional properties.

References

Aguilar, C.A. and Ziegler, G.R. (1994) Physical and Microscopic Characterization of Dry Whole Milk with Altered Lactose Content .1. Effect of Lactose Concentration. Journal of Dairy Science 77, 1189-1197.

Aguilar, C.A. and Ziegler, G.R. (1995) Viscosity of Molten Milk Chocolate with Lactose from Spray-Dried Whole-Milk Powders. Journal of Food Science 60, 120-124.

Arhontaki, J., Gomes, J.C., Coelho, D.T., Rosa, G.P. and Chaves, J.B.P. (1991) Nutritional and Sensory Evaluation of Food Formulas for the Elderly. Arquivos De Biologia E Tecnologia 34, 125-145.

Attaie, H., Breitschuh, B., Braun, P. and Windhab, E.J. (2003) The Functionality of Milk Powder and Its Relationship to Chocolate Mass Processing, in Particular the Effect of Milk Powder Manufacturing and Composition on the Physical Properties of Chocolate Masses. International Journal of Food Science and Technology 38, 325-335.

Augustin, M.A., Sanguansri, L. and Bode, O. (2006) Maillard Reaction Products as Encapsulants for Fish Oil Powders. Journal of Food Science 71, E25-E32

Barbut, S. (2006) Effects of Caseinate, Whey and Milk Powders on the Texture and Microstructure of Emulsified Chicken Meat Batters. Lwt-Food Science and Technology 39, 660-664.

Bolenz, S., Thiessenhusen, T. and Schape, R. (2003) Influence of Milk Components on Properties and Consumer Acceptance of Milk Chocolate. European Food Research and Technology 216, 28-33.

Campbell, L.B. and Pavlasek, S.J. (1987) Dairy Products as Ingredients in Chocolate and Confections. Food Technology October, 78-85.

Caudle, A.D., Yoon, Y. and Drake, M. (2005) Influence of Flavor Variability in Skim Milk Powder on Consumer Acceptability of Ingredient Applications. Journal of Food Science 70, S427-S431

Chandan, R. (1997) Dairy Based Ingredients. Egan Press handbook Series. ISBN 0-913250-94-5

Clarke, P.T. and Augustin, M.A. (2000) Acidified Skim Milk Powders. Australian Journal of Dairy Technology 55, 102

Clarke, P.T. and Augustin, M.A. (2005) Manipulation of Solvent-Extractable Fat Content of Milk Powders. Lait 85, 261-268.

Dewettinck, K., Demoor, H. and Huyghebaert, A. (1996) The Free Fat Content of Dried Milk Products and Flow Properties of Milk Chocolate. Milchwissenschaft-Milk Science International 51, 25-28.

Drake, M.A., Karagul-Yuceer, Y., Cadwallader, K.R., Civille, G.V. and Tong, P.S. (2003) Determination of the Sensory Attributes of Dried Milk Powders and Dairy Ingredients. Journal of Sensory Studies 18, 199-216.

Ellekjaer, M.R., Naes, T. and Baardseth, P. (1996) Milk Proteins Affect Yield and Sensory Quality of Cooked Sausages. Journal of Food Science 61, 660-666.

Fitzpatrick, J., Barry, K., Delaney, C. and Keogh, K. (2005) Assessment of the Flowability of Spray-Dried Milk Powders for Chocolate Manufacture. Lait 85, 269-277.

Girish, P.S., Sanyal, M.K., Anjaneyulu, A.S.R., Keshari, R.C. and Naganath, M. (2004) Quality of Chicken Patties Incorporated With Different Milk Proteins. Journal of Food Science and Technology-Mysore 41, 511-515.

Haines, B. (2004) New Directions in Dairy. Prepared Foods January, 97-104.

Kelly, P.M. (2006) Innovation in Milk Powder Technology. International Journal of Dairy Technology 59, 70-75.

Keogh, K., Murray, C., Kelly, J. and O'Kennedy, B. (2004) Effect of the Particle Size of Spray-Dried Milk Powder on Some Properties of Chocolate. Lait 84, 375-384.

Keogh, M.K., Murray, C.A. and O'Kennedy, B.T. (2003) Affects of Selected Properties of Ultrafiltered Spray-Dried Milk Powders on Some Properties of Chocolate. International Dairy Journal 13, 719-726.

Koc, A.B., Heinemann, P.H. and Ziegler, G.R. (2003) A Process for Increasing the Free Fat Content of Spray-Dried Whole Milk Powder. Journal of Food Science 68, 210-216.

Liang, B. and Hartel, R.W. (2004) Effects of Milk Powders in Milk Chocolate. Journal of Dairy Science 87, 20-31.

Muir, D.D., Hunter, E.A. and West, I.G. (1991a) Optimization of the Properties of Dried Skim Milk for Use in White Sauce Suitable for Use With Frozen Products. Journal of the Society of Dairy Technology 44, 20-23.

Muir, D.D., Hunter, E.A. and West, I.G. (1991b) Skim Milk Powder for Use in Cream of Tomato Soup. Journal of the Society of Dairy Technology 44, 52-54.

Twomey, M., Keogh, M.K., O'Kennedy, B.T., Auty, M. and Mulvihill, D.M. (2000) Effect of Milk Composition on Selected Properties of Spray-Dried High-Fat and Skim-Milk Powders. Irish Journal of Agricultural and Food Research 39, 79-94.

Twomey, M., Keogh, M.K., O'Kennedy, B.T. and Mulvihill, D.M. (2002) Seasonal Effects of Some Milk Powder Characteristics on the Rheology of Milk Chocolate. Irish Journal of Agricultural and Food Research 41, 105-116.

USDEC (2007a) Confectionery Applications For Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007b) Definitions, Composition and Applications. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007c) Functional Properties and Performance of Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007d) Meat Applications for Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007e) Nutritional Beverage Applications For Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007f) Prepared Food Applications For Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

USDEC (2007g) Bakery Applications For Milk Powders. Reference Manual for U.S. Milk Powders http://www.usdec.org Accessed September 18, 2007.

Verbeken, D., Bael, K., Thas, O. and Dewettinck, K. (2006) Interactions Between Kappa-Carrageenan, Milk Proteins and Modified Starch in Sterilized Dairy Desserts. International Dairy Journal 16, 482-488.

Walshe, M.K. (1994) Vital Ingredients. Food Technology in New Zealand February, 22-26.

DAIRYAUSTRALIA
Delivering for the dairy industry

7

Cheese

Content

150 7.1 Introduction to Cheese and Cheese Manufacture

152 7.2 Natural Cheese Types and Their Applications

158 7.3 Processed Cheese

160 7.4 Grading of Cheese

161 7.5 Nutritional Value of Cheese

162 7.6 Cooking and Heating Cheese

163 7.7 Cheese Packaging

163 7.8 Cheese Storage

164 FAQ

172 Glossary

7.1 Introduction to Cheese and Cheese Manufacture

7.1.1 What is Cheese- a Definition?

It is difficult to define cheese as there are so many different types and styles of cheese. However the following statements should help. Cheese is a concentrated and preserved form of milk. Most cheeses are made using an enzyme (rennet) to coagulate the milk. Most, but not all cheese is made using fermentation from bacterial starter cultures. The preservation of the cheese is assisted by one or more of the following; acidification, salting, dehydration, packaging, heating and refrigeration.

7.1.2 Basic Steps in Cheesemaking

Milk Storage	Milk is stored at 4 °C when received at the cheese factory. It is made into cheese within 24 hours.
Milk Standardisation	One of the aims of standardising milk for cheesemaking is to adjust the composition of the milk so that there is enough fat in relation to solids-not-fat to produce cheese which complies with the specifications for fat-in-dry matter (FDM).
Milk Pasteurisation 72 °C x 15 Seconds	Pasteurisation is defined as a heat treatment in which the combination of the temperature and the time for which it is maintained is sufficient to destroy pathogenic (disease-producing) organisms.
Addition of Starter Cultures	Bacteria used in cheesemaking are usually called cheese starters and are used to convert lactose to lactic acid and to produce desirable flavour and texture characteristics in the mature cheese.
Enzyme Addition and Coagulation of Milk	There are two means to coagulate milk, enzymic and acidic. As a general rule all semi hard to hard cheeses use enzymic coagulation whilst most soft and fresh cheeses use acid coagulation to produce what is known as an acid curd
Removal of Moisture (Syneresis)	Moisture is removed from the curd by cutting it into small pieces. After cutting, the curd and whey are heated thereby firming the curd particles while stirring the curd in the whey. The whey is then drained off the curd.
Whey Removal	When the curd has attained the desired level of firmness and acidity, the curds and whey are separated, usually by whey removal.
Texturing of Curd	The handling of curd after the removal of whey determines the final body and texture characteristics of the cheese. For example in Cheddar cheesemaking the cheese curd is turned to encourage matting or Cheddaring whereas in Mozzarella the curd is diced then placed into hot water where it is stretched before moulding into shape.

Milling of Curd	The curd is cut into small pieces approximately 1 cm x 1cm x 15 cm. This increases the curd surface area to facilitate salting.
Salting	The salt may be added directly to the curd or indirectly by placing the pressed cheese in a brine (salt) bath. The addition of salt slows down the acid production thereby limiting the production of lactic acid. The salt also contributes to the final flavour.
Moulding, Pressing or Hooping the Curd	Pressing gives the cheese its final shape. It may take place using the curd's own weight or by using external or vacuum pressure such as presses or block forming towers.
Moulding, Pressing or Hooping the Curd	During maturing, the fat and protein in cheese curd breaks down to develop the body and texture and flavour characteristics. The times and temperature of storage need to be chosen carefully to allow the cheese to mature. The rate of maturing can be accelerated or slowed down for many cheeses by changing the temperature of storage.

7.1.3 Types of Cheese

It is possible to classify the many different cheese varieties into much smaller numbers of cheese types. There are several ways of doing this, such as by the source of milk, cow's milk, goat's milk or sheep's milk.

A second method is to classify cheese by the milk fat content of the milk used: full fat, such as Cheddar, part skim, such as Edam and Parmesan, and skim milk such as Cottage cheese. There are others to which extra cream has been added: Cream cheese is the most familiar, Double Cream Brie and Triple Cream Camembert are other examples.

Yet another classification method is by method of ripening: interior ripened (mainly by bacteria), or surface ripened (mainly by moulds). Another classification is by firmness: Very Hard, Hard, Semi-hard and Soft.

The simplest classification is classifies cheese as either natural or processed cheese.

The following tables show the basic composition and description of the main Australian cheese varieties.

Natural Cheeses

Cheddar Cheese		
Type	% Moisture	% Fat
Natural cheddar	35-38	33-34
Reduced fat cheddar	40	25
Low fat cheddar	55	7

Hard Grating Cheese		
Type	% Moisture	% Fat
Romano	35	24-25
Parmesan	32	23-24
Stretched Curd Cheeses		
Type	% Moisture	% Fat
Mozzarella	46-50	40-45
Pizza cheese	44-46	35-39
Eye Cheese Types		
Type	% Moisture	% Fat
Gouda	39-45	26-30
Swiss	39	26-28
Fresh Unripened Cheese		
Type	% Moisture	% Fat
Cream cheese	45	35
Fetta	54	20
Mould and Surface Ripened Cheeses		
Type	% Moisture	% Fat
Camembert and brie	50-52	25
Blue vein several styles	42-50	25-30
Washed rind cheese	48-50	24-26

7.2 Natural Cheese Types and Their Applications

7.2.1 Fresh Unripened Cheese

Cream cheese has a creamy texture and slightly sour flavour, cream cheese makes an excellent ingredient cheese. Fetta is a cheese which has a salty and acidic flavour and white crumbly body. Reduced salt versions are available.

Types of cheese

- Cream cheese
- Ricotta cheese
- Fetta cheese
- Cottage cheese

Comments

Best used in cold dishes or stirred into a heated dish at the last moment, as their high moisture content means they will loose body and texture when heated.

Ricotta and block cream cheese can be baked, Fetta can be grilled with the exception of Fetta, Fresh unripened cheeses can be used as an ingredient in both sweet and savoury recipes.

Fetta Cheese in block and cubes

Applications

- Cheesecakes (Cream cheese)
- Salads (Fetta)
- Gelatine-based desserts (Cream cheese)
- Dips (Cream cheese, Cottage cheese)
- Processed cheese (Cream cheese)
- Pastries (Ricotta)


Ricotta cheese

7.2.2 White Mould Cheese

Australian white mould cheeses are produced using white penicillium moulds. The mould plays an important role in changing the flavour softening the body of the cheese. The ripening process starts from the surface and progresses to the centre as the cheese matures. The cheese is ready for eating when it is soft to the touch, with the interior of the cheese a uniform creamy golden colour and an almost flowing consistency. The edible rind associated with surface ripened cheese adds to the flavour of the cheese.


Brie cheese

Types of cheese

- Camembert
- Brie
- Triple cream


Camembert cheese

Comments

Camembert and Brie may be grilled or baked but also deep-fried. They can be added to sauces if the rind is removed first, as it can affect the texture of the cooked recipe.

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Crumbed and deep-fried
- Warmed in sandwiches, rolls and baguettes
- On gourmet pizza
- In sauces over pasta and gnocchi
- In salads

7.2.3 Semi Hard Cheese

As distinct from processed cheddar, natural cheddar is a firm textured cheese, light yellow in colour with a delicate to full rich flavour depending on age of the cheese. Reduced fat cheddar has approximately 25% less fat than normal cheddar. The texture is slightly firmer and more elastic. Low fat cheddar has a tougher body and does not have a typical cheddar flavour.

Types of cheese

- Cheddar
- Goshred
- Gouda
- Edam
- Red Leicester

Comments

These cheeses have excellent melting, grilling and baking qualities.

Applications

- Cheddar is the most used ingredient for processed cheese
- Eat natural with bread, dry biscuits and other compatible food
- Grated cheese for cooking can be frozen, however it will become dry and crumbly
- Shave over soups and roasted vegetables
- Grill on toast, pasta bakes
- Stir mild cheddar through sauces

7.2.4 Eye Cheese

Gouda cheese is made in 2 styles, rinded and rindless. The rinded traditional form has higher moisture than the rindless form which is usually made in mechanised Cheddar plants.

Swiss cheese contains large holes known as eyes. The flavour is sweet and nutty as a result of the addition of Propionibacterium bacteria species.

Types of cheese

- Gruyere
- Emmenthaler
- Edam
- Gouda

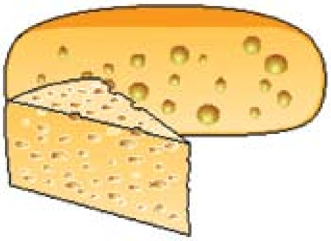
Comments

These are the perfect melting cheeses - their supple texture becomes stretchy when cooked. Care must be taken to ensure the cheese used is not too young or too dry or meting qualities are affected.

Gouda cheese

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Try grated, grilled, sliced, melted and baked
- Use for sauces or when a smooth flowing consistency is required
- Sliced in sandwiches, hamburgers or focaccias
- Grate into soups, fondue and tarts
- Bake onto roasted vegetables



Swiss style cheese

7.2.5 Hard Cheese

Australian hard grating cheeses have a firm body with mild or strong flavour depending on their age. Hard grating cheeses are often fully matured. The relatively low moisture content extends the cheeses storage life.


Parmesan cheese

Types of cheese

- Pecorino
- Parmesan
- Romano
- Pepato

Comments

These cheeses will melt completely with other ingredients to add taste and texture, with great depth of flavour. If aged cheeses are used, small quantities can be used because of their much stronger flavour. They have good grating properties.

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Shave on pizzas
- Grate into soup
- Combine with breadcrumbs as a crumbing base
- Stir through risotto
- Shave into salads or over vegetables
- Add to sauces

7.2.6 Blue Cheese

Australian blue veined cheeses are characterised by a network of green-blue veins of mould throughout the body of the cheese. Several Australian blue veined cheeses are unique to Australia, but others are made in the style of many classic European blue cheeses. The characteristic lines or veins are produced by piercing with fine stainless steel rods to allow air into the cheese, thus encouraging the internal growth of blue mould.


Two different blue veined cheese

Types of cheese

- Gorgonzola styles
- Blue vein
- Blue brie

Comments

These cheeses can be melted and baked. It is important to ensure they are cooked with complementary flavours as they can overpower other foods. Small quantities should be used. White wine, cream or butter can be added to the recipe to soften the sometimes pungent characteristics of blue cheese and lessen the possibility of the blue cheese dominating the flavour.

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Crumble onto salads
- Stir into bechamel sauce
- Mix with chicken mince as a filling for tortellini
- Add to quiche
- Stir into soups
- Serve on pasta, particularly gnocchi

7.2.7 Stretched Curd Cheese

These cheeses are produced by working the curd to a dough-like mass in hot water so that it may be pulled and stretched. At this stage it is soft and semi-fluid. It is then extruded into moulding machines for individual cheese shape and uniform weight control. In the making, the heat of the curd helps expel moisture and produces a smooth, stringy, closed texture in the finished cheese. Individual cheese shapes are retained by placing the shaped cheeses in cold water to set.

Pizza cheese during the stretching process of manufacture

Types of cheese

- Mozzarella
- Bocconcini
- Haloumi

Comments

Stretched Cheeses melt very well, but are best cooked quickly at higher temperatures.

Can also be grilled, baked and melted in sauces. Grate or slice for use. Grated Cheese can be frozen and used only for cooking.

Haloumi is often dry and highly salted, this style should be cooked to improve its eating quality.

Mozzarella – best served cooked due to melting benefits and relatively mild taste.

Soft moist Mozzarella

Applications

- Pan fry haloumi
- Mozzarella is used for toasted sandwiches, foccacia
- Mozzarella is used for pizza

7.2.8 Shredded and Grated Cheese

What is shredded cheese?

Shredded cheese is cheese which has been cut up into small pieces to enhance the application of the cheese.

Why is cheese shredded?

Cheese is sometimes shredded or grated for the convenience of the consumer. This saves the consumer time and effort and allows more time for other activities.

Which types of cheese are best for grating and shredding?

Typically very hard cheeses with low moisture contents are grated whilst semi hard cheeses are shredded. These cheeses have good keeping qualities.

The best cheeses for grating are:

- Parmesan
- Romano
- Aged Pecorino

The best types of cheese for shredding are:

- Cheddar and cheddar types
- Mozzarella
- Gouda
- Goshred (a natural cheese suitable for shredding to be used for pizza topping and bakery applications.)

Are additives used to prevent the cheese sticking together?

It is a common practice to add anti-caking agents to these cheeses to provide improved flowability as well as preventing the shreds from sticking together. This allows them to remain as discrete particles and flow easily from the pack when dispensed.

Uniform size pieces are desired. Pack weights are more easily controlled and packaging and manufacturing processes can be operated at higher efficiencies.

What are the typical applications for these cheeses?

Grated cheese is convenient to use for sprinkling on foods such as pasta, salads and for cooking in casserole dishes. Grated cheese is also used to flavour to soups and sauces. A small quantity of cheese will provide enough flavour.

Shredded cheese is popular in cheese sauces, on tacos, baked potatoes, in sandwiches and as pizza topping.

7.2.9 Cheese Powder

Another popular cheese product is cheese powder that is used in snack food manufacture and as a flavour in a variety of food manufacture. It is produced, by liquefying the cheese and then spray drying it. This is done in a normal processed cheese kettle. The addition of emulsifiers to maintain the homogeneity of the liquid is required. The cheese must be minced into a smooth paste before heating and emulsifier (phosphates and citrates) addition. Water should also be added to the mix

as most cheeses solids levels are too high to enable them to become a flowable liquid. The solids content of the mix is approximately 32-35%. Its temperature must be maintained above 75°C to reduce its viscosity.
A standard spray drier with a cooling fluid bed for production of milk powders may be used.

Cheese powder applications
Cheese powder is used in snacks, dips, dressings, crackers, corn and potato chips and soups.

7.3 Processed Cheese

The Australian definition of processed cheese is "a product manufactured from cheese and products obtained from milk, which is heated and melted, with or without added emulsifying salts, to form a homogeneous mass".

The aims of processing cheese are to produce a cheese that has an extended shelf life and to reduce the need for refrigeration during transport and storage.

Cheddar is the basis of most processed cheeses. A blend of cheeses is selected, comprising of young, semi-matured and matured cheese. The cheeses are shredded, mixed and heated with vigorous stirring in the presence of emulsifying salts. This results in the formation of a thick homogeneous liquid. This liquid is pasteurised and pumped to machines for packaging.

Steam is injected into the mass of cheese to achieve the heating, or pasteurisation. This means that the moisture level of processed cheese increases as the steam condenses in the cheese. For this reason, processed cheese is permitted to contain more water than the unprocessed cheese.

The addition of certain salts, such as sodium citrate or sodium phosphate, to heated cheese assists emulsification. These are therefore called emulsifying salts. Emulsifying salts act in three ways:

- by increasing the pH, thus making the cheese less acidic and easier to disperse
- by forming insoluble calcium salts and thus removing calcium from the protein system
- by dispersing the protein gel that forms

The use of emulsifying salts in the production of processed cheese is essential. Without these salts the processed cheese would be unsuitable for cooking and sauce making.

The variety of processed cheese products available includes sliceable blocks, individually wrapped slices, unwrapped slices, spreads, sticks and dips. These may have various flavours and can be presented in various packages both rigid and flexible.

Processed cheese slices require refrigeration from the time of production.
Processed cheese is not a gourmet item but it is excellent food available in a range of styles and is suitable for many cooking applications.
Processed cheese spread is similar to processed cheese except that a stabiliser and water are added. There are also two types of cheese. Those that are packed in aluminium foil and have a firmer consistency and those that packed in cups, jars and tubes with a softer creamier texture. They

are typically sold unrefrigerated. The soft consistency makes it easy to spread with a knife at room temperature.

Processed cheese food should contain a minimum of 51% cheese. Processed cheese food is the product prepared by mixing and heating together one or more than one variety of cheese, with or without the addition of other constituents of milk (cream, milk, skim milk, buttermilk, and/or cheese whey), other foods, flavouring or condiments or a mixture of two or more of them.

After heating, processed cheese intended for spreading undergoes a creaming step, which includes mechanical kneading of the hot cheese and addition of various dairy products and other additives. Other processed cheese products include cold-packed cheese, cold-packed cheese food, and reduced fat cheeses. All processed cheeses may be enhanced with salt, artificial colourings, spices or flavourings, fruits, vegetables, and meats.

7.3.1 Processed Cheese Processing Steps

Cheese Selection

Processed cheese is made by using a blend of natural cheeses of differing origins, maturity levels and ages.

- **Immature cheese**
- **Mature cheese**
- **Extra mature cheese**

Cheese Selection

The cheese is cut into small portions then mincers are used to grind the cheese into very fine particles.

- **Water**
- **Emulsifying salts**
- **Other additions, could include, whey skim milk powder, colourings, flavourings, nisin, salt**

Blending of All Ingredients

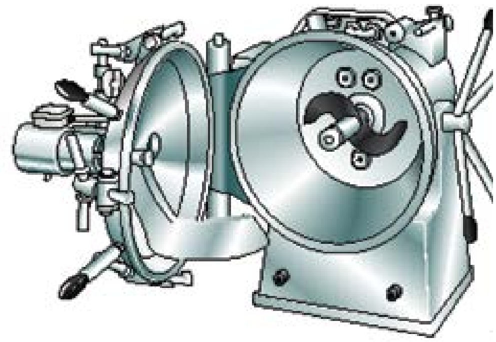
Melting and Cooking

The cooking period takes 5-8 minutes with temperatures of 85-90°C. Higher temperature processing is also used.

Packaging, Cooling and Storage

Typically processed slices are cooled rapidly to refrigeration temperature whereas block and long life products are cooled slowly.

Batch cooker for processed cheese



Cooker open and tilted for emptying

Pictures courtesy: Tetra Laval Handbook.

7.3.2 Processed Cheese Types

Processed cheese has a few basic types but many variations exist within each type.
There are two different types of processed cheese slices. Firstly the slices with a high remelting properties and others for normal consumption that do not require melting. The high remelt slices are typically used in hamburgers and must be able to melt during heating. The second type is not required to melt and is most often used in sandwiches. This type has higher moisture content and is usually in individual wrapped.

Type	% Moisture	% Fat	Description and Characteristics
Processed cheese block or sliceable	45	26	This is the oldest type of processed cheese. The cheese is relatively firm and can be cut without losing elasticity. The flavour varies according to the customer requirements.
Processed cheese slices, individually wrapped. (IWS)	50	23-26	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly.
Reduced fat cheese slices	55	15-16	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly.
Processed cheese slices. (non IWS)	45	27	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly.
Processed cheese spread	55-60	20	The texture of the spread is smooth and creamy. Flavour may vary according to customer requirements.
Processed cream cheese spread	52	31	The texture of the spread is smooth and creamy. Flavour is creamier and has less cheese flavour.

7.4 Grading of Cheese

The purpose of grading is to provide a standardised assessment of cheese quality in terms of flavour, body, texture and condition. This assessment can be used as a basis for payment, and as a guide to the disposal of the cheese.

The grading system described here is used for Australian cheeses for export. This system is based on the allocation of points totalling 100 for the various important characteristics.
The grades are as follows:

- Choicest Quality 93 points or more
- First Quality 90-92 points
- Second Quality 88-89 points

The scoring points are allocated as follows:

- Flavour and aroma maximum 50 points
- Body and texture maximum 30 points
- Colour and condition maximum 20 points

Body refers to the degree of hardness, resilience, and cohesion of the cheese.
Texture refers to the presence or absence of openings, cracks, gas holes, etc.

The typical grading process for cheddar is as follows:

- A representative sample of the batch is taken and brought to between 10°C and 14°C. Typically this is a 20kg block.
- A smaller sample (a plug) of the block is extracted by using a cheese trier.
- The subsample is inspected for aroma and then visually inspected for colour.
- The cheese is plug is bent to assist the evaluation of body.
- A small portion is broken off and worked up between the thumb and fingers, to complete the evaluation of the body.
- A small piece is the tasted for evaluation of flavour


A plug of cheddar about to be evaluated.

7.5 Nutritional Value of Cheese

In comparison to many other foods cheese is a good source of energy, but its greatest value is as a source of protein. Cheese contains more protein than other high protein foods such as meat, fish and eggs.

In most cheeses the protein is nearly all casein, because the lactalbumin and lactoglobulin, two water soluble proteins present in milk, are drained off in the whey. Casein is a complete protein and supplies all of the essential amino acids.

The vitamin content is also variable. When cheese is made from whole milk, the fat-soluble vitamins in the milk are retained in the cheese, but most of the B group vitamins which are water-soluble are lost. However, since cheese is concentrated it may still be a useful source of B vitamins. During the cheesemaking process the starter and other bacteria which grow within the cheese produce and use the B group vitamins, replacing some of those lost in the whey. The extent to which this occurs and how much of the original lost vitamin B is replaced varies from cheese to cheese. However, there will nearly always be more microbially produced vitamins in mature cheese than in the younger cheese. In surface ripened cheese such as Camembert and washed rind cheese there will be more vitamins and calcium near the rind than in the centre of the cheese.

Nutritional values for selected cheeses (per 100 gm)

Cheese	Energy kJ	Protein gm	Fat (total) gm	Fat (saturated) gm	Carbohy-drates gm	Sodium mg
Blue vein	1546	20.3	32.4	20.8	0.1	1090
Cheddar	1684	25.4	33.8	21.5	0.1	655
Edam	1482	28.0	27.2	17.2	0.0	700
Feta	1170	17.8	23.3	15.3	0.3	1070
Gouda	1583	26.1	30.8	19.6	0.0	710
Haloumi	1025	21.3	17.1	11.0	1.8	2900
Mozzarella	1258	26.0	22.0	14.1	0.1	375
Parmesan	1848	38.1	32.4	20.6	0.1	1440
Romano	1568	31.3	27.9	17.7	0.2	1040
Pecorino	1486	28.0	27.2	17.3	0.2	950
Cream	1413	8.5	33.1	21.2	2.6	420
Processed,cheddar type	1386	21.4	27.5	17.4	0.3	1350
Brie	1406	19.3	29.1	18.6	0.1	605
Camembert	1291	18.6	26.3	16.9	0.1	650
Cheddar, reduced fat (25%Lessfat)	1368	28.7	23.8	15.1	0.0	720
Cheddar, reduced fat (50%Lessfat)	1106	31.3	15.5	9.9	0.0	690
Cheddar, low fat	844	33.9	7.2	4.7	0.1	660
Cottage	514	15.2	5.8	3.8	2.4	315
Ricotta	617	10.5	11.3	7.2	1.2	198

7.6 Cooking and Heating Cheese

When heat is applied to cheese, the first thing that happens is that the cheese becomes soft and appears to melt. This is due to the fat in the cheese melting. By the time the temperature reaches about 40°C all of the fat has melted into a liquid. The fat begins to leech out and become separated from the proteins of the cheese.

Upon further heating the water also separates out until you have three distinctive phases, the curds, water, and milk fat.

The milk fat may be reincorporated at about 60°C, because at this temperature, some of the proteins act as emulsifiers. Emulsifiers enable water-based substances and oil-based substances to mix and become stable, where they ordinarily would not. This stable mixture of water and oil is called an emulsion. When the proteins act as emulsifiers, they cause the water and milk fat components to remerge, preventing the separation that causes a problem in cooking. The level of stability of the cheese is dependent upon the particular variety of cheese being heated.

One of the main effects of heating cheese to higher temperatures occurs to the proteins. As the temperature rises, the proteins coagulate and toughen, and we say that they become denatured. At higher temperatures or with prolonged heating, denaturation of the protein can cause the cheese to become matted, stringy, or tough. The surface of the cheese dries out and forms a tough skin. At even higher temperatures it will char. These matted, stringy or charred cheeses cannot be used in cooking.

Water is not lost from the cheese as the temperature increases, because it forms a stable gel with the proteins.

7.7 Cheese Packaging

About 50 years ago a technique for making rindless cheese where the curd was formed in rectangular blocks was developed. After making the cheese it is vacuum sealed in a plastic bag. The result is a block of rindless cheese which was cut into consumer size units easily and with virtually no waste.

This technology was of enormous economic benefit and also brought about the easy cutting of the blocks into consumer size units which were then sealed in plastic wrappers by vacuum or gas flushing. This process keeps water in and thus prevents dehydration. It also keeps the oxygen out and thus prevents mould growth.

Provided the bags are completely sealed, the film remains undamaged and the units are kept refrigerated, these products will keep for a year or more.

Processed cheese was traditionally packed in cans, jars and cartons lined with tin foil coated with a heat sealable compound. This has been replaced by new protective coatings on metal foil. Plastics, both flexible, for processed cheese slices, and rigid for spreads and dips, have become common as a means of processed cheese packaging.

7.8 Cheese Storage

Cheddar cheese is typically stored for several months before use. The temperature of storage is between 4-8°C. Maturation of the cheese occurs faster at higher temperatures. Should higher temperatures be used it is possible for the flavour of the cheese to developed faster but the risk of undesirable flavours developing increases.

Mozzarella may be stored at <4°C if it is to be used with a few weeks but is long term storage of several months is expected it should be frozen. The high moisture of mozzarella allows for rapid proteolysis and deterioration of the temperature is too high. If brine salted Mozzarella is to be frozen then it is important that the salt be given time to diffuse throughout before freezing takes place.

FAQ

1 Milk and Manufacture

1.1 Are there certain breeds of cows that produce milk more suited for cheesemaking?

The most common cow breeds such as Friesian Jersey and Guernsey all produce milk well suited to cheesemaking. For most cheesemaking some of the milkfat has to be removed to enable cheese to be made to specification. The Friesian cows usually produce milk with lower fat content and required less or no fat removal whereas the Jersey produced higher levels of milkfat which therefore requires more fat removal before the cheesemaking process begins.

1.2 Does milk contain antibiotics and if so does the cheese also contain antibiotics?

Every tanker of milk is checked by the dairy factory for the presence of antibiotics. If the result of the test is positive then the milk is immediately discarded and never used for cheese. It is not possible to make normal cheese from milk with antibiotics because the starter cultures that perform the fermentation task will not work.

1.3 What additives are used to coagulate milk to make cheeses?

An enzyme described as a proteinase enzyme and known commercially as rennet is used to coagulate milk. There are three main types of rennet:

- Calf rennet
- Fermentation produced chymosin
- Microbial rennet

1.4 What is the source of the rennet used to make cheeses?

The use of milk clotting enzymes has been practised for centuries. Traditionally an extract of the abomasum (fourth stomach) of the unweaned or milk fed calf provided the source of the enzyme chymosin, which was used as a milk coagulant. Several enzymes including chymosin are present in rennet extract. Chymosin makes up approximately 85-95% of the enzymes with the remainder comprising mostly pepsin.

Calf rennet played an important role in world cheese production until the early 1960's when a reduction in the cow population meant less calves were available for slaughter and a reduction in the number of vells (calf stomachs) for rennet production. An increase in cheese production at this time meant that rennet substitutes were used.

A fermentation produced chymosin is also produced using yeast or fungi. This product is also known as vegetarian rennet. Other milk coagulating enzymes known as microbial rennet are sourced from fungi such as mucor mehei or form other microbial origin.

1.5 Are all cheese made using rennet and are there rennet free cheeses?

Apart from fresh cheeses such as cream cheese, mascarpone and cottage cheese all hard cheeses use rennet to coagulate the milk.

1.6 What is Fat-in-Dry Matter or FDM?

One of the aims of standardising milk for cheesemaking is to adjust the composition of the milk so that there is enough fat in relation to solids-not-fat (SNF) to produce cheese which

complies with the specifications for fat-in-dry matter (FDM).
The value is calculated from the following formula: % FDM = % fat ÷ (100 - % moisture) x 100

It is important to note that the percentage fat content of the cheese and the FDM are different. The fat content of the cheese is calculated as the fats percentage of the entire cheese whereas FDM calculates the percentage fat in the cheese solids.

1.7 Why are Australian cheeses often yellow when the same cheese type from Europe is whiter?

The origin of the yellow colour of cheese is the cow's diet. Cows eating green pastures are able to produce milkfat containing a vitamin known as beta carotene. Beta carotene is responsible for the rich yellow colour of milk fat and cheese. Beta carotene is a natural antioxidant which is responsible for vision, immune function and skin health.

1.8 What causes some cheeses to be coloured orange or red?

The colour of the cheese may be changed by the addition of annatto. Annatto cheese colour is obtained from the covering of seeds of the Annatto tree that grows in the tropics. It contains red and yellow colouring matter, and the ratios of these colours are standardised in commercial preparation of annatto solutions.

The rate of addition may be small to give pale cheese a small 'lift' in colour, or larger quantities may be added to produce cheese which is noticeably coloured, within a range from 'deep straw' to deep brick red.

1.9 What additives are used in cheesemaking?

For natural cheese, the additives are

- Starter cultures
- Rennet
- Salt
- Colour (optional)
- Lipase enzymes

Other additives that may be used on the surface of natural cheese:

- Natamycin

For processed cheese:

- Nisin
- Emulsifying salts
- Colourings

1.10 What is Natamycin and when is it used on cheese?

Natamycin is a food grade mould inhibitor that is manufactured from natural sources. It is naturally derived from fermented milk using lactic cultures and is organic in nature. Natamycin has been used in the cheese and food industry for at least 20 years. Natamycin is not soluble in water or fat and consequently passes through the intestines without getting absorbed. It is not an antimycotic and not an antibiotic. It has no affect on any bacteria; it only prevents growth of yeast and mould.
Natamycin is used on the surfaces of some rinded cheeses.

1.11 What anti caking agents are added to grated and shredded cheese?

The products approved for use are cellulose based, for many years the use of microcrystalline cellulose was exclusive, but eventually powdered cellulose replaced the use of microcrystalline cellulose as the anti-caking agent of choice. Another product silicon dioxide is also approved for used. These products have been tested and approved for use at levels up to 20 grams per kilogram of cheese

2 Using Cheese

2.1 What properties are desirable when cooking with cheese?

When cooking with cheese as an ingredient, it is important that the cheese melts uniformly to enable even dispersion into the other foods. The cheese should also remain in tact rather than separating into its fractions of protein, fat and water.

2.2 What are the factors affecting cooking quality of cheese?

Age: As cheese ripens, the proteolytic (protein splitting) enzymes from the rennet break bonds within the protein molecules which makes them more soluble. This increase in solubility progressively improves the cooking quality of natural cheeses, especially during the first twelve months of maturation.

Fat content: The cooking quality of cheeses that are low in milk fat does not improve with age even though the amount of soluble protein increases. The greater protein solubility is offset by a greater tendency to stringiness, matting, and toughness in low-fat cheeses.

Water content: The increase in solubility of the proteins is more rapid in a high moisture cheese and such cheeses are better for cooking than cheese with low moisture content.

Acidity: If acid is added to a cooked dish containing cheese, it increases the tendency for the cheese to separate and become stringy. This occurs at pH 5-6. If more acid is added to cheese (pH 4-5), the proteins will separate from the cooking liquid and form curd-like pieces. Under more alkaline conditions (pH 6-8) the cheese disperses readily. These effects are due to the calcium. Under acid conditions calcium is free to combine with casein to form insoluble calcium caseinate. When alkali is added the calcium tends to be held in a complex with phosphate so that it cannot combine with casein. This makes the cheese more soluble.

2.3 Is it possible to freeze cheese?

The ice crystals that form when cheese is frozen tend to destroy the texture and therefore if the cheese contains free moisture it is not recommended. Freezing does not affect flavour but tends to create a crumbly or grainy texture. Firm cheeses may have a crumbly texture when thawed and can be frozen for up to three months. Mozzarella and cheddar have been successfully frozen.

To keep this crumbling effect to a minimum, freezing should take place as fast as possible so that smaller ice crystals form. The cheese should be frozen in small portions to allow rapid freezing.

Wrapping in vapour-proof material such as heavy duty foil or plastic film is also necessary to prevent loss of moisture into the extremely dry air.

Thawing of cheese should be done slowly in a refrigerated cool room and not refrozen.

2.4 *What is the shelf life of cheese?*

A guide to shelf life is the cheeses moisture. Cheeses with lower moisture content have a longer shelf life than high moisture varieties and vice versa.

Mozzarella cheese if made to a low moisture (45% or less) is capable of being stored for 4-6 months and maybe stored for longer if frozen.

Cheddar cheese may be consumed as milk cheeses after 2-3 months storage, or matured for years. Cheddar shelf life depends on its composition. Cheddar to be consumed as mild flavoured cheese can be made to higher moisture levels (38%) whereas cheddar destined to be matured for longer periods should have lower moisture levels (35%).

Parmesan cheese with moisture levels below 32% will have an indefinite shelf life.

2.5 *What is the difference between use-by dates and best-before dates?*

In Australia with a use-by date the retailer may not sell the product after the specified date. Use-by dates are appropriate when the likelihood of the cheese being unpalatable or unsafe when eaten is high. Best before dates are used and it is a recommendation for the consumers benefit. Typically cheese consumed after the best before date is stronger in flavour and may not be acceptable to the consumer.

2.6 *What advice should we give consumers for the best way to store cheese?*

Cheese should be purchased in small quantities more often rather than large quantities less often. If refrigeration is not possible, in hot weather buy only the cheese needed for the day of purchase. In colder weather buy what is needed for just a few days. It should be eaten on or before the best before date on the packaging, and once opened must be properly stored to retain flavour and moisture. To prevent hard cheeses and soft mould ripened cheeses drying, wrap in foil, greaseproof paper, plastic cling wrap or waxed paper. Consumers should be aware that if the cheese is stored near strongly flavoured foods it may absorb flavours from the other foods.

Soft cheeses such as cottage and ricotta cheese are best stored in the container in which they were purchased. These cheeses do not keep as well as hard cheese and should be eaten within a day or two of purchase. For best results keep all types of cheese in a refrigerator or cool storage if possible.

Soft cheeses like blue vein and mozzarella will store for a few weeks. Firm cheeses such as cheddar keep for several weeks, even months, whereas hard, low- moisture parmesan keeps almost indefinitely. Blue vein style cheeses should be stored separately from other varieties.

There are three processes that can and usually do occur in a cheese during storage which sets its effective storage life. The first is the continual drying out of the cheese. Small pieces of cheese become very hard and dry in the low humidity of a refrigerator if not correctly wrapped. The second is the absorption of off-flavours of foods stored nearby. The third is a continuing biological change. This change may be the normal advance of maturity caused by bacterial enzymes. It may be the growth of mould and invading bacteria, or it may, in fresh cheeses, be a continuing souring by the starter bacteria.

All these changes are more likely in fresh, high moisture cheeses and this is why such cheeses have much shorter shelf lives. These changes are also more likely in small pieces of unprotected cheese than in large pieces that are wrapped and sealed. Heat treatment also extends life. Cream cheeses that have been heat treated then wrapped in foil will last for 2-3 months in a refrigerator. Processed cheeses sealed in foil will last a long time without refrigeration.

The main defences against dehydration and breakdown in cheese are wrapping in foil or plastic film to keep moisture in and taints out, and cool storage to slow down the bacteria, moulds and enzymes.

Only the fresh cheeses need really cold storage (2-3°C) and they should be kept in the coldest part of the refrigerator close to the freezing compartment. The firmer cheeses are better kept in the warmer zones of the refrigerator - the lower shelves or door shelves. Small left-over pieces are most susceptible to drying out and they are best grated and stored in plastic containers for use later in cooking.

Most cheese should be served at room temperature and should be taken from the refrigerator no more than 15 minutes before use. Fresh cheeses, on the other hand, are best served chilled.

3 Consuming Cheese

3.1 Can people who are lactose intolerant eat cheese?

Certain people are unable to digest the sugar in milk (lactose) properly because they have low levels of the necessary enzyme, lactase. This means that although they can usually deal with small quantities; if they eat large amounts at one go they suffer discomfort. This condition is known as lactose maldigestion or intolerance.

During the production process of cheesemaking 90% of the lactose from the milk is removes with the whey when the whey is removed from the cheese. Most of the remainder is converted into lactic acid by the starter cultures during the process. Little lactose remains in the cheese. A few cheeses made without the use of starter cultures contain some lactose and they should be avoided by lactose intolerant people. Ricotta and Haloumi are two such cheeses.

3.2 Does grated cheese have the same flavour as the original product?

Grating cheese increases the cheese surface area many fold. This has the potential to release and lose flavour. Therefore grated cheese should be grated and packaged in a sealed package as soon as possible after the grating. Failure to do so will result in flavour loss.

3.3 Is the rind of a hard cheese edible?

The rind from a very hard cheese is very tough and may not be able to be eaten directly, but it can be grated finely and used to flavour soups, sauces or sprinkle on pasta or other foods.

3.4 What causes mould growth on cheese?

Mould requires the two elements of moisture and air to grow. Mould can develop on cheese once the package is opened and the product is exposed to air and potentially mouldy environments. Most cheese is packaged under vacuum and thus with the exclusion of air mould growth is not possible. Cheeses at higher risk include shredded, cubed and grated cheese, because they have more surface area.

Some cheeses require the deliberate addition of moulds to the cheese to create the unique flavours and characteristics.

3.5 What does the best before dates on packaged cheese mean?

Best before dates are decided on by manufacturers and it is their judgement as to when the product in its packaged state reaches the end of its ideal eating condition. This does not mean that the product is unsafe after the best before date. Many consumers prefer stronger flavoured cheeses and deliberately seek cheeses beyond their stated best before. Such cheeses are safe to eat after the best before date. Once the package is opened and the cheese is exposed to air, there is the potential for mould to develop.

3.6 What are the main differences between normal and reduced fat cheese?

Milk fat is an important contributor to the body and flavour of cheese. Reductions in the fat levels will bring about some change the flavour and body of a dairy product. With current technology, it is difficult to make reduced fat cheese with the same flavour and consistency as regular cheese. The milk fat levels of the cheese contribute the melting properties and thus a reduced fat cheese may have poorer melting characteristics. If fat levels of the cheese are reduced, the protein levels will be higher. As a result the body of the cheese will become harder and tougher. It is important to increase its moisture level to improve or soften the body.

4 Mozzarella

4.1 How is Mozzarella made?

Mozzarella is made by a similar method to cheddar, however after the cheddaring process the curds are milled and then transferred to hot water. The curds are worked into a smooth mass by mechanical devices. This process changes the texture to have long fibrous strands which has ideal properties for pizza. The curds are then moulded into shape before cooling in cold water.

4.2 What are the important functional properties of Mozzarella?

Mozzarella cheese is a cheese where the functional properties are more important than its flavour. The shredability or machinability is very important from a user's viewpoint. The meltability, stretchability, colour, blister formation and free oil are also important when the cheese is baked on a pizza.

4.3 What are the important properties to look for with respect to the shredability and sliceability of Mozzarella?

Important properties are:

- Ability to shred and or slice the cheese
- Uniformity of the cheese shreds
- Amount of fine particles produced
- Ability of the cheese to flow freely or stick together

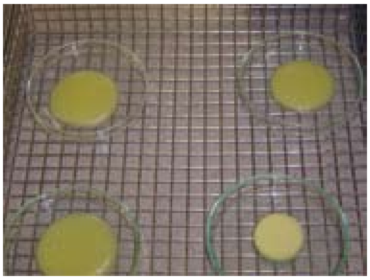
4.4 What are the important things that affect the shredability and sliceability of Mozzarella?

Moist cheese will stick not only in the machines but also shreds will stick together.

Dry cheese will be difficult to shred and will shatter easily and form fine particles. Old cheese will become softer and pasty and will not shred well without clogging and particles sticking together.

4.5 What is meltability and what affects the meltability of Mozzarella?

This relates to the ability of the cheese to melt and flow. The ideal character is for the individual cheese shreds to flow together on a pizza.



Meltability testing

Cheese becomes more meltable as it ages, and when it has higher moisture and becomes less meltable if the cheese has a high pH and a high salt content.

The section on the lower right shows the unmelted cheese. The other 3 are different samples of cheese after the melt test. The diameter of the melted cheese is measured to determine the meltability.

4.6 What is stretchability and what factors affect it?

This relates to the ability of the cheese to form fibrous strands when pulled.

The stretchability of the cheese follows that of meltability.

A simple stretch test using a fork.

4.7 What is meant by the term "free oil formation" and why is it important?

This relates to the amount of free oil releases from the cheese during the pizza baking process. This is important because the pizza consumers object to large pools of oil on the surface of a pizza but It is important to have enough free oil produced to ensure that the cheese does not burn too much during the baking process.

4.8 What are the factors that affect the "free oil formation"

The amount of free oil increases with cheese age, higher moisture cheese, low salt levels, and higher Fat in Dry Matter levels of the cheese.

4.9 *What are the factors that affect the browning of a cheese during pizza baking?*

This relates to the colour of the cheese during the pizza baking process.

There is nothing that can be done to the cheese once purchased to control the browning during baking. Browning increases with higher lactose levels in the cheese. The cheese used must have low lactose levels. The only remedy possible is to blend cheese with low lactose levels with the problem cheese.

Pizza with typical blister and browning

5 Processed Cheese

5.1 *Why does processed cheese sometimes melt or flow when heated?*

This may be caused by the use of whey powder or milk powders in the raw material blend. Using too much old cheese or rapid cooling after processing may also cause the problem. Another cause is the addition of already processed cheese in the mix.

Pizza with excessive browning

5.2 *Why does the processed cheese burn during baking?*

The cheese will burn and turn brown if there is too much lactose in the cheese. This may be due to overuse of whey or skim milk powders in the blend.

5.3 *What can be done to reduce the cheese flavour level of the processed cheese?*

The flavour of the processed cheese is the sum of the constituents. If too much old and strong cheese is used then the flavour will be too strong. Use younger raw material. Also ensure that the cheeses used do not have a high pH.

5.4 *What is the cause of white specks in the processed cheese?*

There are a number of possibilities. To reduce or eliminate the problem use less very old cheese, ensure that all of the emulsifier salts are dissolved and review the use of emulsifier salts to ensure that excessive levels are not being used.

5.5 *The cheese has crystals which are a little different to the white specks. What are these?*

They are most likely lactose crystals so use less whey powder or skim milk powder in the blend. Also ensure that the correct emulsifier combination is used.

5.6 *What is the cause of holes in the processed cheese?*

There are three main possibilities. Firstly the cheese raw material may contain spores which are not being deactivated by the heating process. The addition of nisin or ensuring that the temperature of processing is high enough to kill the spores will eliminate this problem. Secondly ensure that the vacuum on the processing system is working properly.

5.7 *What are the causes of the processed cheese slices becoming fragile and break readily.*
There are several possibilities,
- Inadequate processing time or temperature
- Low cheese moisture
- Low cheese pH
- Too much emulsifier salt
- Too much young cheese
- The cheese is being cooled down too slowly

5.8 *Why is the cheese too sticky after processing?*
There are several possibilities,
- Increase quantities of younger cheese
- Increase agitation during the processing
- Increase processing time
- Reduce moisture content
- Review emulsifier suitability

5.9 *What can cause the body of the cheese to become grainy in appearance?*
The pH of the final cheese is too low and should be corrected by the use of acidity correction salts. The processing time may also be too short or the level of emulsifier use is too low.

Glossary

Acid curd
The gel-like state that milk is brought to when a high level of acidity is achieved. The acidity is produced by the activity of starter culture bacteria, and it precipitates the milk protein into a solid curd.

Acidity
The amount of acid (sourness) in the milk.

Bacteria
Microscopic single cell organisms found almost everywhere. Lactic acid-producing bacteria are useful and essential in the production of fermented products.

Body
The inside of a product which is assessed by graders using terms such as, firm, soft, weak, grainy, pasty, flaky, close, short etc.

Brine
A solution of salt and water used for salting certain cheeses.

Calf rennet
Calf rennet is derived from the fourth stomach of a milk-fed calf. It contains the enzyme chymosin, which has the ability to coagulate milk.

Casein
The major protein in milk

Cheddaring
The process during cheddar cheesemaking after the whey is drained from the curds. The curds are then kept warm for approximately 90 minutes.

Chymosin
The name of the active enzyme in most rennets.

Coagulation
The solidification of milk through the action of acid and/or enzymes. The enzymatic method uses a product known as rennet.

Colostrum
The milk produced for up to 7 days after calving.

Cooking
A step in cheesemaking during which the cut curd is heated to assist in whey removal from the curds.

Curd
The soft rubbery solid produced when milk is coagulated.

Cutting the curd
A step in cheesemaking in which the curd is cut into equal-sized pieces.

Draining
The step in cheesemaking in which the whey is separated from the curd.

Dry matter
All parts of milk products excluding the moisture: i.e. fat, protein, lactose and minerals. Also known as the cheese solids.

Enzyme
A catalyst that accelerates a reaction. They are composed mostly of protein and may contain some minerals. Enzymes are responsible for rapid coagulation of milk, and breaking down the larger milk components of fat and protein to create the flavour and body characteristics of the final cheese.

Eyes
They round openings found in certain cheese caused by gas formation by introduced bacteria.

% Fat-in Dry matter
Refers to the percentage of milk fat of the cheese solids.

Hooping
A step in cheesemaking during which the curd is placed in a cheese mould (hoop).

Inoculation
The addition of microbes such as bacteria to milk.

Lactic acid
The acid produced in milk or curd during cheese and yoghurt making. Starter culture bacteria break down the milk sugar (lactose), and produce lactic acid as a by-product.

Lactos
The sugar naturally present in milk. Lactose can constitute up to 5% of the total weight of milk. It is not a very sweet sugar compared to sucrose.

Lipase
Lipase is an enzyme that is added to the milk for selected cheese varieties. The enzyme is extracted from the epiglottis of animals. The lipase enzymes act on the fat molecules. It splits the fatty acids from the fat molecule. These fats are then known as free fatty acids. Once released from the fat molecule the flavour of the fatty acid is also released.

Lipolytic
The action of the lipase enzymes. Also refers to the flavour created form lipase action on milk fat.

Maturation
A step in cheesemaking in which the cheese is stored at a particular temperature and/or relative humidity for a certain time in order to develop its distinct flavour and/or for the body to breakdown.

Milling
A step in cheesemaking during which the curd is diced into smaller potato chip like pieces before being salted.

Pasta filata
Italian expression for plastic-curd cheeses, where thin strips of cheese curd are placed into a hot water bath and worked up until homogenous.

Pasteurisation
The heating of milk by either batch method i.e. 63°C and holding it for 30 minutes or by a high temperature / short time method of 72°C and holding for 15 seconds. The aim is to destroy pathogenic organisms that may be harmful to humans.

Pathogenic
This word refers to the potential of some micro-organisms to cause disease in humans. The disease may be caused by eating the bacteria in the food or by consuming a poisonous substance produced by the bacteria.

Pressing
A step in cheesemaking during which the curds are placed under pressure to remove whey and create a closer textured cheese.

Rennet
A substance containing powerful enzymes capable of coagulating milk. Calf rennet is derived from the fourth stomach of a milk-fed calf. It contains the enzyme Chymosin that has the ability to coagulate milk. Animal rennet is commonly available in liquid form.

Rind
The outer surface of a cheese which is drier and denser than the rest of the cheese.

Soft cheese
A cheese that is not pressed, contains a high moisture content, and is eaten very soon after production. eg ricotta and cottage.

Standardisation
This term refers to adjustment of the fat, protein or SNF levels in milk to achieve the desired specifications of the end product. Fat may be removed and protein or other solids added.

Starter
A bacterial culture added to milk as the first step in making cheeses or fermented milk products. The bacteria produce an acid in the milk and in the curds.

Starter culture
Same as starter.

Vegetarian rennet
A product used to coagulate milk. It is produced by either yeast or bacteria. The enzyme is extracted from the cells, then filtered, and is free of any of the yeast or bacteria.

Whey
The liquid portion of milk which separates from the curds after coagulation of the milk protein. Whey contains water, milk sugar, whey proteins, minerals and some fat. It should be a clear greenish colour and not milky.

Whey protein
Protein in milk which is not precipitated by the addition of rennet.

DAIRYAUSTRALIA
Delivering for the dairy industry

8

Cheese Applications in Food Service and Bakery Sectors

Content

177 8.1 Introduction

178 8.2 Cheese and the Consumer

178 8.3 Functional Benefits of Cheese as an Ingredient

181 8.4 Cheese Varieties and Use in Bakery and Foodservice

195 8.5 Conclusion

196 FAQ

200 Glossary

201 References

8.1 Introduction

The manufacture and description of the major cheese varieties has been covered previously in the cheese chapter. The cheese applications chapter further explores the major cheese types, and how they can be used as ingredients within food systems.

Cheese is widely used as an ingredient within food applications to impart benefits such as appearance, texture and flavour, and can enhance the cooking properties of selected foods.

Cheese provides the essential texture in many foods designed for quick heating and eating, such as pizzas and frozen entrees. Some cheese varieties contribute a flaky or crumbly texture, which can add contrast to a melting cheese in heated applications. These cheeses can be used cold or heated in salads, or as toppings for soups, pastas and casseroles. Smooth flowing cheese sauces are often used for their smooth texture, flavour and thickening properties as a base for soups and sauces.

The diverse use of cheese is further extended when it is subjected to secondary processing to create a variety of ready-to-use grated and shredded cheeses, cheese powders and processed cheese products.

Figure 1 Use of Cheese as an Ingredient

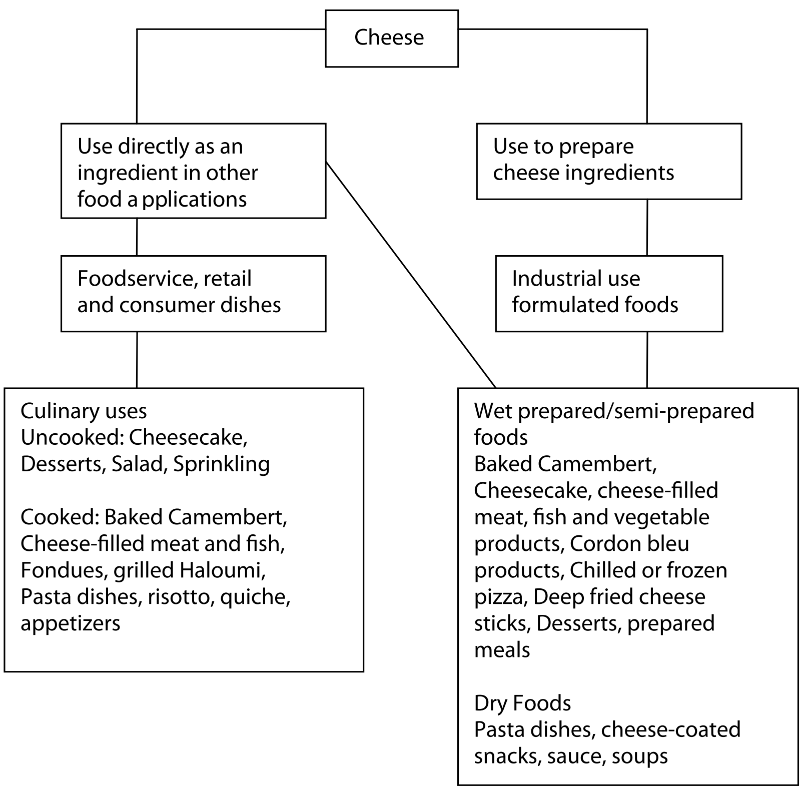


Table 1 Cheese availability in the food service sector

Cheese Variety	Type	Size Available	Application
Cheddar	Individually wrapped slices (IWS)	100g, 250g, 500g, 625g bags	Route trade foodservice, use in sandwiches and burgers.
	Slice on slice (SOS)	1kg, 1.5kg bags	Busy food service areas such as fast food and sandwich bars. Used in burgers and sandwiches.
	Shredded	250g, 500g, 750g, 2kg bags	Many food service applications, including sauces, pizzas and salads.
	Cubed cheese	250g, 500g, 2kg bags	Use in salads and entrees.
	Portions	20g bags	Used by airlines and hotels for a quick, nutritious snack.
Mozzarella	Block	5kg, 10kg, 20kg in box	Used for high melt applications, such as pizza and pasta bakes
	Shredded	2kg bag, 12kg box	Used for high melt applications, such as pizza and pasta bakes
Pizza cheese	Block	10kg, 20kg in box	Blended specifically for use on pizzas
	Shredded	12kg in box	Blended specifically for use on pizzas
Cream cheese	Block	2kg box	Used in cheesecakes, dips, spreads and frostings

8.2 Cheese and the Consumer

8.2.1 The Cheese Ingredient Market

Cheese is available to the consumer through three main sectors:

- The food service sector – cheese may be presented in the form of a cheese board or cheese platter, or used as an ingredient in various dishes.
- The retail and consumer sector – cheese is mainly in the form of portions, such as blocks and slices, which are consumed in the home directly as a table food, or indirectly as an ingredient in various dishes.
- The industrial sector – cheese can be used as an ingredient in several types of assembled products, such as pizzas and hamburgers, or formulated foods such as prepared meals and desserts.

A summary of cheese use by the consumer is provided below in Figure 1.

8.2.2 Cheese Availability in the Consumer Market

Cheese is available in numerous varieties, types and sizes for a number of food applications. A summary of the types of cheese available for the food service and the retail/consumer sectors is provided below in Table 1 and 2.

8.3 Functional Benefits of Cheese as an Ingredient

Most often used for flavour, cheeses are also used to improve texture, increase viscosity, add mouthfeel, improve colour or bind other ingredients. Cheese can also be tailor made to provide specific functional properties such as controlled browning, restricted melt and sharper flavour profiles. The functional properties of cheese are an integral element in the development of cheese applications.

Table 2 Cheese availability in the retail/consumer sector

Cheese Variety	Type	Size Available	Application
Cheddar	Individually wrapped slices (IWS)	250g (12 slices), 500g (24 slices) and 1kg (48 slices)	Use in sandwiches and hamburgers.
	Slice on slice (SOS)	12 or 24 slice packs	Used in hamburgers and sandwiches.
	Shredded	250g, 500g bags	Many applications, including sauces, pizzas and salads.
	Cubed cheese	250g, 500g bags	Use in salads and entrees
	Portions	20g bags	On the go nutritious snack.
Mozzarella	Block	250g block	Used for high melt applications, such as pizza and pasta bakes
	Shredded	250g, 500g bags	Used for high melt applications, such as pizza and pasta bakes
Cream cheese	Block	250g box	Used in Cheesecakes, dips, spreads and frost-ings

8.3.1 Flavour, Aroma and Flavour Enhancement

Food applications benefit not only from the background flavour that cheese can provide, but also from the ability of cheese to carry, shape, refine and improve the flavours of other ingredients. Cheese helps to ensure complete flavour release when used in combination with fat-soluble ingredients, spices, herbs and sweet flavours, and evenly distributes flavour throughout the product. This characteristic is due to the low melting point of the milkfat in cheese.

In low moisture products, cheese powders may be used to boost the cheese flavour profile of foods such as dry soup mixes. The flavour and aroma of cheese is influenced by its fat and protein content, together with other ingredients such as starter cultures, mould and ripening bacteria. Ripening or ageing, together with curd washing and salting can also affect the flavour of cheese.

Several cheese varieties exist, each with differing flavour profiles. Blending of cheese varieties further increases the variety of available cheese flavours.

8.3.2 Texture and Mouthfeel

Higher moisture cheeses, such as fresh ripened cheeses, have a smoother mouthfeel than hard grating cheeses, which are low in moisture and higher in protein. Temperature treatments also affect the texture of most cheeses, although some cheeses are designed to keep their integrity during cooking (no melt) or during freeze-thaw cycles.

8.3.3 Cooking Ability and Melt

The physical properties of melted cheese are highly complex and give rise to at least five different functional attributes:

1. Meltability
2. Flowability
3. Stretchability
4. Elasticity
5. Free oil formation and
6. Browning/blistering.

Meltability refers to the ability of cheese particles to join to form a uniform continuous melt when heated.

Flowability refers to the ability of a cheese, once it has melted, to flow. Cheese with a high flowability, such as a soft Cream Cheese, is desirable for use in cheese-filled meat applications such as a chicken cordon bleu, while a cheese with a low flowability, such as Haloumi, is more suited to fried applications, such as grilled Haloumi.

Stretchability is the ability of the melted cheese strands to form cohesive fibres, strings or sheets that elongate without breaking under tension. It may also be referred to as stringiness.

Elasticity, sometimes referred to as flow resistance or 'strength of the stretch', is the resistance to elongation of the fibrous strands as they are stretched, which in turn inhibits flow.

Free oil formation, also known as 'oiling off' or 'fat leakage', is the separation of liquid fat from the melted cheese body into oil pockets, particularly at the cheese surface.

Browning/blistering occurs at the surface of cheese during high temperature baking. It is characterised by the formation of a skin-like layer containing colour patches that may range from light or golden brown to black in extreme cases.

When heating or cooking foods that contain cheese, the best results are usually obtained when items are cooked at a low temperature for a minimum amount of time. For examples, in sauces, cheese should be added as the last ingredient and heated until just melted. Dicing, shredding or crumbling the cheese can reduce melting time in any application.

8.3.4 Colour Development and Browning

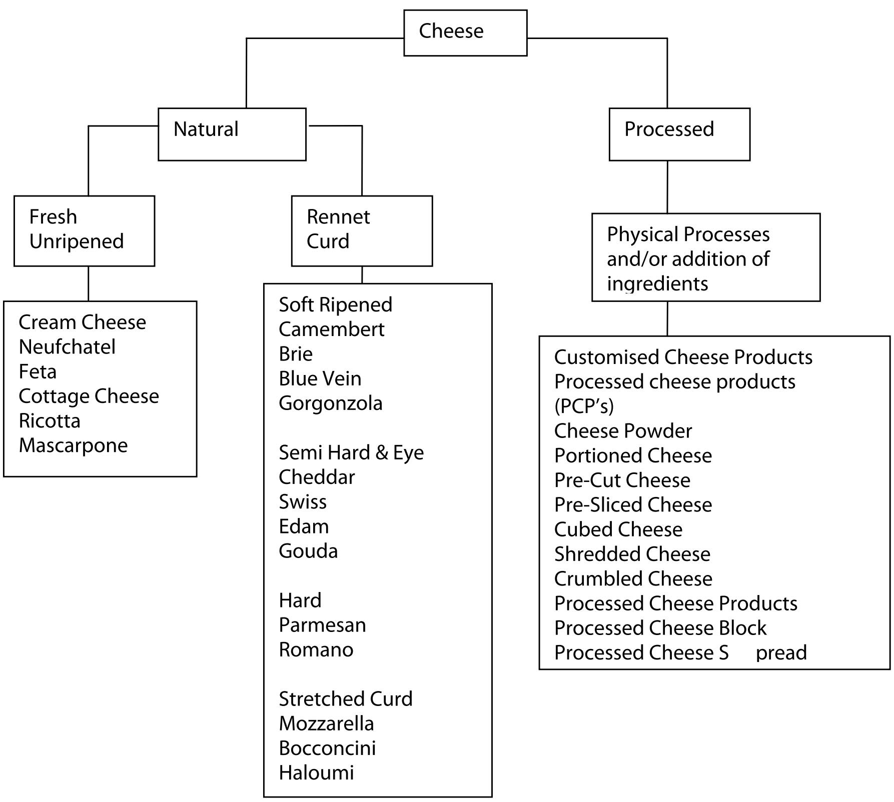
In melted applications, cheese performance is influenced by the same factors that determine cheese texture: pH, cheese composition and the degree of protein breakdown. The factor to best consider depends on how the cheese is heated ie. microwave, thermal, forced air. For thermal heating of young cheeses, melt is less influenced by protein breakdown, although it becomes more important for aged cheeses. In microwave applications, degree of protein breakdown is very important, as is cheese pH and amount of fat in the dry matter. Depending on degree of melt required (restricted melt versus flow) and the type of heating that will be used, specific cheeses may be better suited for certain applications.

Cheese colour can be tailored for specific applications. Regardless of its original colour, cheese can brown when heated or cooked. Surface browning of cheese is usually caused by the Maillard reaction, a heat induced reaction that occurs between proteins and sugars during the baking of cheese. Maillard browning often occurs in Mozzarella cheese, where the selected starter cultures and high temperatures used during mixing result in incomplete fermentation of lactose, or an accumulation of galactose. For pizzas or other products cooked at very high temperatures (ie.>200°C), Maillard browning can cause undesirable browning.

8.4 Cheese Varieties and Use in Bakery and Foodservice

Cheese is a highly versatile ingredient that adapts well to many food systems. In some applications,

Figure 2 Cheese types and industrial cheese ingredients



the primary role of cheese is browning or melting, while in others it is used to contribute flavour, colour or nutrients. Natural cheeses may be suited to certain applications, while processed cheeses and cheese powders offer specific advantages to others. Based on performance objectives, specific cheese varieties and forms are selected to best deliver the desired product benefits.
A summary of the available cheese types is listed below in Figure 2

8.4.1 Natural – Fresh Unripened

Examples of cheese types in this category: Cream Cheese, Neufchatel, Feta, Cottage Cheese, Ricotta Cheese, Mascarpone.
Functional benefits of fresh cheese use in foodservice and bakery applications:

- This cheese type has a neutral flavour profile, making it a suitable flavour carrier for other ingredients, and can be used in sweet or savoury dishes.
- Can be used in applications to impart a fresh, creamy, mild and delicate flavour.
- Can provide density in applications such as dips, spreads and baked cheesecakes.
- May be used as a binder or texture agent.
- Used in baked goods, such as cheesecake, at low temperatures to provide even browning without blistering or cracking.
- High moisture content of this cheese variety (45-55%) makes it suitable for ingredients within wet foodservice and consumer applications, such as dips, frostings, sauces and fillings.

A summary of the application and use of fresh unripened cheese in food applications is shown in Table 3.

Table 3 Application and use of fresh unripened cheese

Cheese Type	Application	% Use
Cream cheese	Icing and frosting	30-45
	Dip	60-70
	Cheesecakes – Baked	20-50
	Cheesecakes – Refrigerated	30-40
Feta	Pizza	20-35
	Meat dishes – as a stuffing or topping	35-50
	Salads	Sprinkled on top, as desired
	Soup	Stirred through, as desired
Cottage cheese	Vegetable dishes	20-30
	Baked meals	20-60
	Muffins	20-35
Ricotta cheese	Baked meals	10-50
	Muffins	20-30
	Pasta	25-40
	Appetisers	60-70
	Topping	60-70
	Icing	80-85
Mascarpone	Dessert	15-35
	Pasta	5-10
	Risotto	2-5

Cream Cheese

- Contributes a creamy appearance and fresh dairy notes to Cream Cheese icing and frosting. The incorporation of a beating action at room temperature with other ingredients incorporates friction into the mix, which in turn causes the Cream Cheese to change from a solid mass into a smooth, spreadable mix. Example: Lemon Blueberry Cupcakes with Fluffy Lemon Frosting.
- Contributes a creamy appearance and a bland flavour to dip and spread applications. May be made sweet or savoury, depending on the application. The incorporation of a beating action at room temperature with other ingredients incorporates friction into the mix, which in turn causes the Cream Cheese to change from a solid mass into a smooth mixture, perfect for dipping and spreading applications.
- Example: ricotta and cream cheese spread
- Acts as a flavour carrier in baked and refrigerated cheesecakes, and contributes to the density as well as creamy, rich colour of the final product. Baked cheesecakes are cooked at 150-160°C for 50-60 minutes. The long baking time at the lower temperature ensures even baking of the cheesecake without excessive browning. Following baking, cheesecakes are left in the oven to cool, with the door ajar to ensure heat escape. The slow cooling prevents surface cracking of the baked cheesecake. Examples: Baked Cheesecake and Basic Lemon Cheesecake.

Feta

- Can be crumbled and used alone or in combination with other cheese varieties in pizza applications. Pizzas are baked at 200-230°C, with the Feta providing a curd-like consistency with no melt, maintenance of a firm colour, a bland flavour profile and some browning. Example: Char-Grilled Vegetable Pizza.
- May be crumbled and used as a meat stuffing. Meat dishes are baked at 180-220°C for 30-40 minutes to impart some browning in the stuffing. The meat dish is left undisturbed for 10 minutes prior to carving to allow the stuffing to firm up and create a sliceable, stuffing-filled meat. Example: Turkey Breast with Feta and Craisin Stuffing.
- High moisture content and loose curd allows it to break into small, irregularly shaped pieces when rubbed. These can be crumbled over a final prepared salad for fresh cheese flavour. Example: Marinated Julienne Salad in a Crouton Bowl.
- Can be stirred through soup just before serving, or may be crumbled over the soup as a garnish just before serving, imparting a mild cheese flavour.

Cottage Cheese

- Can be used in vegetable dishes for its binding properties and to add bulk to the final product. Cottage Cheese also provides a smooth texture with a mild cheese profile. Baking conditions range from 180-200°C for 20-30 minutes. Example: Cheese and Broccoli Flan.

- Can be used in meat dishes to provide a smooth creamy product with a mild cheese flavour. May be used as a substitute for béchamel sauce in low-fat lasagna products. Example: Trim and Terrific Beef Lasagne.
- Can be used in muffins where it acts as a flavour carrier for sweet ingredients. Muffins are baked at 180°C for 20-30 minutes, with the Cottage Cheese retaining its curd-like structure during baking, imparting a curd-like texture throughout the final muffin product. Example: Apricot Cottage Muffins.

Ricotta Cheese

- Combines well with other ingredients, provides binding and acts as a flavour carrier in baked meal applications. Baked at 180-200°C for 10-30 minutes, Ricotta provides a smooth texture and contributes some colour to the final baked product.
- Can be used in muffins where it acts as a flavour carrier for sweet ingredients. Muffins are baked at 180°C for 20-30 minutes, with the Ricotta cheese acting as a binding ingredient and imparting a smooth texture in the final baked muffins. Example: Apricot Cottage Muffins.
- Acts as a binding ingredient and a flavour carrier for savoury ingredients within pasta dishes and appetisers. These products are baked at 200°C for 10-30 minutes. Example: Smoked Salmon, Rocket and Ricotta Linguine , Mini Roast Capsicum and Olive Baked Ricotta.

- Can be whipped with fruit and used as a carrier for topping applications, where Ricotta acts as a flavour carrier for the fruit, and provides density, which allows it to hold as a topping on pancakes. Example: Buttermilk Pancakes with Whipped Raspberry Ricotta.
- Can be utilised as the main ingredient in icing for baked applications, where Ricotta acts as a flavour carrier for sweet ingredients, and also provides body to the icing mix, allowing it to remain on top of the baked good once applied. Example: Banana Sultana Muffins with Honey Ricotta.

Mascarpone

- Can be whisked and combined with other ingredients to impart a smooth, creamy flavour and texture to desserts. Mascarpone also acts as a flavour carrier for sweet ingredients, and provides body to the final product. Example: Tiramisu.
- Can be used at low levels in pasta dishes to bind, act as a flavour carrier and impart creaminess to the final pasta dish. Example: Macaroni Cheese.
- May be stirred into a final prepared risotto to provide a creamy mouthfeel and flavour, and to enhance the flavour of the savoury ingredients within the risotto. Example: Three Cheese Risotto with Chicken, Rocket and Roasted Red Capsicum.

8.4.2 Soft Ripened Cheese (White and Blue Mould Cheese)

Examples of cheese types in this category: Camembert, Brie, Blue Vein.

Functional benefits of soft ripened cheese in foodservice and bakery applications:

- Provides strong, distinctive flavour profiles that add intensity to foodservice applications such as sauces and dressings.
- Soft cheeses have an adhesive property, yet undergo flow when force is applied; making them suitable materials in the preparations of fondues and sauces, as well as appetiser spreads.
- Good binding characteristics make them suitable to combine with other ingredients for baked meat fillings.
- Can be baked alone or in combination with other cheese varieties at 190-230°C as a pizza topping, a meat topping or in filled pasta applications to impart some browning and a firm texture.

A summary of the application and use of soft ripened cheese in food applications is provided in Table 4.

Table 4 Application and use of soft ripened cheeses

Cheese Type	Application	% Use
Camembert	Meat Dishes	35-50
Blue Vein	Appetisers and baked dishes	30-40
	Meat Garnish	25-35
	Salad	10-20
	Sauce	10-20
	Risotto	1-3

Examples of soft ripened cheese use in foodservice and bakery applications:

Camembert

- Can be sliced and used as a meat stuffing, where its function is to bind dry ingredients, and provide a nutty, mushroom flavour. Meat dishes are baked at 180 - 220°C for 30 - 40 minutes to impart some browning in the stuffing. The meat dish is left undisturbed for 10 minutes prior to carving to allow the stuffing to firm up and create a sliceable, stuffing-filled meat. Example: Camembert Turkey Fillet with Creamy Cranberry Sauce.

Blue Cheese

- Can be used in appetisers and baked dishes, where it is sliced or crumbled with other ingredients, and baked at 200°C for 20 minutes. Used to impart a distinctive tangy flavour. Example: Smoked Chicken and Blue Cheese Tart.
- Used as a meat garnish when combined with other ingredients, creating a distinctive flavour that compliments red meat. Example: Beef Fillet with a Creamy Blue Cheese Topping.
- Can be crumbled and used as a garnish for salads, where it imparts a distinctive tangy flavour and adds to the texture of the salad. Example: Char-Grilled Asparagus, Blue Cheese and Walnut Salad.
- May be melted with other ingredients to create a cheese sauce with a distinctive flavour.

When making, all other ingredients are combined and heated on the stovetop at around 75-90°C. Once these ingredients have combined, the sauce is removed from the heat and the cheese is stirred into the sauce. tirring in the cheese following the application of heat allows for a smooth texture and a moderate flavour profile without excessive browning Example: Blue Cheese and Chive Fondue.

- May be used as a garnish to provide flavour to risottos. Example: Three Cheese Risotto with Chicken, Rocket and Roasted Red Capsicum.

8.4.3 Semi Hard Cheese and Eye Cheese

Examples of cheese types in this category: Cheddar, Swiss, Edam, Gouda.
Functional benefits of semi-hard cheese in foodservice and bakery applications are as follows:

Cheddar

Cheddar cheese can impart various flavour and texture profiles, depending on the maturity of the cheese used.

- **Mild Cheddar** imparts a low flavour profile and a smooth, firm texture that can be easily sliced, cubed and shredded. Mild cheese is useful in applications such as children's meals, and blended with other cheese ingredients for pizzas, where other functional benefits of Cheddar may be required, but the smooth, low flavoured profile is preferred.
- **Tasty Cheddar** imparts a well-rounded, mature flavour, with a slightly weaker texture compared to mild Cheddar. Tasty cheese can also be sliced, cubed and shredded, and is the most commonly used Cheddar type in bakery and foodservice applications, including muffins, soups, pastas, pizzas, hamburgers, sandwiches and sauces.
- **Vintage Cheddar** imparts a sharp, distinctive cheese flavour, with a crumbly texture, and is best suited as an ingredient in soups, salads and pasta dishes.

A summary of the key Cheddar properties, with their levels of maturity, is shown below in Table 5.

Swiss, Edam and Gouda Cheese

Swiss, Edam and Gouda Cheese, also known as eye cheeses, can be used interchangeably with Cheddar in many bakery and foodservice applications.

- Swiss cheese provides unique, buttery and nutty flavours to food applications. Its texture is firm, and contains large eyes throughout.
- Swiss cheese is available in shredded or sliced form, and has superior melting properties, making it useful as an addition to soups, fondues, sandwiches, sauces and microwave applications.

Table 5 Properties of Cheddar Cheese

Cheddar Type	Maturation Period	Body	Flavour
Mild	1-3 months	Firm	Clean, mild, slightly acidic
Tasty	9-12 months	Semi-weak	Balanced sharp, creamy
Vintage	16-18 months	Weak	Extra sharp, 'bite'

- Edam and Gouda cheese have mild buttery and nutty flavours, with Edam having a smooth and firm texture, whilst Gouda has a smooth and creamy texture.
- Edam and Gouda cheese can be sliced or cubed, and have good melting properties, making them suitable for a variety of cooking applications, including soups, sauces and sandwiches.

A summary of the application and use of semi hard eye cheese in food applications is shown in Table 6.

Table 6 Application and use of semi hard and eye cheeses

Cheese Type	Application	% Use
Cheddar	Snacks	30-65
	Vegetable Dishes	20-30
	Soup	10-20
	Sauce	10-20
	Baked Pasta	10-30
	Quiche	10-20
	Pizza	10-15
	Muffins	5-25
	Risotto	1-3
Swiss	Baked Pasta	15-20
	Meat	10-15
	Sandwiches	10-15
Edam	Frittata	10-15

Cheddar

- Can be grated, mixed with other ingredients and baked at 200°C for 10-15 minutes to provide a cheese snack that has a strong cheese flavour and imparts a golden yellow colour Example: Cheese Straws.
- May be heated on the stovetop and melted with other ingredients to provide a sauce for baked vegetable dishes. These dishes are baked at 200°C for 20-60 minutes, with the Cheddar cheese contributing to good melting properties, imparting a strong cheese flavour and providing a golden brown colour. Example: Caramelised Onion, Pecorino and Potato Flan.
- Can be stirred through a simmering soup, or sprinkled over a soup as a garnish, where it contributes a good cheese flavour, has good melting properties and adds body to a soup. Example: Pumpkin Soup with Tasty Cheddar Cheese.
- Can be stirred in with other ingredients over a low stovetop heat and be used in the preparation of fondues. The excellent melting properties of Cheddar allow it to provide a smooth texture and contribute a good cheese flavour. Example: Cheese and Beer Fondue.
- Can be stirred in with other ingredients following heating on a stovetop, and used in pasta bake dishes, where its melting properties allow it to combine well with other ingredients and provide a good cheese flavour and golden brown colour to the final baked pasta dish. Example: Macaroni Cheese.
- May be placed on top of a quiche and baked at 180°C for 20-30 minutes, where the Cheddar melts well to create a smooth, well flavoured and slightly crisp golden brown surface. Example: Asparagus and Capsicum Bread Quiches.
- Can be combined with other ingredients and baked at 180°C for 20 minutes for the manufacture of muffins. Cheddar provides flavour, melts on heating, and contributes a golden

brown colour to muffins. Example: Cheese and Buttermilk Corn Muffins.

- May be shredded and used over the top of other ingredients in a pizza base, where it is baked at 200-230°C for 10-15 minutes. The good melting properties offered by the Cheddar cheese enable it to hold other ingredients on the pizza, whilst at the same time providing a good cheese flavour and a crisp, golden brown texture and colour to the pizza surface. Example: Char-Grilled Vegetable Pizza.
- May be stirred through a risotto at the end of cooking, where its excellent melt properties allow the ingredients to combine, and it also contributes a cheese flavour. Example: Three Cheese Risotto.

Swiss

- Can be combined with other ingredients and stirred on the stovetop until melted, providing a sauce for baked pasta applications. Swiss cheese adds flavour and excellent melting properties to pasta bakes, and works well as a binder for other ingredients. Example: Swiss Cheese, Pasta and Ham Bake.
- May be sliced and melted over the top of meat, where its excellent melting properties allow for a smooth, melted mass with a unique, nutty and buttery flavour. Example: Swiss Cheese, Pork and Apple Steaks.
- Can be sliced and used as a sandwich filling, where it provides good melting properties when toasted, and contributes to flavour. Example: Crispy Swiss Cheese Finger Sandwiches.

Edam

- Can be whisked together with other ingredients and heated on the stovetop to form a frittata. Edam melts well and acts as a binding ingredient for other ingredients when heated within the frittata, and the cheese also contributes to a golden-brown colour within the final product. Example: Turnip and Sweet Potato Frittata.

8.4.4 Hard Cheese

Examples of cheese types in this category: Parmesan, Romano

Functional benefits of hard cheese use in foodservice and bakery applications include:

- Parmesan offers a buttery, sweet and nutty flavour, while Romano provides a sharp, piquant flavour. The flavour of hard cheeses intensifies with age, and imparts a fresh, clean flavour.
- The low moisture content of Parmesan and Romano cheese causes them to have a hard, granular texture that is brittle in nature and is well suited to grating.
- Provide good melting properties and melts rapidly and evenly when used in applications such as pasta, soups, stuffing and sauces.
- Can be grated, shaved or powdered to provide good free-flow

properties that are ideal where sprinkling or measured delivery is required.

A summary of the application and use of hard cheese within food applications is provided below in Table 7.

Parmesan and Romano cheese can be used interchangeably to provide the same characteristics to a variety of food applications.

Table 7 Application and use of hard cheese

Cheese Type	Application	% Use
Parmesan	Meat coatings	3-20
	Meat topping	5-15
	Pasta sauces	5-15
	Baked meals	2-5
	Salads	2-5
Romano	Sauce	30-40
	Meat coatings	3-20
	Baked pasta	2-5
	Salad	2-5
	Risotto	1-3

Parmesan

- Can be combined with other ingredients and be used as a meat coating, which is baked at 180-200°C for 10 minutes. Parmesan contributes to a crunchy texture when baked, and provides a good cheese flavoured coating. Example: Cheesy Chicken Nuggets.
- The rapid melting properties of Parmesan make it suitable as a binder for other ingredients on a meat topping, where it is grilled and to provide a smooth, molten cheese with a golden surface appearance that provides a good flavour profile to the meat topping. Example: Chicken Parmigiana.
- Can be combined with other ingredients and gently brought to the boil under stirring to form a pasta sauce. The rapid melt of Parmesan adds body to the pasta sauce, and provides a smooth texture that has a strong cheese flavour. Example: Creamy Mushroom Parmesan Pasta.
- May be sprinkled over the top of a pasta dish and baked at 180°C for 20-25 minutes, where it provides a crisp texture, golden brown surface and buttery, nutty flavours. Example: Chicken Macaroni Cheese.
- Can be shaved and added as an ingredient to salads, where it provides a strong cheese flavour with a brittle, granular texture that easily breaks in the mouth when consumed. Example: Grilled Chicken, Rocket, Pear and Parmesan Salad.

Romano

- Can be stirred in with other ingredients over a low stovetop heat and be used in the preparation of fondues. The rapid melting properties of Romano allow it to provide a smooth texture and contribute a good cheese flavour. Example: Cheese and Beer Fondue.
- Can be combined with other ingredients and used as a meat coating, which is baked at 180-200°C for 10 minutes. Romano contributes to a crunchy texture when baked, and provides a good cheese flavoured coating. Example: Parmesan and Herb Crumbed Lamb Cutlets.
- May be sprinkled over the top of baked pasta dishes, and baked at 180°C for 15-20 minutes. Romano provides good melt, as well as contributing to flavour and a golden-brown surface colour. Example: Swiss Cheese, Pasta and Ham Bake.

- Can be shaved and added as an ingredient in salads, where it provides a strong cheese flavour that compliments the other salad ingredients. Example: Romano Nicoise Style Salad.
- Can be stirred through risottos, where its quick melting properties allow it to bind with other ingredients and provide a smooth, creamy texture. Romano also imparts a good cheese flavour. Example: Three Cheese Risotto.

8.4.5 Stretched Curd Cheese

Examples of cheese types in this category: Mozzarella, Bocconcini, Haloumi.

Functional benefits of stretched curd cheese use in foodservice and bakery applications include:

- Stretched curd cheeses have a sweet, mild flavour that can compliment other flavours and is compatible with a wide range of flavourings, spices and herbs.
- Has a close texture which is smooth, soft and moist, and the cheese may be sliced, shredded or cubed for use in food applications.
- Offer a range of cooking properties, and may be used in applications in their grilled, baked or melted forms to provide body and mouthfeel.
- Provide a uniform and consistent melt.
- Add visual appeal to Italian-style dishes.

A summary of the application and use of stretched curd cheese within food applications is shown in Table 8.

Table 8 Application and use of stretched curd cheese

Cheese Type	Application	% Use
Mozzarella	Appetiser	60-70
	Baked Pasta	5-15
	Pizza	5-10
	Meat topping	5-10
Bocconcini	Appetiser	20-30
	Pasta	10-20
	Salad	70-80
Haloumi	Appetiser	80-85

Mozzarella

- Can be used to compliment meats, such as prosciuto and chicken in appetisers, which are baked at 180°C for 12-14 minutes. Mozzarella melts well and acts as a binding ingredient for the meat. The mild flavour of the cheese is well suited to meat, while the cheese imparts a soft, smooth texture to the application. Example: Proscuito Wrapped Mozzarella and Chicken Bites.

- May be sprinkled between pasta sheets and meat in a baked pasta application, and baked at 180°C for 30 minutes. Mozzarella melts on heating and provides a smooth, molten mass with a mild cheese flavour that compliments the flavour of the meat/sauce mix. Mozzarella also contributes to stretch and provides a stringy texture when consumed. Example: Beef Lasagne with Spinach.
- May be grated and sprinkled over the top of pizzas and baked at 200°C for 10-15 minutes. Mozzarella melts evenly and assists in holding the other topping ingredients on the pizza; it contributes a mild cheese flavour that compliments the other pizza topping ingredients and provides stringiness and stretch to the pizza, together with the development of a golden-brown colour. Example: Char-Grilled Vegetable Pizza.

- Can be used as an ingredient within a meat topping, where it is baked at 200°C for 15 minutes. Mozzarella melts well, and assists in holding the other ingredients onto the surface of the meat. It also provides stringiness and stretch to the product when consumed, imparts a smooth mild flavour and contributes to surface colour of the meat topping. Example: Mozzarella and Asparagus Chicken.

Bocconcini

- Can be combined with sliced meat and other antipasto ingredients and served as an appetiser. The mild flavour of Bocconcini compliments the other ingredients, whilst the smooth texture imparts a pleasant mouthfeel. Example: Spiced Bocconcini and Rocket Salad.
- Can be torn and added to heated pasta, where it provides a sweet, mild flavour and provides moistness to pasta dishes. Example: Eggplant, Basil and Bocconcini Spirali.
- The mild flavour profile and smooth texture of Bocconcini lends itself well within salad applications, where it can be coated with spicy ingredients and act as a flavour carrier. Example: Spiced Bocconcini and Rocket Salad.

Haloumi

- May be coated in savoury ingredients and pan fried to produce a savoury Haloumi cheese appetiser. The mild flavour profile allow Haloumi to be a good flavour carrier for savoury ingredients, while the close structure allows this cheese to be fried without melting or breaking. Example: Pan-fried Haloumi with Tomato Salsa.

8.4.6 Processed Cheese

The major ingredient in processed cheese products is cheese, and the amount of cheese and the maturity of the cheese used within a processed cheese formulation depend on the application. Cheese spreads contain a minimum of 51% cheese of a medium-ripe maturity that breaks and melts when a shear force is applied. Block processed cheese accounts for up to 98% cheese of a young maturity, with a close structure that maintains its form when sliced, cubed or shredded.

Processed cheese spread products combine two or more cheeses to create flavours that are richer and more complex than the flavour of a single cheese, or to obtain a desired texture. Processed cheese spread products are created by combining two or more cheese varieties into a homogeneous blend using the application of heat, shear and the addition of emulsifying salts.

Functional benefits of processed cheese in the Foodservice and Bakery Applications include:

- Offer a variety of flavour, consistency and functional properties for food applications due to the variety of formulations and processing conditions available for this cheese type.

- Are able to deliver consistent properties such as melt, stretch, flavour and colour. development.
- Allow food manufacturers to create specific dishes in a consistent and cost-effective manner.
- Lower manufacture costs compared to natural cheese, since they utilise low grade cheese types, together with low cost non-cheese ingredients.
- Have a relatively long shelf life, assisting in eliminating wastage.

Examples of processed cheese use in Foodservice and Bakery Applications:

- May be used in pre-sliced cheese applications to deliver excellent melt and hold properties for use in sandwiches and burger cheese slices.
- May be dried and used as a coating for savoury snack foods.
- May be used in foodservice to top a variety of dishes and fast food products and also as ingredients in cheese-stuffed entrees, casseroles, microwaveable meals, soups, sauces and meat dishes.

Processed Cheese Block

Examples of processed cheese block products: Processed Cheese, Processed Cheese Food.
Functional benefits of processed cheese blocks in the Foodservice and Bakery Applications:

- Can be manufactured to specific flavour and texture requirements for use in food applications.
- Convenient and ready to use.
- May be shelf stable products, making them convenient in areas where refrigeration may be unreliable or unavailable.

Examples of processed cheese block use in Foodservice and Bakery Applications:

- May be sliced and used in sandwiches or burgers to impart a uniform flavour and good melt properties.
- May be shredded and used in cheese sauces, risottos and pizzas to provide a uniform cheese flavour and contribute to melting properties.
- Can be substituted for natural cheeses, making them useful in a wide range of food applications.

Processed Cheese Spread

Examples of processed cheese spread products: Cream Cheese, Cheddar blends.
Functional benefits of processed cheese spread in the Foodservice and Bakery Applications:

- Smooth cheese product that is a blend of two or more natural cheeses, being blended specifically for the application in which it will be used.
- Provide excellent spread ability and a good cheese flavour.
- Convenient and ready to use.
- Shelf stable products, making them convenient in areas where refrigeration may be unreliable or unavailable.

Examples of cheese spread use in Foodservice and Bakery Applications:

- May be used as a base for soups and sauces.

- May be spread and used as an appetiser topping, such as a dip or a spread, for bread or crackers.
- Used as a filling in baked goods.

8.4.7 Customised Cheese Products

Customised cheese products are developed to meet the specific needs of end users, and are often subjected to size reduction operations involving a combination of shear and compressive stresses that result in fracture, and lead to the formation of a ready to use product.

Examples of customised cheese available for use include cheese powder, portioned cheese, pre-cut cheese, grated cheese, cheese cubes, sliced cheese, crumbled cheese, pre-blended cheese and other cheeses that are further processed to reduce the on-site labour required to prepare cheese for its end use. Many restaurants and foodservice outlets use customised cheese products not only for their labour savings, but also to ensure control over the consistency of final food products.

Cheese Powder

Examples of powdered cheese products: Parmesan, Romano, Cheddar, Blue.
Functional benefits of cheese powder in the Foodservice and Bakery Applications include:

- Provides good cheese flavour profiles with an enhanced cheese flavour, without providing additional moisture to foods, making them suitable for dry food applications.
- Imparts a dry, powdery texture and mouthfeel.
- Convenient and ready to use.
- Offer the flexibility of blending with other dry ingredients.
- Powdered form makes them easy to deliver into/onto a food.
- Can be used in baked goods, where it retains flavour under high temperatures.
- Contributes to yellow-golden colour appearance on surface of baked products.

Cheese powders typically consist of a base cheese material which is comminuted with other ingredients, including water, colours, milk solids, flavours, flavour enhancers, starches, maltodextrin and emulsifying salts and spray dried to create a free flowing powder with a low moisture content of around 3-5%.

The final composition of a cheese powder can vary, and cheese solids can range from low solids of ~20%, medium cheese solids of ~35%, up to high cheese solids of ~65%.

Examples of cheese powder use in Foodservice and Bakery Applications:
Cheese powders can be used as flavouring ingredients in a wide variety of low moisture food applications, including:

- Snack coatings, such as potato chips, nachos and tortilla shells
- Cheese sauces
- Soups
- Savoury dressings
- Savoury biscuits
- Sprinkled over pasta as a garnish
- Value added and extended shelf life products

Portioned Cheese

Examples of portioned cheese products: Cheddar, Edam, Tasty and Swiss Cheese.

Functional benefits of portion cheese in the Foodservice and Bakery Applications:

- Sliced into portion sized pieces and individually wrapped for consumer freshness and convenience.
- Provide the same flavour, aroma and texture properties as the base cheese material in a nutritious grab and go pack.
- Convenient and ready to use.
- Perfect shape for complimenting with dry biscuits.

Examples of cheese portion use in Foodservice and Bakery Applications:

- Perfect for catering services, airlines and hotels to provide a quick, nutritious grab and go snack.
- Used as a quick andL convenient Children's snack in lunchboxes.

Pre-sliced Cheese

Examples of pre-sliced cheese products: Cheddar, Edam, Swiss and Tasty.

Functional benefits of portion cheese in the Foodservice and Bakery Applications include:

- Most popular type of convenience cheese available.
- May be sold as individually wrapped slices (IWS) that are ideal as domestic use or for route trade food service, with the wrapping contributing to a hygienic, ready to use form.
- Can also be sold in Slice on Slice (SOS) format making them easy to use in applications during busy service periods, in applications such as sandwiches and hamburgers.
- Provide the same flavour, aroma and texture properties as the base cheese material.
- May be natural cheese products, or processed cheese blends specifically suited to an application.
- Convenient and ready to use.
- Available in variety of shapes, thicknesses and sizes to suit consumers needs.

Examples of cheese pre-sliced cheese use in Foodservice and Bakery Applications:

- Used in sandwiches and toasted sandwiches for their flavour and good melt properties.
- Used in hamburgers, where the pre-sliced cheese has good shape retention on melt, and reduced overhang when added into the burger.

Cubed Cheese

Examples of cubed cheese products: Cheddar.

Functional benefits of cubed cheese in the Foodservice and Bakery

Applications:

- Available in rectangular or square shapes of 1.5-2cm thickness.
- Available as rectangular sticks.
- May be cut to specified, consistent lengths.
- Provide the same flavour, aroma and texture properties as the base cheese material in a nutritious grab and go pack
- Convenient and ready to use.

Examples of cubed cheese use in Foodservice and Bakery Applications:

- Cubes may be used as an ingredient in salads.
- Can be combined with other ingredients and used as appetisers.
- Cheese sticks can be used as a quick and convenient children's snack in lunchboxes.

Shredded Cheese

Examples of shredded cheese products: Mozzarella, Parmesan, Cheddar.

Functional benefits of shredded cheese in the Foodservice and Bakery Applications:

- Available in three forms:
  - standard shred (0.2-0.3cm diameter, 1.5-3cm in length)
  - Fine shreds (<0.15cm diameter, 1.2-4.5cm length)
  - flat shreds (0.15-0.35cm diameter with a flat hand shred appearance)
- Provide the same flavour, aroma and texture properties as the base cheese material.
- Convenient and ready to use.

Examples of shredded cheese use in Foodservice and Bakery Applications:

- Shredded Mozzarella is best suited to high melt applications, such as pizzas, pasta bakes and toasted foccacias. Shredded Mozzarella works well in pizza as it provides the right mix of flavour, melting, stretch and elasticity characteristics. Its form is usually a flat shred.
- Shredded Parmesan cheese is used to add flavour and body to risottos. It is usually sold as a fine shred.
- Shredded tasty cheese is used for its flavour and melt properties in baked goods, Mexican nachos and frozen manufactured foods. It is commonly sold as a standard shred.

8.5 Conclusion

Cheese is widely used as an ingredient within food applications to impart benefits such as appearance, texture and flavour, and can enhance the cooking properties of selected foods.

The versatility of cheese ensures that it can be used on many foods, with some varieties imparting quick melt for use in baked goods, some contributing a flaky or crumbly texture for use in baked or cold foods, some as toppings for hot dishes and some providing smooth flow for sauce applications.

An understanding of the cheese types available, together with their application, enables those in the foodservice and consumer sectors to successfully select and use cheese as a food ingredient.

FAQ

Natural Fresh Unripened Cheese

1. *How do I prevent cream cheese lumps in a baked or refrigerated cheesecake?*
   Ensure the cream cheese is warmer than refrigerator temperature before combining it with other cheesecake ingredients. The best way to quickly soften cream cheese is to place the unwrapped sample into a bowl and microwave on high for 30 to 45 seconds or until completely softened. For baked cheesecakes, it is important that all cheesecake lumps be removed from the mix before adding eggs, since eggs trap air in the batter, and excess air in the mix can lead to surface cracking.

2. *How can I ensure the good textural properties of feta without causing too much saltiness in my product?*
   Feta is available in two varieties, soft and semi-hard. Soft feta has a higher moisture content and is sweeter and less salty than the semi-hard feta, which has a stronger flavour and aroma. If the feta is not to be consumed immediately, it may be stored in a shallow container of milk. This ensures the cheese is kept moist and also helps to reduce its saltiness.

Soft Ripened Cheese

1. *What affects flavour development in soft ripened cheeses, and how do I select a cheese that best suits the food application?*
   Soft ripened cheeses develop in flavour over time. When young, 4-6 weeks before the use by date, the cheese has a chalky centre core and a firm texture. When at the peak of their maturity, just before the best before date, the core disappears, leaving a creamy luscious textured center and a delicate flavour.
   Mild flavours are imparted when using a young soft ripened cheese in bakery and foodservice applications, while creamy, more mature flavours are imparted when using a mature soft ripened cheese in bakery and foodservice applications.

2. *How do I ripen soft ripened cheese?*
   Ensure you store soft ripened cheese at 4°C in a refrigerator, and ensure cool air is circulating around the product, since the cheese generates its own heat as it matures.
   If you cut into a cheese to check for ripening, and it is not ripened to your liking, rewrap the cheese in its silver foil packaging. The silver foil contains perforations, which allow the cheese to

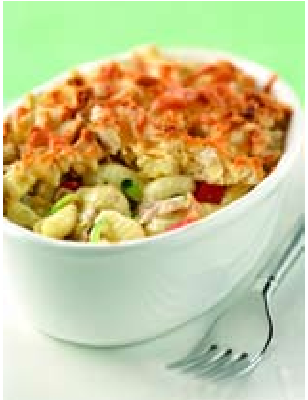
breathe and mature. Do not wrap in plastic film, as this does not allow the cheese to breathe properly.

Semi-hard Cheese and Eye Cheese

1. *Can cheddar cheese showing mould growth be used in food service or bakery applications?*
   Mould spots on cheese can contain harmful bacteria, and should not be consumed. Generally, if you see spots of green, blue or white mould on a cheddar cheese block, the cheese may still be used, provided the mouldy part of the cheese is cut out of the block, and that the knife removing the block does not contaminate good cheese with mould. The remaining cheese is then safe for consumption.
   If the mould on the cheese is red, yellow or black or if the mould is white or brown in colour with hairy growth, the cheese is not safe for consumption and should be immediately thrown out.
   To avoid mould growth on cheese, ensure the cheese is kept free from air by wrapping it in plastic film, or placing it in an airtight container during storage.

2. *Can I use low fat cheese as a substitute for cheddar within recipes?*
   The use of low-fat cheese in foods depends on the functionality required. Low fat cheeses are cheese products that contain no more than 3g of fat per serving, and must contain a minimum of 25% less fat compared to their regular cheese counterpart. Low fat cheese generally contains a high moisture content, and as such, requires lower cooking temperatures to achieve the same functional properties when used as an ingredient within food applications. Generally, low fat cheeses are more suitable for serving cold rather than for use in cooked dishes.

3. *What is the best way to ensure cheese melts when used in food applications?*
   Some of the more common methods to ensure a good cheese melt when using cheese as an ingredient in foods include:
   - Shredding, grating or cutting the cheese into pieces before use.
   - Adding cheese as a topping at the end of the baking process, giving it just enough time to melt over the surface of the food.
   - When making cheese sauce, add the cheese at the end of the process, and continue to heat until it has just melted.
   - For quick results, cheese may be softened in the microwave on medium to high power to a short period of time.



Hard Cheese

1. *What form of parmesan cheese is used in bakery and foodservice applications?*
   The physical form of parmesan cheese used depends on the application. In baking applications, diced parmesan is commonly used, whilst for non-baked applications, such as salads, a shaved or shredded parmesan is preferred.

2. *Why does parmesan retain its shape when heated?*
   Parmesan cheese has a higher protein content compared to many other cheese varieties; this

causes it to melt slower and provides good shape retention in baked applications.

Stretched Curd Cheese

1. *How is the application of Mozzarella cheese in pizzas influenced by its maturation?*

During storage at 4°C, Mozzarella undergoes characteristic changes in melted functionality. Following initial manufacture, Mozzarella melts to a tough, elastic consistency that is not suitable for pizza. During the first few weeks of ageing, however, the melted consistency of the product mellows substantially, and the cheese soon melts to a desirable, moderately elastic state. Upon further storage, the cheese becomes excessively soft and fluid when melted, and is no longer suitable for use on a pizza. Under refrigerated conditions, Mozzarella has a relatively short period of acceptability, and should be used shortly after it is opened to counteract its short shelf life.

2. *Can cheese varieties be blended?*

Cheese varieties can successfully be blended, and blends are commercially available to meet the specific needs of the purchaser. The most common use of blended cheese varieties is for pizzas, where mozzarella is combined with other cheese varieties such as cheddar, parmesan or feta. As a general rule, pizza blends require at least 50% mozzarella in the final blend in order to create a final cheese blend with good stretch. A combination of mozzarella with cheddar provides a quick melt and a sharp flavour, while a combination of mozzarella with feta provides flavour development and contributes to browning.

3. *Which cheese is best for colour development on a pizza?*

In general, whole milk cheeses exhibit little or no browning, while part skim cheeses yield some browning during cooking. Hard cheeses such as parmesan brown well, although they do not melt easily, therefore,it is best to place Parmesan under the mozzarella in order to prevent undesirable browning.

4. *How should I test oiling off for a pizza cheese blend?*

The best way to test for oiling off is to test the blend on a pizza base containing just the tomato paste and the cheese, since meat ingredients used as pizza toppings, such as ham or salami, can also contribute to oiling off.

5. *Can Mozzarella Cheese be frozen?*

Mozzarella can be frozen; however freezing changes the texture of cheese, making it unsuitable for fresh applications, but is ideal for cooking.

To freeze, place mozzarella in an airtight, snap lock freezer bag. To use the cheese, thaw it slowly overnight in the fridge, and then use it as quickly as possible within cooked dishes. Frozen mozzarella should be thawed and used within 2 months of freezing.

Processed Cheese

1. *What is the difference between processed cheese foods and processed cheese spreads?*

   Processed cheese foods are products that may contain dry milk, whey solids, or anhydrous milk fat added, which reduce the total amount of cheese the finished product. Processed cheese foods must contain at least 51% of the cheese ingredient by weight, have a moisture content of less than 44%, and contain at least 23% milkfat.

   Processed cheese spread is a product that may contain a sweetener and a stabilizing agent, such as xanthan gum or carrageenan, to prevent ingredient separation. Processed cheese spread must be spreadable at 21°C, contain 44-60% moisture, and have at least 20% milkfat.

2. *What is the shelf life of a processed cheese product?*

   The shelf life of processed cheese products varies, depending on how it has been manufactured. Processed cheese slices are cooled rapidly and thus have a shorter shelf life and require refrigerated storage. Block processed cheese is allowed to cool slowly over 24 hours. As it remains hot for several hours, it has a longer shelf life and is stored without refrigeration.

Customised Cheese Products

1. *What is the best way to store grated cheese?*

   Grated cheese contains a free-flowing agent that prevents clumping on storage, and will prevent a grated cheese product from clumping together if the cheese is kept for up to 3-4 days without refrigeration in a sealed container. If the opened bag of shredded cheese is not to be consumed within 3-4 days of being opened, it can be frozen, and used as frozen or thawed by placing it in the fridge and slowly letting it thaw. This, however, will change the internal structure of the cheese and may compromise the texture of the product.

2. *Will the storage of cheese powder affect its flavour and use in snack foods?*

   Like any perishable product, cheese powder will undergo changes if not stored under correct conditions. Exposure to air can cause deterioration in flavour due to oxidative rancidity, and colour deterioration can also occur due to non-enzymic Maillard reactions.

3. *Is cheese safe for pregnant women to consume?*

   The only cheeses that are unsafe for pregnant women to consume are those with a high water content, such as cheese that has been aged for less than 8 weeks, like the soft cheeses, camembert and brie. The high water content of soft cheeses can promote the growth of harmful bacteria, such as Listeria, E.coli and Salmonella. Listeria has been found to contribute to complications in pregnant women, from infection to premature birth or miscarriages.

   Other cheese varieties, such as cheddar, parmesan and eye cheeses are safe for consumption during pregnancy.

Glossary

Body

Body refers to the structure of a cheese product. Terms used include weak, firm, soft, close and flaky.

Browning/Blistering

Sensory attribute of cheese that occurs at the cheese surface during high temperature baking. It is characterised by the formation of a skin-like layer containing colour patches that may range from light or golden brown to black in extreme cases.

Curd

The soft robbery solid produced when milk is coagulated.

Elasticity

Elasticity, also referred to as flow resistance or 'strength of the stretch', is the resistance to elongation of the fibrous strands as they are stretched, which in turn inhibits flow.

Eye

The round openings found in certain cheese caused by gas formation by introduced bacteria.

Flowability

Flowability of cheese refers to the ability of a cheese, once it has melted, to flow. Cheese with a high flowability, such as a soft Cream Cheese, is desirable for use in cheese-filled meat applications such as a chicken cordon bleu, while a cheese with a low flowability, such as Haloumi, is more suited to fried applications, such as grilled haloumi.

Free oil formation

Free oil formation, also known as 'oiling off' or 'fat leakage', is the separation of liquid fat from the melted cheese body into oil pockets, particularly at the cheese surface

Individually wrapped slices (IWS)

Individually Wrapped Slices is a term used to describe processed cheese products that are sliced and individually wrapped for consumer convenience. The wrapping ensures extended shelf life, minimised wastage, and provides a hygienic barrier to the cheese.

Maillard reaction

Maillard Browning is a heat induced reaction that occurs between proteins and sugars during the baking of cheese.

Meltability

Meltability of cheese refers to the ability of cheese particles to join to form a uniform continuous melt when heated.

Slice on slice (SOS)

Slice on slice is a term that is used to describe cheese that is manufactured, and stacked in slices, without the use of individual wrapping. Slices are available in offset stacks for easy separation, and are commonly used in food service applications.

Stretchability

Stretchability of cheese refers to the ability of melted cheese strands to form cohesive fibres, strings or sheets that elongate without breaking under tension. It may also be referred to as stringiness.

References

Fox, P.F., Guinee, T.P., Gogan, T.M., McSweeney, P.L.H. (2000) 'Fundamentals of Cheese Science', Aspen Publishers, USA.

Fox, P.F. (1999) 'Cheese: Chemistry, Physics and Microbiology – Second Edition, Vol.1 General Aspects', Chapman and Hall, United Kingdom.

Roginski, H., Fuquay, J.W. and Fox, P.F. (2003) Encyclopedia of Dairy Sciences, Academic Press, London. Chapters of interest – Cheese as a Food Ingredient, pp.418-427.

US Dairy Export Council (1998) 'Reference Manual for US Cheese as Ingredients', US Dairy Export Council, USA.

DAIRY AUSTRALIA
Delivering for the dairy industry

9

Butter and Milk Fat Products

Content

203 9.1 Introduction

204 9.2 Brief Overview of Manufacturing Principles

209 9.3 Functionality of Milk Fat Products

215 9.4 Quality of Milk Fat Products

218 9.5 Applications of Butter and Milk Fat Ingredients

225 9.6 Conclusion

226 FAQ

231 Glossary

232 References

Abbreviations

AMF	Anhydrous Milk Fat
CLA	Conjugated Linoleic Acid
DAG	Diacylglycerol
FFA	Free Fatty Acid
FTV	Flavour Threshold Value
MAG	Monoacylglycerol
MFG	Milk Fat Globule
MFGM	Milk Fat Globule Membrane
MSNF	Milk Solids Non Fat
SCFA	Short Chain Fatty Acids
SFC	Solid Fat Content
SSHE	Scraped Surface Heat Exchanger
TAG	Triacylglycerol

9.1 Introduction

Milk Fat products include butter, spreads, blends, anhydrous milk fat (AMF), butteroil, frozen cream and butter powder. These products are used as ingredients in a range of food applications such as bakery, confectionery, sauces and soups as well as in various recombining applications. Understanding the end use of milk fat is essential to being able to provide an appropriate product that will match expectation.

The processing of milk into milk fat products requires that the fat globules are separated out into cream, leaving behind the skimmed milk portion. The cream is then further processed into butter by churning and phase inverting the cream to form a bulk fat phase.

Milk fat products are manufactured to certain standards and specifications that define their chemical, physical and microbiological characteristics. Other specifications may relate to the functionality of a milk fat product related to a specific application. The quality and functionality of milk fat products can be influenced by various factors including handling, processing, storage and seasonality.

The milk fat product types discussed in this chapter include:

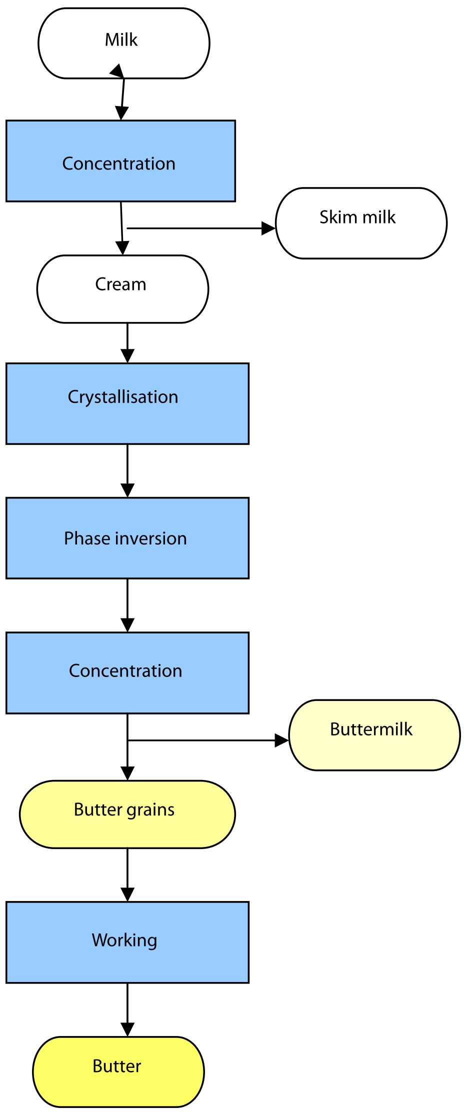
- **Butter**, which can be divided into two main categories, sweet cream butter and cultured or sour cream butter. It may be further categorised according to salt content: unsalted, reduced salt, salted or extra salted.
- **Dairy blends**, which have a similar fat content to that of butter (80%), however only 70-80% of this is milk fat, whilst the remaining 20-30% is vegetable fat. Milk fat is also a component of reduced fat and low fat dairy spreads products.
- **Milk fat blends**, where milk fat is blended with other ingredients to specification for a particular purpose. Milk fat blends may include milk fat blended with cocoa, sugar, oil, coconut oil, flour or other ingredients for use in bakery or confectionery products. This enables manufacturers to save time and costs associated with ordering separate ingredient products as well as simplifying the manufacturing process.
- **Anhydrous Milk fat (AMF)**, which comprises almost pure milk fat (99.8%). AMF can be

manufactured either from cream or from butter. Its manufacture from cream involves the concentration of milk fat, phase inversion and oil concentration. Anhydrous milk fat is semi-solid at room temperature with a light yellow colour which melts to a bright yellow or golden coloured liquid on heating. Anhydrous milk fat has a clean and bland flavour which is free from foreign flavours and odours.

- **Frozen cream**, which can be prepared with fresh, low acid cream, with desirable flavour and 40-70% fat. The intended use of the frozen cream is an important consideration with respect to whether or not the retention of the milk fat in globule form is required.

This chapter considers the manufacture, specifications, functionality, applications and nutritional aspects as they relate to these milk fat products and then considers a range of frequently asked questions.

Figure 1 Process steps for buttermaking



9.2 Brief Overview of Manufacturing Principles

9.2.1 Butter

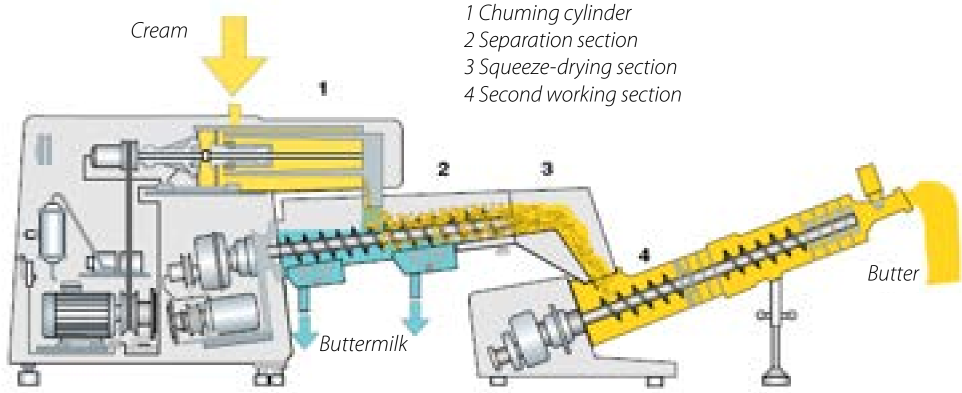
There are a number of stages involved in the manufacture of butter, with many factors influencing the functionality and quality of the butter at each stage. The basic steps in the butter making process are shown in Figure 1.

The first step is to concentrate the fat by separating the milk into cream and skim milk portions. The cream then goes through various treatments to prepare the fat for the churning step where phase inversion occurs.

Cream preparation involves pasteurisation, vacreation, cooling and ageing.

- **Pasteurisation** – In order to kill all pathogenic and most spoilage microorganisms as well as inactivate lipolytic and proteolytic enzymes, the cream is pasteurised at 85-110°C for 10-30s.
- **Vacreation** – The cream may be vacuum deodorised by exposure to reduced pressure to remove undesirable flavours or aromas.
- **Cooling** – The cream is generally shock-cooled to 6-8°C to initiate fat crystallisation, although slow cooling may also be used.
- **Cream ageing** – The cream then undergoes a physical ripening stage to optimise the

Figure 2 A continuous buttermaking machine



consistency of butter. The process lasts several hours at successive temperatures in order to control fat crystallisation within the fat globules. The heat treatments used for the cream will influence the final properties of the butter and relates to the fatty acid/triglyceride composition of the milk fat.

- Cold-warm-cold ripening (hard fat)
- Warm-cold-cold ripening (soft fat)

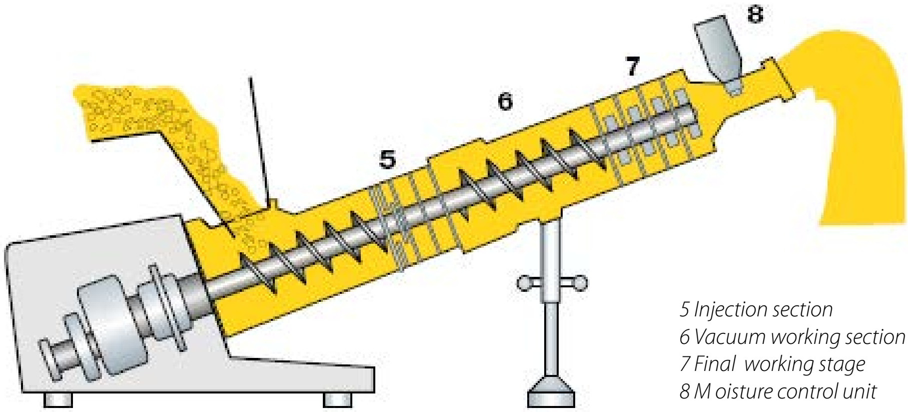
Once the cream is ripened and the fat is in an appropriate state of crystallisation, it is ready for the churning stage.

The churning process involves a mechanical agitation of the cream which continues until the fat globules begin to destabilise and lose their protective membranes releasing liquid or 'free' fat. The fat globules begin to stick together or agglomerate and become visible as yellow 'grains' of butterfat. Eventually, partial phase separation and phase inversion occurs, and most of the aqueous phase removed as buttermilk. Butter granules are then worked and the remaining water is finely dispersed (water-in-oil emulsion). Working the butter involves the kneading together of the grains, the squeezing out of further buttermilk, and the mixing and shearing of the resulting butter mass.

There are several types of continuous buttermaking machines available, with most following the principles of the Fritz method. A sectional view of a butter maker is shown in Figure 2. The prepared cream is first fed into a double-cooled churning cylinder (1) fitted with beaters that are driven with a variable speed motor. Rapid conversion takes place in the cylinder and, when finished, the butter grains and buttermilk pass on to a separation section (2), also called the first working section, where butter is separated from the buttermilk. As it leaves the separation section the butter passes through a conical channel and a perforated plate, into the squeeze-drying section (3), where any remaining buttermilk is removed. The butter grains then proceed to the second working section (4).

A more detailed view of the second working section, also known as a vacuum working section, is shown in Figure 3. Following the last working stage, salt may be added by a high-pressure injector in the injection chamber (5). The vacuum working section (6) reduces the air content of the butter

Figure 3 The vacuum working section



and is connected to a vacuum pump. The final working stage (7) is made up of four small sections, each of which is separated from the adjacent one by a perforated plate. Perforations of different sizes and working impellers of different shapes are used to optimise the treatment of the butter. Moisture content is also regulated in this section through an injector. Transmitters (8) for moisture content, salt content, density and temperature can be fitted in the outlet from the machine. The signals from the instruments can be used for automatic control of these parameters. The finished butter is discharged from the end nozzle as a continuous ribbon into the butter silo for further transport to the packing machines.

9.2.2 Spreads and Blends

There are many varieties of milk fat based spreads available, categorised mainly according to the total fat and milk fat content as shown in Table 1. Different manufacturing processes are used commercially depending on the starting material/s.

Vegetable oil is added to the milk fat to improve the spreadability of the product at refrigeration temperatures. In some processes, the oil is added to the cream and blended prior to churning.

Dairy Blends

Mixtures of butter and up to 50 per cent of edible vegetable oils help to make it spreadable from the refrigerator. Retaining the taste of butter, they are a dairy alternative to margarine.

Table 1 Categories of milk fat blends and spreads

Product	Fat ontent %	Milk fat %	Vegetable oil %
Butter	80	100	-
Dairy blend	80	50 min	50 max
Reduced fat dairy spread	30-60	50 min	50 max
Low fat dairy spread	<30		

Reduced Fat Dairy Spreads

These products contain between 30 per cent and 60 per cent in total fat of which at least half must be milk-fat. The remaining ingredients may include water, milk proteins, cultures, herbs, spices, gelatine, vitamins, sugar or salt.

Low Fat Dairy Spreads
This category of table spreads have a total fat and oil level below 30 per cent to which milk, vegetable proteins, flavourings, herbs, spices, vitamins, sugars, gelatines and starter cultures may be added. These spreads are not recommended for cooking due to their high moisture content.

Milk fat blends may also include customised blends of milk fat with a variety of other ingredients for particular applications such as cocoa, sugar, oil, coconut oil, flour or other specified ingredients.

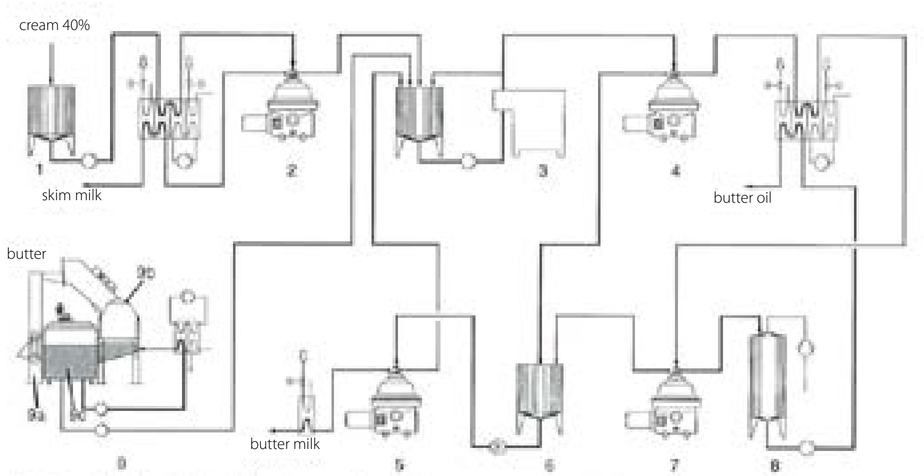
9.2.3 AMF

Anhydrous milk fat can be manufactured via two methods depending on the starting material. One method uses cream as the fat source, and the other uses (stored) butter as the fat source. In both cases, production starts with preconcentrating raw milk to a 35-40% cream, as for buttermaking, following the same quality requirements. The cream is pasteurised and either churned or directly processed into butteroil. The flow-sheet of a typical plant for the manufacture of AMF from cream or butter is shown in Figure 4.

AMF may also undergo additional refining processes for various purposes including:

- Polishing – involves washing of the oil with hot water to obtain a clear, shiny product.
- Neutralisation – to reduce the level of FFA present in the oil.
- Vacuum dehydration – vacuum drying at about 90°C to further reduce moisture and remove some of the more volatile flavour compounds.

Figure 4 AMF process flow sheet



Flow-sheet of typical plant for the manufacture of anhydrous milk fat (AMF) from cream or butter. 1, cream; 2, cream concentrator; 3, homogenizer (emulsion breaker); 4, oil concentrator; 5, buttermilk separator; 6, buttermilk balance tank; 7, polishing separator; 8, vacuum dryer; 9, butter-melting system - (9a) elevator (9b) block cutter (9c) melting tank. (By courtesy Westfalia Separator, Oelde, Germany.)

9.2.4 Frozen Cream

Production of frozen cream is a two stage process, which includes the manufacture of cream followed by the freezing process.

Cream Production

Production of cream with approximately 40% butterfat is standard practice for buttermaking, while a variety of other fat levels from 30% up to 48% are produced for table cream. In all cases the cream should be fresh and of good quality. Pasteurisation methods depend on the customer's specification with some preferring a slightly nutty taste historically associated with vacreation and the reduction of volatile flavours, while others prefer standard plate pasteurisation with a small de-aeration step.

Frozen Cream

Cream intended purely for ingredient use where the retention of the fat emulsion is not important, may be frozen without any special precautions. In other cases where it is required that the properties of the defrosted product closely resemble those of natural cream, fast freezing to prevent damage to the MFGM is essential.

Fresh cream flavour and maintenance of a majority of the cream emulsion at fat levels of 30 to 48% is readily achievable by cooling quickly to 6 to 8 degrees in a wide gap plate cooler then packing and blast freezing quickly. Cream for further processing can be stored for periods of 6-10 months at temperatures below –18oC if handled properly.

High Fat Frozen Cream

Most of the demand for butterfat in the form of high fat frozen cream is in the export arena and, as it is expensive to transport water. Depending on the import regulations of the customer, these fat levels can range from 55% up to 75% with stipulations on functionality, flavour and texture on thawing.

The fat content of cream will affect the freezing process, from the pre-cooling stage through to the thawing stage. As the fat content increases to 70% it becomes more difficult to maintain this emulsion to the point where retention of 80% of the emulsion is a practical maximum without the use of stabilisers or emulsifiers.

The higher the fat content of the cream:

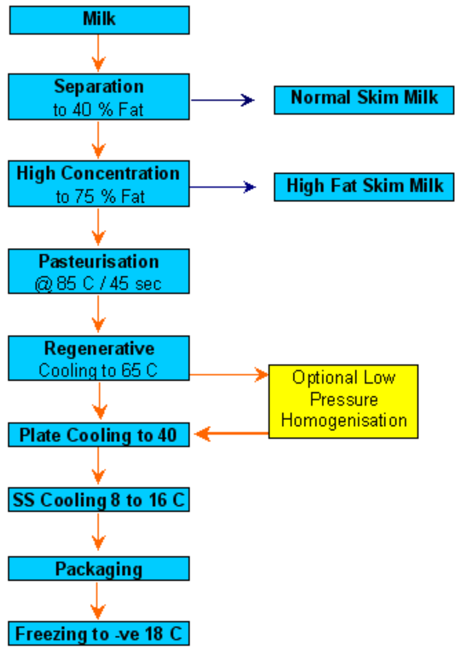
- the harder it is to maintain the emulsion.
- the thicker and higher the viscosity of the cream.
- the longer the cream will take to cool and freeze.

Cream with a higher fat content will thicken considerably at low temperatures and because of this, it should not be chilled below 10℃, and should be frozen within 4 hours of cooling otherwise the viscosity will prevent consistent freezing during filling.

For a high fat cream product, this precooling is usually conducted in a scraped surface heat exchanger (SSHE). The SSHE consists of a jacketed cylinder with a rotating dasher holding rows of scraper blades. Product gets pumped through the cylinder whilst the cooling medium is circulated between the cylinder and the jacket. SSHE's are designed to continuously remove product from the heat transfer cylinder wall. This is essential for the successful cooling of products that have large particulates, high viscosity, or would crystallise during cooling. The scraper blades prevent any build-up on the cylinder wall and optimise thermal exchange and run time.

The subsequent increase in viscosity associated with high fat cream then requires a second cooling stage using scraped surface heat exchange and is represented in Figure 5.

Figure 5 Frozen cream process flow diagram



Depending on the functionality required, low-pressure homogenisation could be used as means of controlling the viscosity of the cream, while declustering the fat globules and maximising the contact of available protein over the surface of the fat globules. Homogenisation also decreases the average size of the fat globules depending on the pressures used so that quick freezing can result in smaller average crystal sizes.

9.3 Functionality of Milk Fat Products

9.3.1 Milk Fat Functionality

Chemistry of Milk Fat

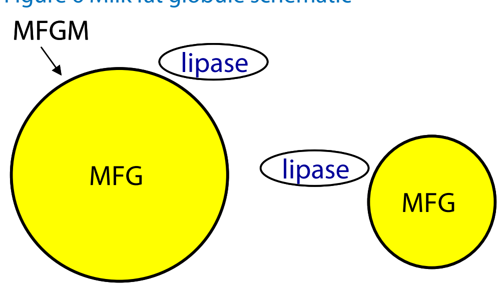
Milk is a complex food and there are many factors that can affect its composition. The milk fat component is present at around 3.9% and exists in the milk as an emulsion of small milk fat globules dispersed in the milk serum.

The milk fat globules are stabilised by a milk fat globule membrane (MFGM), which surrounds the fat globules, protecting the fat from attack by lipase enzymes and keeping the fat suspended in the milk. The fat globules range in size from 0.5 to 5µm in diameter and there are some 15 billion globules per ml.

Triacylglycerols form the major component of milk fat, whileL diacylglycerols, monoacylglycerols, phospholipids, fatty acids, sterols, carotenoids, vitamins and trace elements form the minor components of milk fat.

An example of the structure of a triglyceride is given below in Figure 7, where fatty acids are attached to a glycerol backbone in three positions. Fatty acids can differ in the length of the carbon chain and the degree of saturation. The type and amount of the individual fatty acids making up the triglycerides determines the physical properties of the milk fat. The shorter the carbon chain and the more unsaturated the fatty acids, the lower the melting point. Therefore, the more unsaturated fatty acids a fat contains, the

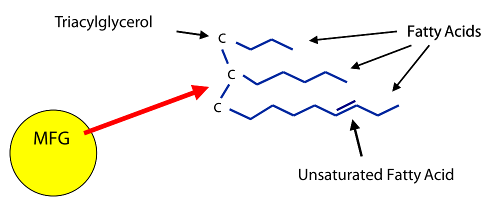
Figure 6 Milk fat globule schematic



softer the milk fat will be.

The fatty acid composition of milk fat is quite diverse and includes a high level of short-chain fatty acids from butyric (C4) to capric (C10) acids. Table 2 shows a typical fatty acid composition in milk fat. This fatty acid composition can vary throughout the year, leading to variation in the triacylglycerol composition and therefore physical properties.

Figure 7 Triacylglycerol schematic



Physical Properties of Milk Fat

Milk fat is one of the most complex fats, made up of a wide variety of triacylglycerols. Milk fat is liquid above 40ºC and usually completely solidified below –40ºC. At intermediate temperatures, such as room temperature, it is a mixture of crystals and oil, the oil usually being the continuous phase. The state of crystallisation affects many properties, for example:

- the susceptibility of globules to churning or clumping
- the resistance of the globules to disruption
- consistency and mouthfeel of high fat products
- and in some conditions, the creaming rate

Melting Range

Pure compounds have a sharp and constant melting point, but mixtures of many components like milk fat have a long and variable melting range, because of the large differences in melting point of the many component triacylglycerols.

The melting properties of fats can be examined by a solid fat content (SFC) analysis, where the proportion of fat in the solid state is measured over a range of temperatures. Examples of typical solid fat content diagrams are given for comparison in Figure 8 for butter, a blend of butter with vegetable oil and margarine.

As shown in Figure 8, although at room temperature (20ºC) the three samples have similar % solid fat

Table 2 Fatty acid composition of milk fat

Carbon Number	Common Name	Melting Point (°C)	Type	Typical Composition (% w/w)
4:0	Butyric	-8	short chain, saturated	3.9
6:0	Caproic	-4	short chain, saturated	2.5
8:0	Caprylic	17	short chain, saturated	1.5
10:0	Capric	32	medium chain, saturated	3.2
12:0	Lauric	44	medium chain, saturated	3.6
14:0	Myristic	54	long chain, saturated	11.1
16:0	Palmitic	63	long chain, saturated	27.9
18:0	Stearic	70	long chain, saturated	12.2
18:1	Oleic	16	long chain, unsaturated	21.1
18:2	Linoleic	-5	long chain, unsaturated	1.4
18:3	Linolenic	-10	long chain, unsaturated	1.0
Others				10.6

contents, at refrigeration temperatures (5°C), the % solid fat contents are quite different and reflect the relative spreadability of the three products. This is an example of the behaviour of milk fat in the bulk fat phase, however the behaviour of milk fat in the globular form, as in cream, will be different.

Lodine Value

The iodine value is an indicator of the hardness or softness of the milk fat. The iodine value states the percentage of iodine that the fat can bind. Lodine is taken up by the double bonds of the unsaturated fatty acids. Since oleic acid is by far the most abundant of the unsaturated fatty acids, which are liquid at room temperature, the iodine value is largely a measure of the oleic acid content and thereby the softness of the fat.

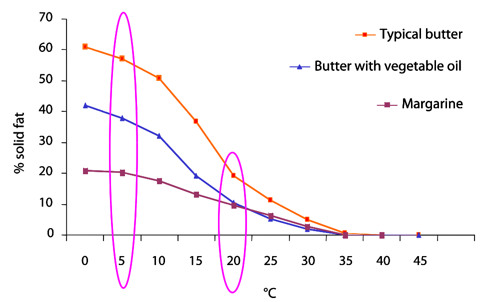
The iodine value of butterfat normally varies between 24 and 46. The lower the iodine value, the "harder"the milk fat. For butter of optimum consistency, the iodine value should be between 32 and 37.

Butter Functionality

Flavour

Flavour is one of the most critical attributes of milk fat, and the likely effect of processing and handling on the flavour needs to be carefully considered. A large number of compounds, many of which are below their individual flavour thresholds, contribute to the overall balance or profile perceived.

Figure 8 Solid fat content diagrams for butter, a butter blend and margarine.



Flavour is a complex sensation arising from both the aroma and the taste. The aroma comprises compounds which are sufficiently volatile at body temperature to reach the nasal receptors, while tastes, such as sour and bitter, are usually attributed to more water-soluble compounds detected on the palate. The perceived flavour is influenced not only by the volatility of the various components, but also by the rate of release from the food. A complex emulsion such as butter, which contains both water and fat constituents, can vary in flavour depending on the melting properties of the fat, as well as on the distribution of the aqueous phase within the fat matrix.

Numerous factors play a role in the development of butter flavour, including the diet and breed of the cows, and the season and stage of lactation. In addition, more than 120 flavour compounds have been identified in butter. It is not completely understood to what degree or how all the flavour compounds in butter interact. However, there is general agreement that a few primary flavour compounds are the principal flavour components in butter including: free fatty acids, methyl ketones, lactones and dimethyl sulfide.

- **Fatty Acids**

  Flavourful fatty acids play an important role in the flavour of butter and are present at varied concentrations. Although long-chain fatty acids are present at higher concentrations in butter, they do not make a significant contribution to flavour. Short-chain fatty acids (SCFA), on the other hand, do play an important role in butter's flavour.

Typically, SCFA are found in the serum portion of butter (aqueous solution of all non-fat components) where their flavour potential is stronger. They occur below their Flavour Threshold Value (FTV): the minimum concentration level below which aroma or taste is not detected. Despite low concentrations, SCFA act together to provide characteristic flavours found in butter. Butyric acid is the most widely known and most potent SCFA and is attributed to providing intensity to fatty acid-type flavours associated with butter. Butter also contains a variety of fatty acid precursors, such as 4-cis-heptenal, a compound which provides butter with a creamy flavour.

However, high levels of free fatty acids (released from the triglycerides by a lipolysis reaction) are undesirable in milk fat products, firstly because the SCFA's can contribute to an off flavour typified by butyric acid and secondly because they can catalyse the oxidation reaction.

- **Lactones**
  In fresh butter, precursors to lactones and free lactones exist in small concentrations. Free lactones exist in the lipid phase of butter, where they have higher threshold values. Despite their low concentration in fresh butter, free lactones are important flavourants, which act in an additive manner to impart the perceptible sweet, fruity flavours characteristic of butter. Upon heating, the lactone precursors are converted to lactones and their total concentration rises above their FTV. Thus, they provide the rich flavour notes commonly associated with heated foods containing butterfat. Lactones in butter are also the major source of flavour in confections and high-quality candies where they provide the unique, pleasurable flavours associated with these products.

- **Methyl Ketones**
  Methyl ketones exist in their precursor form in fresh butter as alkanoic acids. As such, they may be only marginally important in contributing to the flavour of fresh butter. However, when heated, the precursors are converted to methyl ketones and their total concentration rises above their FTV. Thus they are very important in providing flavours associated with heated or cooked foods containing butter. Diacetyl is another ketone flavourant and is very important in providing the rich or heated note in butter flavour. Diacetyl is also the primary flavour compound in starter cultures and distillates which are used in producing cultured butter.

- **Dimethyl Sulfide**
  Dimethyl sulfide is originally derived from the feed of cows and occurs in butter at concentrations above its FTV. Dimethyl sulfide helps to smooth the harsher flavour notes of diacetyl and other acidic substances in butter and is also largely responsible for the freshly cooked note associated with freshly churned butter.

Flavour of Cultured Butter

Cultured butter differs in flavour from sweet cream butter. Cultured butter has a more pronounced, distinct flavour which stems from starter cultures that are added to the cream during churning. Starter cultures are typically mixtures of flavour concentrates produced by one strain or mixed strains of bacterial cultures. ***Streptococcus diacetilactis*** produces diacetyl, the flavor most commonly associated with flavored butter and ***Streptococcus lactis*** is used to produce lactic acid, which contributes to the acidic flavor typically associated with cultured butter. Cultured butter has a lower pH (4.4-5.6) compared to sweet cream butter (pH 6.0).

Functional Properties

Colour and Appearance

The natural yellow colour of butter, in combination with its smooth, slightly matt surface appearance, gives a particular impression of richness. A 'faultless' butter cuts cleanly when sliced and does not appear greasy or shiny. The yellow colour mainly results from β-carotene (provitamin A) which, dissolved in butterfat, originates from green plant nutrients in fresh or silaged feed. Lush spring pasture produces the highest levels of carotene in the milk fat, but these levels fall as pastures mature in summer, and rise again in autumn. Lower milk fat carotene levels result from dried feeds such as hay, grain and other feed concentrates. Milk fat from pasture-based dairy industries is thus more yellow than from many other areas, and varies throughout the season.

Texture and Mouthfeel

The texture of butter is rather specific and due to the specific melting properties of the butterfat. Butter undergoes a rapid meltdown in the mouth, is readily converted to an oil-in-water emulsion, releasing volatile and water dissolved flavours. The heat required for melting the fat is drawn from the mouth resulting in a cooling sensation.

Setting and Work Softening

Freshly produced butter increases in firmness on keeping, at a fast rate initially and then more slowly over time. This process, called setting, can be attributed to a reversible build up of network structure. Work softening, where the crystal network is broken down by mechanical working, results in the butter becoming soft again.

Spreadability

One of the main disadvantages of butter is its poor spreadability at refrigeration temperature. Butter is a mixture of solid and liquid fats at most handling temperatures. Spreadability begins to become acceptable below solid fat levels of 45%. To obtain optimum spreadability, the butter must be allowed to soften at room temperature.

There are many factors that can influence the spreadability of butter including:

- *Seasonal diet and lactation stage* – This can lead to variation in the fatty acid and triacylglycerol composition of the milk fat, altering the ratio of solid and liquid fat at particular temperatures.
- *Physical cream ripening* – by special temperature treatments of the cream prior to churning the fat, changes to the resulting butter properties are possible which relate to controlling the microstructure of butter in terms of the spatial arrangement of solid and liquid fat, the size, number and shape of fat crystals and the overall ratio of solid to liquid fat.
- *Work softening* – Butter that has been stored can be mechanically reworked to break down the crystal network that has built up and result in a softer butter.

Other approaches to improve the spreadability of butter including whipping, blending and fractionation.

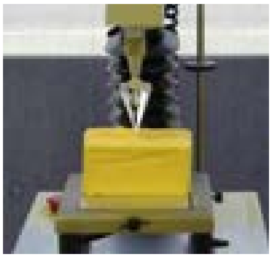
Measurement of Textural Properties

Many techniques have measured the textural properties of butter, with butter hardness using a cone penetrometer being the most widely reported. Typically, hardness is determined by placing a cone on the surface of a butter sample and measuring the force required to depress the butter a certain distance.

9.3.2 Frozen Cream Functionality

Frozen cream is used in a number of applications where cream is required. The main uses for frozen cream rely on its flavour, functionality and fat content. From a consumer perspective, the purpose of freezing cream is to increase convenience, giving a product that can be stored for an increased shelf life and, if properly processed, can be of a quality equal to the fresh product.

When using this cream, customers have a variety of functional requirements, from basic butterfat supply for recombining, through to good whipping properties for cake toppings. Cream intended for ingredient use is suitable for reprocessing into cream soups, recombined milk, butter or ice cream, where pasteurisation and homogenisation will restore the original fat emulsion or churning will continue to induce fat (butter) separation.



There are many drivers for the use of frozen cream, including:

- **Price** – relative to other fat sources or fresh cream and taking into consideration costs of storage;
- **Flavour** – major reason for use, however may be used in applications where flavour is not critical;
- **Convenience** – in terms of addition to process, ease of handling or to have a consistent ready supply available in frozen storage; and
- **Storage** – need to have facilities available to handle the transport and storage of frozen cream (-18°C).

Thawing

When using frozen cream, the thawing process is in the control of the end user and is usually the result of what facilities they have at hand, rather than a designed thawing facility. The main issues revolve around thawing time, which is a function of temperature differential, mechanical energy and time. Different combinations can have differing effects on the flavour, functionality and microbiological quality of the thawed cream. The functionality requirement in the end product will determine whether slow or fast thawing is the better option. This area is normally developed between supplier and customer depending on the intended use of the cream and the economies of scale.

Pasteurised Cream Functional Properties

The basic functional attributes of cream include:

- **Flavour** – The unique natural flavour of cream adds richness to many foods and enhances other flavours in food products. Due to the narrow melting range of the milk fat in cream, cream provides a quick release of flavours.

- **Texture** – Cream adds a rich, smooth viscosity and mouthfeel to many food products such as soups and sauces, primarily due to the milk fat and the fat-protein network created during homogenisation.
- **Fat-soluble ingredient carrier** – The milk fat in cream acts as a carrier of fat soluble vitamins and aids in the even distribution of other fat soluble ingredients.
- **Emulsification** – The natural proteins present in cream act as emulsifiers and aid in emulsification, aeration, foaming and overrun to give products such as whipped cream and ice cream a smooth and stable texture.
- **Browning** – Cream contributes to the browning of cooked foods through the Maillard browning reaction of the proteins and lactose found in cream. The Maillard reaction will also contribute to brown flavours in cooked food products containing cream.
- **Whitening colour** – Cream adds a whitening effect in products such as coffee. The colouring power of cream depends on the suspension of particles within the cream. Large particles in cream such as fat globules and casein, reflect and scatter light creating a whitening effect.

9.4 Quality of Milk Fat Products

9.4.1 Milk Fat Quality

Milk fat products are manufactured to certain standards and specifications that define their chemical, physical and microbiological characteristics. Example specifications for several milk fat products are given in Table 3. Other specifications may relate to the functionality of a milk fat product related to a specific application. The quality and functionality of milk fat products can be influenced by various factors including handling, processing, storage and seasonality.

Table 3 Example specifications for milk fat products

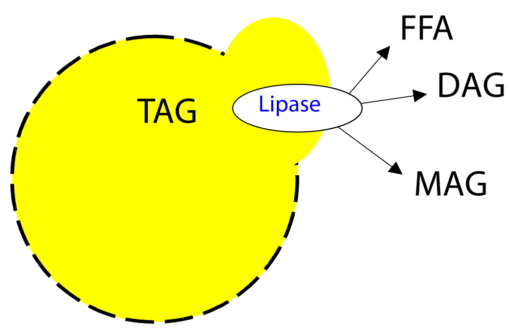
	Butter	Unsalted Butter	AMF
Chemical and physical specifications			
Fat (%)	80.0 min	82.0 min	99.9 min
Moisture (%)	16.0 max	16.0 max	0.1 max
Salt (%)	1.4-2.4		-
Flavour and odour	Satisfactory	Satisfactory	Satisfactory
Appearance and colour	Satisfactory	Satisfactory	Satisfactory
Peroxide value (meq.O_2/kg)			0.1 max
Free fatty acids (%)			0.3 max
Microbiological specifications			
Standard plate count Cfu/g	20 000 max	20 000 max	<1000
Yeasts and moulds			<50/g

Food manufacturers using butter must also work carefully to ensure that the maximum flavour potential of the ingredient is maintained. Butter should be stored in dry, tightly sealed, poly-lined cartons, away from highly aromatic food. Storage rooms should have controlled humidity of 80-85 percent. Butter stored under refrigeration can be kept for up to four months at 0-3°C and for up to one year at -23 to 29°C.

There are several reactions that can occur involving milk fat that are detrimental to the flavour and functionality of the milk product. Milk fat can undergo hydrolytic (lipolysis) and oxidative (oxidation) rancidity.

Lipolysis is the breakdown of fat into glycerol and free fatty acids catalysed by lipase enzymes. The development of free fatty acids and in particular, short chain free fatty acids can lead to off flavour development. Flavour defects are often called rancid, astringent, bitter, butyric and lipolytic. However this can only occur if the milk fat globules have been damaged, exposing the fat as shown in Figure 9.

Figure 9 Lipolysis schematic



The native lipase enzymes naturally present in the milk are inactivated during pasteurisation. Contaminating psychrotrophic bacteria can also produce heat-stable lipases (microbial lipases) that are active after pasteurisation, even though the bacteria have been destroyed. It is the heat-stable lipase that can continue to act during storage, producing off-flavours over time.

Treatments that damage MFGM and induce lipolysis are called activation treatments and can include agitation, temperature fluctuations, homogenisation and foaming or air incorporation. Care must be taken during processing to minimise the effects of these treatments.

Spontaneous lipolysis usually occurs on farm and is initiated by cooling to less than 10°C. This type is typically associated with cow factors and can be inhibited by the mixing of spontaneous and 'normal' milks.

Lipolysis can be detected through a number of different methods based on chemical or sensory (taste, smell) properties. The by-products of lipolysis can be analysed, particularly free fatty acids, which can be measured through a titration. The amount of 'free fat', that is amount of fat not contained in fat globules, can be measured as an indicator of the degree of damage to the MFGM and therefore the percentage of fat available for attack by lipase. Particular 'lipolysed' flavours might also be detected by sensory grading to determine the acceptability of a product.

A high microbial count in the raw milk may also indicate that the milk is contaminated and will be prone to lipolysis through the lipases produced from the contaminating bacteria. High microbial counts are usually accompanied by high free fatty acid levels.

Oxidation is the reaction between oxygen and the unsaturated fatty acids in the triacylglycerols. The oxidation reaction requires the presence of oxygen and is catalysed by light, heavy metals such as copper and iron, and by certain reaction products. It results in a metallic off-flavour and gives butter an oily, tallowy taste. Lipolysis can promote oxidation, as it occurs more readily in free fatty acids than those attached to a triglyceride molecule.

The reaction begins when an energetic form of oxygen (singlet oxygen) attaches to an unsaturated fatty acid adjacent to a double bond. The resulting intermediate hydroperoxide is stabilised by the presence of additional double bonds, so that the reaction rate of linoleic acid may be of the order of 20 times that of oleic acid. The hydroperoxide is detected by the peroxide value (PV) test and has no flavour, but rapidly decays through a variety of pathways to form highly flavoured compounds such as unsaturated aldehydes, ketones and fatty acids.

The inhibition of oxidation at low temperature is assisted by the fact that, during crystallisation, milk fat eliminates oxygen from the crystal structure. This factor, together with the reduction in oxidation rate with temperature, may partly explain why products stored frozen, such as butter and cartoned AMF, have better flavour than AMF stored at ambient temperature for the same time.

Assessment of Milk Fat Quality

The main tests used to assess milk fat quality are the peroxide value (PV) and free fat acidity (FFA). The PV test is used as a measure of how far the milk fat has deteriorated because of oxidation, whereas the FFA test is used to determine the extent of lipolytic deterioration. The International Dairy Federation (IDF, 1977) standard for anhydrous milk fat provides for a maximum PV of 0.2mEquiv kg-1 and a maximum FFA of 0.3% as oleic acid. The results of these tests give some indication both of the probable flavour quality, and of how rapidly further deterioration may be expected to occur.

9.4.2 Frozen Cream Quality

Freezing is a food preservation technique that works by slowing down the enzymatic and chemical reactions that can take place, thus inhibiting spoilage micro-organisms and pathogens. Freezing changes the physical state of a substance by changing water into ice when energy is removed in the form of cooling below freezing temperature. Usually the temperature is further reduced to storage level (-18^{o}C).

Water is made unavailable for the growth of micro-organisms by being in the form of ice. When water freezes, it expands by 9% in volume while forming ice crystals that vary in size depending of the rate of freezing – slow freezing gives large crystals, fast freezing gives smaller crystals. In the case of frozen cream, large crystals may damage the fat globule membrane resulting in the loss of emulsion stability and the formation of free fat on thawing.

It is important to realise that successful freezing will only retain the inherent quality present initially in the product and will not improve quality characteristics, thus quality level prior to freezing is a major consideration.

Cream

There are many factors that influence the quality of the cream during processing and on storage. Damage to the MFGM can result in the fat being released from the globule and forming free fat. Several damaged milk fat globules can also stick together resulting in aggregation or clustering of the fat globules as shown in Figure 10.

The freezing of cream in bulk containers increases its shelf life greatly but can also lead to gross separation of fat and serum solids upon thawing. Cream processed in this manner is suitable for

Table 4 Common butter defects

Defect	Possible Cause/s
Flavour	
Tallowy, rancid	Oxidation of the fat, especially due to air incorporation
Soapy	Contamination with cleaning agent residues
Rancid, old	Enzymatic fat decomposition, improper and too long storage of butter
Empty, bland	Insufficient flavour development
Texture	
Open (holes)	Insufficient working, temperature of butter at working is too high and the butter is too soft.
Free moisture	Insufficient working or incorrect churning temperature
Leaky butter (moist, open)	Churning at too high a temperature
Colour	
Mottled colour	Improper salt incorporation
Streaky, marbled	Uneven salt distribution, uneven working, blending of different butters

reprocessing into cream soups, recombined milk, butter or ice cream, where pasteurisation and homogenisation will restore the original fat emulsion or churning will continue to induce fat (butter) separation. Frozen cream can also be used in applications where the retention of the cream emulsion is important for functional properties, such as whipped toppings.

9.4.3 Butter Grading and Defects

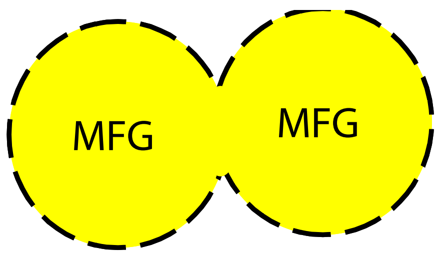
Butter can be graded using a points system to assess the quality of the butter. The maximum points allocated when grading butter is 100 with the flavour of the product accounting for 50 of the possible 100. For Body and Texture, the allocation is 30 points, and 20 points is allocated to Colour and Appearance. Butter can be graded into categories of Choicest (>93), first grade, second grade and pastry.

Trained graders are able to identify defects in the end product due to possible breakdowns in the manufacturing process. As with other products, points are deducted if defects in the flavour, texture, condition and colour of butter are noticed. Some common butter defects are outlined in Table 4.

9.5 Applications of Butter and Milk Fat Ingredients

Please note that the example recipes provided are available from the Dairy Australia website: www.dairyaustralia.com.au

Figure 10 Milk fat globules agglomerating



9.5.1 Non-Dairy Applications

Butter is an important ingredient in a range of non-dairy applications, primarily for its unique pleasant flavour.

Bakery

Butter and various tailor-made milk fat products are important ingredients for great tasting bakery products. The role of fat in bakery products depends on the specific individual use. Not only do milk fat products help to impart the characteristic flavour to fresh baked goods, but they also help in maintaining crumb softness, aid in the development of flaky crusts and pastries and provide significant added value. everal examples and typical levels of milk fat used in bakery products are given in Table 5.

Table 5 Use of milk fat in bake

Milk Enriched Bread	Butter	2
Scones	Butter	7-8
Pastry		
Sweet short crust	Butter	30
Short crust	Butter	21
Danish	Butter	23
Puff	Butter	30-34
Croissants	Butter	44
Cakes		
Madeira	Butter	20
Butter sponge	Butter	7-8
Biscuits		
Sweet biscuit	Butter	20-30
Shortbread	Butter	20-33

Flavour

Milk fat and butter is used for many reasons in baked goods, but one of the primary reasons is for flavour. Butter is used to add a rich, unique flavour to pastries, cakes, biscuits, pies and breads. Milk fat and butter can also act as a flavour carrier for fat-soluble ingredients, spices, herbs and sweet flavours.

Although there are over 120 different compounds that contribute to butter's unique flavour, the five primary factors responsible for butter's flavour include: fatty acids, lactones, methyl ketones, diacetyl and dimethyl sulfide. Methyl ketones and lactones are the primary components responsible for the cooked flavour associated with baked goods made with butter. Both methyl ketones and lactones are present in fresh butter at levels which are below their Flavour Threshold Value (FTV) or below the concentration at which their taste is perceptible. Upon heating, however, the total concentration of both lactones and methyl ketones exceeds their FTV. The two compounds also react in a synergistic manner, providing the rich flavour associated with baked goods made with real butter. The methyl ketones and lactones also interact with the flavours developed through the Maillard reactions (browning reactions between sugars and proteins) which occur during baking. The combination of all flavour compounds contributes to the overall appeal and flavour of the finished baked good.

Functional Properties

Milk fat and butter provide various functional properties to different bakery products.

Pastry

- Butter is the ideal ingredient for the development of a flaky crust or pastry dough. For pastry doughs, butter should be kept as hard and cold as possible so that the fat remains solid and separates layers of dough with a well-developed gluten network. When butter is trapped between layers of dough, it melts during baking, making the batter slightly more fluid or flexible. Carbon dioxide, which is released during baking, travels more easily to the air pockets left by the butter. The air pockets trap the carbon dioxide and the resulting dough is flaky.
- For puff pastries, a near-waxy consistency of the layering fat is required. To make puff pastry, cold butter is mixed into the flour to form a short consistency. The dough is then rolled around a thick slab of butter under a series of folding, turning and rolling steps until the butter is dispersed throughout the dough. The final dough contains hundreds of this dough layers separated by butter films. Butter causes the pastry to rise. When pastry is heated, the butter

melts and boils, creating steam which lifts each dough layer higher and higher during baking. Butter also contributes to flavour and colour development within the pastry during baking.

Example: Apple Tarte Tatin (short crust pastry)
Chilled butter is blended with other ingredients in a food processor under high speeds until a dough is formed. Bake at 200°C for 20-25 minutes until golden.

Butter is added chilled so that when baked, it combines with the other ingredients to form a well-developed structure. As the fat melts during cooking, butter acts as a binding agent, while the cooking also promotes the release of buttery flavour notes. Butter also contributes to the golden appearance of baked pastry products.

Cake

- In cake batter, butter should be thawed prior to use and creamed well with the sugars to dissolve sugar crystals, incorporate air and ensure a complete, even distribution in the final batter. In most other bakery applications, butter can be added either in its solid or melted form.
- Butter helps to improve crumb softness by retarding the development of gluten, coating the strands, making them shorter and hence keeping the product tender. As a result, butter contributes to the tenderness of cakes, breads and biscuits.

Example: Lemon Blueberry Cupcakes with Fluffy Lemon Frosting.
Butter accounts for 14% of the total cake formulation, and is beaten with the sugar and baked at 180°C for 15-20 minutes.

The high butterfat content of butter contributes to the air bubbles incorporated within a cake batter. Lots of air bubbles in the fat ensure maximum aeration, which creates a cake batter with good volume and a soft crumb. Butter provides tenderness and flavour to the batter, as well as contributing to batter volume.

Biscuits

- Butter also functions as an emulsifier, resulting in better distribution of the ingredients throughout the dough, and helping to prevent "fat bloom" spoilage in biscuits.
- Milk fat and butter also add to the visual appeal of bakery products by contributing a golden yellow colour.

Example: Caramel Yo-Yo Biscuits.
Butter accounts for 25% of the total biscuit formulation. Butter is creamed with sugar and is baked at 190°C for 12-15 minutes.

Example: Basic Butter Shortbread.
Butter accounts for 20% of the total biscuit formulation. The butter is beaten together with the sugar until the two have creamed. The product is baked at 160°C for 12-15 minutes.

In both of the above cases, butter provides a fat surface that coats all the other biscuit ingredients, assists in the binding of ingredients, and contributes to the rich buttery flavour of the biscuits.

Confectionery

Many confections are made with butter and milk fat products, as they provide unique flavour and mouthfeel. The role of fat in confectionery products depends on the specific individual use. Several examples and typical levels of milkfat used in confectionery products are given in Table 6.

Flavour

As in bakery products, butter's flavour is important and confections which use butter typically require heating to bring out the full flavour and create a rich, buttery taste. Butter also interacts with flavour components which result from Maillard reactions (browning reactions between sugars and proteins), creating flavour notes traditionally associated with caramels, pralines, and toffee. Most sources agree that a good quality caramel must be made using condensed milk and butter.

Butter can also function as a flavour carrying agent for other ingredients, including vanilla and sweet spices. Food manufacturers producing confections with cream centres can use butter to produce a myriad of new flavours while maintaining the desired texture of the filling.

Functional Properties

- Butter contains 0.24 percent lecithin, a natural emulsifier. Although naturally present in small quantities, it performs a variety of important functions in confectionery products. The lecithin in butter aids in the emulsification of fat and aqueous products which would otherwise not mix thoroughly. This is important for the mouthfeel of the product and it improves the overall product stability. In addition, emulsification aids in moisture control, thereby helping to extend the shelf life of many confectionery products.

- The lecithin in butter is particularly important in helping to prevent stickiness in high sugar solutions, especially with products like caramels and toffee. Butter thus aids in simplifying the production of confections which otherwise might be difficult to handle.
- Butter characteristically has a sharp Solid Fat Index (SFI) curve which stems from butter's narrow melting range (28-36°C). The sharp SFI curve of butter at these temperatures ensures quick flavour release and complete melting of butter at body temperatures, for a "melt-away" effect. This aids in smooth mouthfeel, which adds to the eating qualities and is of particular importance in confectionery products. Confections made with oils which have broader SFI curve at these temperatures tend to have a waxy mouthfeel and do not offer pleasant chewing characteristics. In addition, they have poor flavour release as compared to confections made with butter.

Example: Chocolate Fudge Squares.

Butter accounts for approximately 8% of a total fudge formulation. The butter is melted on low heat in a saucepan with sugar-based ingredients until smooth. Butter contributes to a rich, buttery flavour and is added at the final stages to provide smoothness and inhibit large crystal formation.

Table 6 Use of milk fat in confectionery

Confectionery Product	Milk Fat Product	Typical Usage Levels (%)
Milk chocolate	AMF	5-7
Caramel	AMF	2-3 (softer, lighter caramel)
	AMF	5-8 (harder, darker caramel)
Fudge	Butter	2-3 (soft ball)

Chocolate

Milk fat contributes to the flavour and smooth texture of chocolate. One of the most functional properties of milk fat is its ability to form part of the continuous fat phase as a result of its compatibility with cocoa butter. Milk fat can be used to replace a portion of cocoa butter in many confectionery formulations to reduce costs.

Anhydrous milk fat can be added with skim milk powder as a replacement for the combined protein/fat source of full cream milk powder. The advantages of the SMP/AMF combination is that 100% of the fat is available as free fat. This may reduce the viscosity of the chocolate and therefore reduce the quantity of cocoa butter required in the formulation to obtain a specific viscosity.

The use of milk fat in chocolate may provide a creamy flavour and a softer texture in milk chocolate when compared to dark chocolate. Milk fat can be added in very small quantities to dark chocolate to prevent 'fat bloom' and ensure the product remains visually appealing to the consumer.

Sauces

Milk fat and butter have many functional advantages when used as an ingredient in sauces. Not only does butter provide a unique, rich flavour, but it contributes to the smooth, creamy mouthfeel of sauces as well. Butter works well with sweet and savoury sauces, and is an important ingredient in dessert toppings, such as butterscotch. Several examples and typical levels of milkfat used in sauces are given in Table 7.

Flavour

Butter is used most often in sauce applications for its unique, delicious flavour. Butter flavour compounds not only react with one another, but with other flavour compounds as well, providing a full-bodied flavour. Butter can be used to provide the primary, characteristic flavour of a sauce, as in Bechamel-type sauces, or in dessert toppings, such as butterscotch. It can also be blended with other ingredients to add rich dairy background flavour notes, as in pasta sauces and gravies.

Butter can be heated to different temperatures to produce characteristic flavour notes associated with different sauces. For example, lightly melted butter is typically used in creamy, white sauces, such as Hollandaise, Bordelaise or Bernaise, to provide rich, dairy notes. Slightly overheated butter provides roasted, cooked notes which complement brown sauces and gravies. Overheated, unburned butter will contribute flavour notes which complement flavours in barbecue and smoke flavoured sauces.

Functional Properties

- Mouthfeel and flavour are two of the most important characteristics of a sauce. Butter also provides a smooth, creamy consistency to sauces, which can be attributed to the mixture of nonfat milk solids and fatty acids naturally present in butter. The nonfat milk solids provide butter with body and mouthfeel, which are then transmitted into the final sauce.
- Butter is unique in that it can also solubilise other flavours to create full-bodied condiments and uniquely flavoured butters. Butter can solubilise sweet spices and vanilla for sweet sauces and toppings, and herbs and spices for savoury applications, for added flavour. Butter's ability to function as a flavour carrying agent has led to the development of numerous types of flavoured butters which include, among others, dill, garlic and fennel. Manufacturers can create a wide variety of products simply by flavouring the butter itself or using the butter to solubilise other flavours.
- Butter aids in the even distribution of oil-soluble flavours throughout sauces and soups. Butter can sometimes be used as the sole emulsifier in sauces. Its narrow melting range ensures quick flavour release and complete melting of butter at body temperatures for a "melt-away" effect, which aids in smooth mouthfeel.
- Butter contributes a visually appealing golden colour, or a darker color after heat treatment, to sauces and soups.
- Example: Bechamel Sauce.
- Butter accounts for ~7% of the total Béchamel sauce formulation. Butter is melted in a saucepan, and the flour is stirred in to the melted butter. This mixture is cooked until golden and just bubbling. Butter is used to provide a fat coating to the flour, enabling it to form a smooth heated product. Butter also contributes to the flavour and colour development within a sauce.

Table 7 Use of milk fat in sauces

Sauces	Milk Fat Product	Typical Usage Levels (%)
White sauce	Butter	3
Bernaise sauce	Butter	30
Bechamel sauce	Butter	7
Butter sage sauce	Butter	75

Example: Cheese Ravioli with Butter Sage Sauce.
Butter accounts for ~75% of the total content of the sauce. The butter is melted in a saucepan until hot and foamy. Sage leaves are added, cooked for 2 minutes until crisp, and then removed. Spring onions are added and sauted for 30 seconds. Heated melted butter acts as a flavour absorber for savoury ingredients, and also assists in creating a fried effect in savoury ingredients. Hint: Cook butter over medium heat, taking care not to burn it. Butter should be light brown with a nutty flavour.

Example: Banana Split with Butterscotch Sauce.
Butter accounts for ~23% of the total butterscotch sauce formulation. Butter is combined with brown sugar and sour cream and is simmered on the stovetop until the sugar has dissolved and the sauce is slightly thick. Butter contributes to flavour development in butterscotch sauce.

9.5.2 Dairy Products

Recombining

Recombined milk products are defined as the milk products resulting from the combining of milk fat and milk solids non fat, with or without water. This combination must be made so as to re-establish the product's specified fat to solids non-fat ratio and total solids content. Other ingredients used in the formulation of recombined milk products include a country's local milk or cream supply, and, where permitted, vegetable oils such as coconut or palm. The term "filled"is used when all or some of the milk fat is replaced with vegetable oil. Products that can be recombined include fluid milk in pasteurised or sterilised form, UHT fluid milk, thickened cream and creamers, evaporated milk, sweetened condensed milk, and ice cream. Several examples and typical levels of milk fat used in recombined products are given in Table 8.

Unsalted butter can be used in the manufacture of recombined milk products, but it must be kept under refrigerated storage. AMF is the most common source of milk fat for recombination, which can be kept at ambient temperatures.

The fat must be added at a temperature above its melting point. To assure this, AMF must be added at above 40ºC. Milk fat packed in cans can be melted by immersion in hot water at 80ºC for 2-3 hours. Drums of AMF, however, require longer melting times. The drums can be stored in a hot room at 45-50ºC for 24-28 hours before use, or in a steam chest or tunnel, which can melt the contents of the drums in about 2 hours. Once melted the AMF should be transferred to a jacketed holding tank with facilities for maintaining the temperature.

Table 8 Use of milk fat in recombined products

Recombined product	Milk Fat Product	Typical Usage Levels (%)
Recombined Sweetened Condensed Milk (RSCM)	AMF	9
Ice cream	AMF	10
Recombined cream	AMF	35-45
Recombined milk	AMF	1-4

The fat should not be added to the reconstituted milk until the hydration period is complete. Addition of fat at the same time as or before the addition of milk powder should be avoided, as this can lead to processing problems and impaired product quality. An emulsifier is often added to facilitate and improve the emulsification of the milk fat. It is important to thoroughly mix the fat to ensure a uniform distribution. During continuous operation the melted fat is normally metered into the line followed by thorough mixing in a static or a mechanically operated mixer before entering the homogeniser.

Ice Cream and Dairy Desserts

Milk fat, butter and cream are important ingredients in ice cream, ice cream confections and many dairy dessert applications.

Ice cream is a frozen mixture of a combination of milk components, sweeteners, stabilisers, emulsifiers and flavouring. This blend, called the 'mix', is pasteurised and homogenised before freezing. During freezing the mix is agitated vigorously to incorporate air, thus imparting the desirable smoothness and softness of the frozen product. Formulation of the mix is the most important part of the ice cream manufacturing process, to ensure a mix that is balanced with respect to milk fat, MSNF, sweeteners, flavouring and stabilisers.

Manufacturers use milk powders for milk solids, and/or anhydrous milk fat for their milk fat requirements. Milk solids provide the overall body and texture of the ice cream with milk fat the major source of flavour and colour. Fresh or frozen cream can also be used in ice cream manufacture. Several examples and typical levels of milk fat used in ice cream and dairy desserts are given in Table 9.

Functional Properties

- Milk fat accounts for most of the rich, creamy taste of ice cream, provides body and contributes to the smooth texture.
- Butter is used extensively throughout the dairy industry in variegates, particulates, and toppings such as toffee bits and caramel swirls, and contributes to their "creamy" flavour.

There are a range of classifications for ice cream based on the composition and types of ingredients. The milk fat contents of each category are shown in Table 9. In general, economy ice creams are made with more economical ingredients, while the super premium products are more likely to be made with fresh concentrated milk and cream.

Table 9 Use of milk fat in ice cream and dairy desserts

Ice Cream and Dairy Desserts	Milk Fat Product	Typical Usage Levels (%)
Ice cream		
Non-fat ice cream (hard)	AMF/cream	<0.8
Low-fat ice cream (hard)	AMF/cream	2-5
Light ice cream (hard)	AMF/cream	5-6
Reduced-fat ice cream	AMF/cream	7-9
Economy ice cream	AMF/cream	10-12
Regular ice cream	AMF/cream	11-13
Premium ice cream	AMF/cream	12-15
Super premium ice cream	AMF/cream	14-20
Desserts		
Vanilla pudding	Cream (35% fat)	13
Chocolate mousse	Cream (35% fat)	15
Fromage frais	Cream (35% fat)	20
Custard	Butter	6

9.6 Conclusion

Milk fat products, such as butter and cream, are versatile food ingredients that are used in a variety of dairy and non-dairy applications. Milk fat products contribute to the flavour of foods, providing buttery or cooked flavour notes on heating or acting as a flavour carrier. Milk fat products also contribute in a functional way, particularly through their unique melting properties, to many foods by adding to the mouthfeel, texture and structure.

FAQ

Quality of milk and cream

1. *How does lipolysis affect flavour of milk fat products?*

   There is a fine balance between attractive and undesirable flavour depending on the level of different compounds in specific products. Low levels of fatty acids contribute to the flavour of milk fat products. Off flavours in butter and anhydrous milk fat can be caused by lipolysis before or after manufacture. Off-flavours originating before manufacture are mostly due to milk lipase action and result in soapy, bitter and 'back palate' taste sensations at manufacture. This is characterised by a high FFA content at manufacture. Lipolysis occurring during storage is due to heat stable bacterial lipase action and results in characteristically sharp, butyric, 'front palate' flavours. This type of lipolysis occurs more readily in butter because of its higher water content.

2. *How are off-flavours in milk fat minimised?*

   To minimise off flavours, manufacturers need to handle the milk carefully to ensure that the milk fat globule is not damaged during initial processing of the milk which can lead to lipolysis of the milk fat and the development of off flavours.

   There are various factors that can promote lipolysis in raw milk before pasteurisation due to the handling and storage of the milk.

   At the farm, the various handling procedures usually involve milking, pumping and bulk storage before pick up to factory. Problems can be introduced through excessive air intake at the milking stage, at the claw or teat cups, milk hose and loose line joints. Pipelines that rise, particularly vertical sections connecting one pipe to another at a higher level and excessively long pipelines can contribute to damage to the milk through a constant mixing of milk and foam. If the inlet pipe in the holding tank is too high, excessive splashing and agitation can occur when filling the tank. Addition of fresh warm milk to previously cooled milk may cause thermal activation. Prolonged storage times can also allow the growth of psychrotrophic bacteria, which grow at refrigeration temperatures and can produce heat-stable lipases. This means that they can survive pasteurisation and continue to be active in manufactured products.

   The main source of activation in the factory is from pumping (especially if foaming is also occurring). The same factors apply to the bulk storage tank at the factory as at the farm. To prevent and minimise lipolysis, manufacturers can:

   - Avoid excessive agitation, foaming and turbulence
     – check pipes for leaks, avoid long pipelines and / or high speed pumping
     – avoid excessive stirring
   - Pasteurise milk as soon as possible, minimise storage time
   - Pasteurise milk before homogenisation (or if not practical, immediately after)
   - Control temperature of storage
   - Store pasteurised milk at appropriate refrigeration temperatures to minimise lipolysis by microbial lipases
   - Maintain a high hygiene standard

Processing and manufacture of milk fat products

1. *What are the different temperature treatments for cooling of cream prior to ageing and churning based on various iodine values?*

Before churning, the cream is subjected to a program of temperature treatment which will control the crystallisation of the fat so that the butter will have the desired consistency. The consistency of the butter can be optimised if the temperature treatment is modified to suit the iodine value of the fat. The higher the iodine value, the higher the content of unsaturated fatty acids and the 'softer' the milk fat. The temperature treatment regulates the amount of solid fat to a certain extent – this is the major factor that determines the consistency of butter. Table 10 gives examples of programs for different iodine values. The first temperature is the value to which the cream is cooled after pasteurisation, the second the heating/souring value and the third the ripening value.

2. *What is the role of vacreation in milk fat processing?*

Off-flavors can be removed from milk and cream by the process of vacreation, where steam is injected into the product and removed, along with the unwanted flavors, under a partial vacuum.

3. *What is the effect of reworking on butter consistency?*

The firmness of butter usually increases with time, eventually reaching a maximum after about 3 weeks or more depending on the temperatures to which it has been subjected to before and after packing. This results from the development of two types of secondary crystal structure:
1. the weak, thrixotropic, association of many small (<1µm) fat crystals to form a three-dimensional structure
2. realignment and stronger bond development between larger fat crystals.

Mechanical reworking of butter causes work softening due to irreversible destruction of the stronger bonds and temporary disruption of the weaker links. Therefore, in practice, butter reworked from bulk 25kg blocks is softer than the same butter put into retail packs directly from the butter maker.

4. *What is the effect of head space and dissolved oxygen in AMF drums on oxidation and flavour?*

The shelf-life of AMF can be extended at ambient temperature by minimising the oxygen in the package. At the time of packing, oxygen can be present both in the liquid product (dissolved oxygen) and in the headspace gas. he solubility of oxygen in milk fat at 40oC is approximately 38 mg/kg for milk fat saturated with air. Dissolved oxygen in AMF is usually reduced to less than 1 mg/kg by the vacuum deaerating step in the manufacturing process and each subsequent pumping operation or exposure to air in the balance tanks or silos will rapidly increase the level. The level of dissolved

Table 10 Principal temperature programs adjusted to the iodine value

Iodine Value	Temperature Program (°C)
<28	8-21-20
28-29	8-21-16
30-31	8-20-13
32-34	6-19-12
35-37	6-17-11
38-39	6-15-10
>40	20-8-11

oxygen in the AMF at packing therefore reflects the efficiency of the post-manufacturing handling and filling operations. Sparging with nitrogen gas can help reduce the dissolved oxygen levels in AMF, although there seems to be a lower limit of about 4 mg/kg. Minimising the oxygen levels during storage will minimise any oxidation reactions that can lead to off-flavour development in the AMF.

Storage and handling of milk fat products

1. *What are the most suitable storage conditions for butter?*

Butter must be protected from moisture evaporation and light-induced photo oxidation which can spoil its flavour and appearance. Butter should be stored at a low temperature, in a cool dark place. Butter is best kept refrigerated at 4˚C, protected from light and sealed in its original container or wrapping until it is used, as it readily absorbs odours from other foods. Salted butter will keep longer than unsalted butter because the concentration of salt in the aqueous phase is high enough to inhibit growth of many organisms. Always check the use-by date, to ensure natural freshness and quality.

Butter will keep refrigerated for up to eight weeks, but it is best to obtain butter when required rather than storing it. Properly sealed, butter may be kept frozen at -15ºC for 4-6 months and at -18 to -23ºC for up to 12 months. Butter should be placed in the refrigerator to thaw prior to use.

2. *How do I thaw frozen cream?*

Thawing is a reversal of the physical processes used for freezing. Fat melts at higher temperatures than those at which it solidifies. The production of liquid cream generally requires a temperature above 35ºC for the fat to be emulsified and blended. The thawing technique used will depend on the intended application and whether or not retention of the emulsion is required.

Instant thawing

In this case, the frozen cream can be broken up mechanically while being heated and melted on a continuous basis. This limits the possibility of microbiological growth, but can cause major phase separation as the water phase is in the form of ice crystals, which mechanically shear the fat structure, while not allowing sufficient time for the protein to re-hydrate. This method is suitable in applications where homogenisation is an essential part of the process. In some cases microwave technology can be incorporated as the heat source.

Slow thawing

Slow thawing introduces a number of difficulties and requires much more rigorous controls as it can take up to a week depending on the end use.

Optimum temperature during thawing is < 5ºC for three main reasons:

- To minimise bacterial growth in the external layers as these thaw first and remain at the thawing temperature for the duration of thawing.
- To maximise re-absorption of the water phase by the protein. A 2 to 10% whey off can normally be expected, depending on the processing and freezing methods used. This is

normally recovered when processed.

- Higher temperatures, such as 20 ºC can bring on severe rancidity within 24 hours, as there is insufficient protein to protect all the triglycerides from hydrolysis by lipase enzymes.
- Experience has shown that this method results in maximising protein hydration over time, which helps maximise retention of the cream emulsion.

Functionality and Applications

1. *What is the difference between AMF, butteroil and ghee?*

In general AMF and butteroil are exclusively obtained from cow's milk, cream, or butter by means of processes which results in almost the total removal of moisture and solids not fat. Ghee can be made from milk, cream or butter from various animal species and is almost pure milk fat that has been heat treated during processing to obtain a cooked flavour and intense yellow colour. Specifications for the various concentrated milk fat products are given in Table 11.

Table 11 IDF Specifications for AMF, anhydrous butteroil, butteroil and ghee.

	Anhydrous Milk Fat (AMF)	Anhydrous Butteroil	Butteroil	Ghee
Definition of product	Water-free milk fat made from top quality milk, cream or butter and to which no neutralising substances are added.	Water-free butter fat made from cream or butter of any age.	Dry butter fat made from cream or butter of any age.	Ghee is made from milk, cream or butter from various animal species, contains almost no water or MSNF and has an especially developed physical structure
Milk fat Minimum	99.8%	99.8%	99.3%	99.6%
Water Maximum	0.1%	0.1%	0.5%	0.3%
Free fatty acids (%) maximum	0.3	0.3	0.3	0.3
Copper (ppm) maximum	0.05	0.05	0.05	0.05
Iron (ppm) maximum	0.2	0.2	0.2	0.2
Peroxide (meq O2/ kg fat) maximum	0.2	0.3	0.8	1.0
Coliforms	Negative/g	Negative/g	Negative/g	Negative/g
Taste and texture	Clean and bland (at 20-25oC)	No pronounced unclean or other objectionable taste and odour	Not too pronounced unclean or other objectionable taste and odour	Not unacceptable
Neutralising substances	None	Traces	Traces	Traces

2. *What is the effect of season on milk fat functionality?*

In a pasture based feeding regime, the different seasons result in changes to the grass growth and can influence the milk fat in number of ways. When green pasture is available for the cows, the milk fat tends to have a higher concentration of unsaturated fatty acids leading to a 'softer' fat which has a higher iodine value (~36). Regional variations in butter firmness can also exist and the stage of lactation can also affect the textural attributes of butter.

3. *Is there a difference in the flavour of milk fat from cows fed on pastures and on concentrates?*
Variation in the flavour of milk fat between countries and regions within countries can be attributed to the flavour compounds derived from the diet of the cow. In Australia, the dairy industry is pasture based. Different pasture types can also contribute to variation in milk fat flavour. In colder climates, where pasture growth is not supported, the animals are kept indoors and fed on grain or feed concentrates such as silage. It is known that certain feeds can contribute to off- or 'feed'- flavours in milk and the subsequent butter.

4. *Can I soften or melt butter in the microwave?*
The best way to thaw or soften butter is to transfer it from the freezer to the refrigerator, or remove it from the refrigerator to let it soften at room temperature. However, butter may be softened or melted in the microwave provided a medium heat power level is used for short intervals at a time and the butter checked in between. If you put the butter in the microwave for a few seconds to soften and it overmelts, use it for something else such as flavouring vegetables or as a dip. Make sure to soften some fresh butter for baking to achieve the right texture.

5. *What types of fresh cream are available and what can they be used for?*
Fresh cream can be divided into several categories based on the fat content as shown in Table 12. In all cases, the cream is required to have a standard plate count not exceeding 500 000 micro-organisms per millilitre and have a coliform count not exceeding 100 coliforms per millilitre (Food Standards Regulations, 1985).

Table 12 Types of fresh cream and suggested uses.

Cream Type	Milk Fat %	Suggestions for Use
Rich, Double, Pure, Pure rich, Thick or Double thick cream	45-60	• Dollop or spoon. It will hold its shape. • Accompaniment to dessert, puddings and soups. • Stir into hot dishes for richness.
Cream, Pure (pouring or thin), Thickened, Thick or Whipping	35	• Whip and add to sauces, soups, vegetable gratins, quiches and custards. Pour over desserts. Add to cocktails. • It has a light airy texture when whipped, so is ideal for cake fillings, mousses, ice creams and cheesecakes. • Pure cream is commonly used in reduction and pasta sauces. • Substitute for milk and butter in scone-making.
Lite, Lite Thick (thickened), or Light	18	• Pourable • Add to sauces, soups, drinks and desserts. • Not suitable for whipping.

Others

1. *Do butter and milk fat ingredients contain trans fat?*
Yes, but the level of ***trans*** fat in dairy foods and dairy ingredients is naturally very low. Milk fat is more saturated than many vegetable fats. As a result it is naturally more stable against oxidation, better able to crystallise and does not require hydrogenation - a process that can lead to the creation of unfavourable ***trans*** fatty acids. Milk fat is not completely free of ***trans*** fatty acids as small amounts of these molecules are naturally formed in milk as a result of

hydrogenation by microbes in the rumen.

In product formulations using dairy ingredients, total ***trans*** fat will depend on the percentage of dairy ingredients in the formula, serving size and the ***trans*** fat contribution from all ingredients.

2. *What is CLA?*
Conjugated linoleic acid (CLA) is a collective term used to describe one or more positional and geometric forms of the essential fatty acid linoleic acid. CLA is naturally present in cow's milk and beef and other ruminant meats. Milk fat, in particular, is the richest natural dietary source of CLA in the cis-9, trans-11 (c9, t11) configuration. Emerging research indicates that milk-derived CLA is highly bioactive and might hold anti-cancer properties as well as offer potential cardiovascular health benefits.

A variety of factors, such as the cow's diet, can influence the CLA content of milk fat. Because the CLA content of dairy products is related to their fat content, CLA levels are greater in higher fat than in lower fat products.

Glossary

Emulsion
An emulsion is a suspension of droplets of one liquid in another. Milk is an emulsion of fat-in-water, butter an emulsion of water-in-fat.

Fat globule
Fat globules are the droplets of fat in milk. The droplets are separated from the aqueous phase by a milk fat globule membrane that surrounds and contains the fat.

Fatty acid
A fatty acid molecule is composed of a hydrocarbon chain and a carboxyl group. Three fatty acids attached to a glycerol backbone comprise a triacylglycerol – the main fat component in milk.

Free fat
Free fat is fat which is easily extractible(fat not contained within fat globules) from milk or cream by a solvent under standard conditions of time, temperature and agitation.

Lipolysis
Lipolysis is the reaction catalysed by lipase enzymes where fatty acids are cleaved from the triglycerides resulting in free fatty acids and leads to the development of off flavours in the product.

Oxidation
Oxidation is a breakdown reaction of the milk fat that occurs at the double bonds of the unsaturated fatty acids in the fat. Oxidation can lead to a metallic off-flavour in milk fat products.

Phase inversion

When milk and cream are turned to butter, there is a phase inversion from an oil-in-water emulsion to a water-in-oil emulsion.

Triacylglycerols

Triacylglycerols are the main fat components in milk and are comprised of three fatty acids attached to a glycerol backbone.

References

Early, R. (1998) The Technology of Dairy Products (2nd edn), Blackie Academic & Professional, London.

Fox, P.F. and McSweeney, P.L.H. (1998) Dairy Chemistry and Biochemistry, Blackie Academic & Professional, London.

Food Standards Regulations, 1985, Standard Regulations 254, H2: Cream and cream products, p142-148, H6: Butter and butter products, p154-155.

International IDF Standard 166: 1993 Guidelines for fat spreads.

International Standard 68A: 1977 Anhydrous milkfat, anhydrous butteroil or anhydrous butterfat, butteroil or butterfat, ghee : standards of identity.

Roginski, H., Fuquay, J.W. and Fox, P.F. (2003) Encyclopedia of Dairy Sciences, Academic Press, London. Chapters of interest – Butter p220-236, Cream p545-557, Lipids p1544-1626.

Tetra Pak (1995) Dairy Processing Handbook

Tetra Pak Processing Systems AB, Lund, Sweden

DAIRYAUSTRALIA
Delivering for the dairy industry

10

Bioactive Dairy Ingredients

Content

234 10.1 Introduction

236 10.2 Colostrum

238 10.3 Glycomacropeptide

239 10.4 Lactoferrin

241 10.5 Lactoperoxidase

242 10.6 Casein and Whey Protein Hydrolysates

245 10.7 Milk Minerals

247 FAQ

252 Glossary

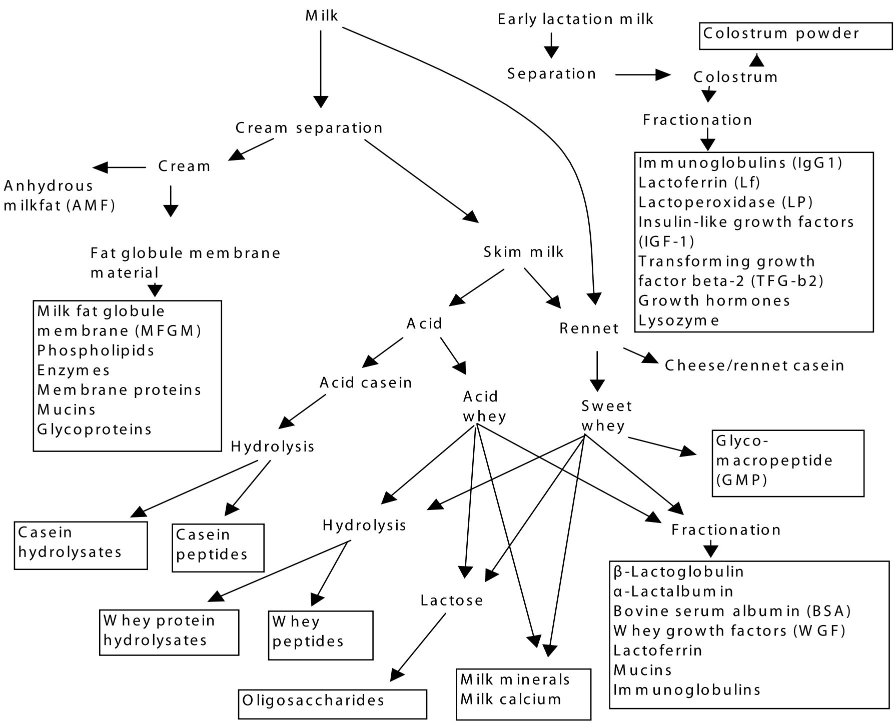
255 References

10.1 Introduction

Milk has been a source of nutrition for centuries but recent advances in analytical and biochemical techniques have helped in identification of several bioactive components and verification of their bioactivities from milk. Although many of the bioactive components from milk remain unexploited as commercial ingredients, developments in new processing technologies such as membrane filtration and ion exchange chromatography have stimulated commercialisation of some of the biologically active components from milk. The growth in functional foods and nutraceuticals offer new opportuntites for bioactive ingredients from milk.

Figure 1 Bioactive ingredients from milk.

**Some of the ingredients may not yet be available commercially.*



Milk contains bioactive components both in the lipid and in the skim part. Although the milk phospholipids have been commercially available from the lipid part for a while, other components are still under development. By far, skim milk and whey are the major bioactive-rich streams of milk and a range of bioactive ingredients have been commercialised. Further research and development, no doubt is likely to lead to commercialisation of more ingredients in future. This chapter highlights biological functionality and applications of major bioactive ingredients from milk and provides a list of frequently asked questions to help users of these ingredients.

Figure 1 shows some of the bioactive components identified from milk and summarises general processing steps employed during fractionation of milk into bioactive ingredients. One of the foremost bioactive-rich fluids produced by the cow is the colostrum. Colostrum provides life-supporting immune and growth factors that ensure the health and vitality of the newborn. Colostrum is a rich source of several bioactive components including immunoglobulins, lactoferrin, lactoperoxidase, lysozyme and several growth factors.

In order to fractionate, isolate and concentrate bioactive components from milk, the first step is separation of fresh milk into cream and skim milk. The cream part contains almost all of the fat globules, and the associated fat globule membrane that is a rich source of several bioactive components (see Figure 1). Skim milk is usually treated with acid or rennet to separate casein from whey proteins; both casein and whey streams then become raw materials for isolation of bioactive components. Although many biologically active peptide segments have been identified in casein (identified as casokinins), the current commercial product range is limited to casein hydrolysates and phosphopeptides. During cheese manufacture, part of κ-casein released in whey during rennet action is commercially available as glycomacropeptide (GMP). In the dairy industry, whey available from cheese manufacture remains the most abundant source of whey-based bioactive ingredients. Several bioactive ingredients have been commercialised from whey as shown in Figure 1. Among these are ingredients enriched in whole proteins (e.g. β-lactoglobulin, α-lactalbumin, lactoferrin and lactoperoxidase), hydrolysed forms of proteins (e.g. whey protein hydrolysates with varying degrees of hydrolysis), and milk minerals. Dairy manufacturers are actively researching and developing new physiological or bioactive ingredients from milk that no doubt will be available in the future.

Table 1 summarises the main biological functions of bioactive ingredients from milk.

Table 1 Biological function of bioactive ingredients from milk

Bioactive Ingredient	Potential Biological Function	Potential Food Applications
Colostrum	Immune factors, growth factors, anti-microbial	Sports formulation, calf feeding
Immunoglobulins	Antibacterial and immune enhancing	Infant formula
Lactoferrin	Iron binding ability responsible for many functions such as bacteriostatic effect, cell growth promotion, antioxidation and iron delivery and absorption	Infant formula, sports nutrition, meat preservation
Lactoperoxidase	Preservation effect. Bacteriostatic effect against Gram +ve bacteria and bactericidal effect against Gram –ve bacteria, e.g. Pseudomonads, Coliforms, Salmonella, Listeria	Food preservation in general, meat products
Casein and whey protein hydrolysate	Reduced allergenicity, increased protein absorption, increased peptide bioactivity, lowering blood pressure	Infant and enteral formulation, geriatric products, sports beverages, weight control diets
Casein and whey peptides	Fast absorption Non-allergenic	Infant and enteral formulation, isotonic beverage, sports nutrition
Caseinophosphopeptide (CPP)	Mineral carrier, helps in re-mineralisation and mineral absorption, protection against dental caries, antibacterial	High mineral beverages, chewing gum, breakfast cereals
Glycomacropeptide (GMP) or Caseinomacropeptide (CMP)	Satiety, low phenylalanine	Phenylketonuric diets, sports nutrition
Milk minerals and milk calcium	Bone health and osteoporosis	Mineral fortification of beverages, breakfast cereals

10.2 Colostrum

Colostrum is the first milk produced by a cow after the birth of a calf. Colostrum is a rich source of antibodies, growth factors and nutrients for the suckling neonate and may provide passive immunity to the newborn against various infectious microorganisms, particularly those that affect the gastrointestinal tract. It may also have other health benefits.

A comparison of the composition of colostrum obtained during the first three milkings of a cow with normal cow milk is shown in Table 2. As seen in the Table 2, the composition of colostrum rapidly changes with the increase in number of milkings. The first milking has the highest amounts of protein and bioactive ingredients such as immunoglobulins, and is normally fed to the calf. This is particularly important for the defence of the newborn calf as a newborn calf is born without antibodies in the blood that are critical for the proper function of the immune system. Colostrum differs considerably from normal milk. Colostrum contains over 10 times the amount of immunoglobulins present in normal milk (Table 3). Immunoglobulins are very heat-sensitive proteins, which makes the processing of colostrum into an ingredient a difficult process.

Table 2 Composition of colostrum[1]

Component	Milking Number after Birth of Calf			Normal Milk
	1	2	3	
Specific gravity	1.056	1.040	1.035	1.032
Total solids, %	23.9	17.9	14.1	12.9
Protein, %	14.0	8.4	5.1	3.1
Casein, %	4.8	4.3	3.8	2.5
IgG, mg/mL	48	25	15	0.6
Fat, %	6.7	5.4	3.9	3.7
Lactose, %	2.7	3.9	4.4	5.0
Vitamin A, µg/L	2950	1900	1130	340
Vitamin D, IU, g fat	0.9-1.8			0.4
Riboflavin, µg/L	4.8	2.7	1.9	1.5
Choline, mg/mL	0.70	0.34	0.23	0.13

Colostrum is also a rich source of growth factors as shown in Table 4. Growth factors are key regulators of a variety of cellular functions and are involved in the control of tissue growth and repair. Extensive research has identified a number of applications for their use in clinical medicine and biotechnology. The most important of these is likely to be a therapeutic potential in wound healing.

Table 3 Immunoglobulins found in bovine colostrum and normal milk[2]

Immunoglobulin	Colostrum (g/L)	Milk (g/L)
IgG1	52-87	0.31-0.4
IgG2	1.6-2.1	0.03-0.08
IgA	3.7-6.1	0.03-0.06
IgM	3.2-6.2	0.04-0.06

A general scheme for manufacture of colostrum ingredients is shown in Figure 2. Manufacture of colostrum powder or protein concentrate requires stringent quality control during collection, transport, processing, handling and storage so that the bioactivities of components are retained. Colostrum obtained from the first few milkings is generally pooled, and either frozen or transported chilled to the dairy processing facility. After separation of colostrum cream (which can be fed to the calf), the skim colostrum can be concentrated and dried into colostrum powder. In order to remove casein, skim colostrum is usually treated with rennet or acid, and the casein-free whey is used for development of colostrum whey powder or colostrum whey protein concentrate. Colostrum whey protein concentrate is particularly valuable as it is rich in bioactive protein components and contains low levels of lactose. Commercial drying of colostrum is either carried out by freeze-drying or by spray drying under mild temperatures.

[1] *Foley & Otterby (1978)*

[2] *Pakkanen & Aalto (1997)*

Bovine colostrum is marketed in several forms. Commercial colostrum products are available with immunoglobulin contents ranging from 16 to 50%. Composition of a colostrum product with 22% IgG is shown in Table 5.

Colostrum: Functionality and Applications

Colostrum products can provide a number of physiologically functional properties. The benefits of colostrum to the human body - from boosting the immune system to promoting cell repair are continually being researched and discovered. Major functionality and applications of colostrum include[3]:

- Source of growth factors
- Source of antimicrobial components
- Immune-enhancing properties and intestinal benefits
- Sports and performance applications

Source of growth factors

In addition to being a rich source of essential nutrients such as amino acids, carbohydrate, lipids and minerals, colostrum contains a range of growth factors that can stimulate healthy development of cells and tissues. Growth factors from colostrum and whey have been commercially available for some time. Growth factors present in colostrum include insulin-like growth factors-1 and 2 (IGF-1 and IGF-2), transforming growth factors – β1 and β2 (TGF-β1 and TGF-β2) and epidermal growth factor (EGF). Some of these factors are also present in regular milk but in very small amounts (100-1000 times less than colostrum). The IGFs stimulate the immune system, promote cell repair and growth, and influence how the body uses fat, protein and sugar. The IGFs acting as endocrine, autocrine and paracrine hormones enhance cellular glucose uptake stimulating synthesis of proteins, DNA, RNA and lipids. The amino acid sequence of bovine IGF-1 is identical to that of human IGF-1 and bovine IGF-2 differs from human IGF-2 by only three amino acid residues. Both IGF-1 and IGF-2 are heat-stable proteins that help in growth and differentiation of cells.

Table 4 Concentration of growth factors in colostrum and normal milk[2]

Growth Factors	Colostrum (μ/L)	Milk (μg/L)
IGF-1	50-2000	<10
IGF-2	200-600	<10
TGF-β1	n.d.	4.3
TGF-β2	n.d.	n.d.
EGF	n.d.	<2

IGF – insulin-like growth factor
TGF –transforming growth factor
EGF – epidermal growth factor
**n.d. – not determined*

Figure 2 Processing schemes for manufacture of colostrum based ingredients

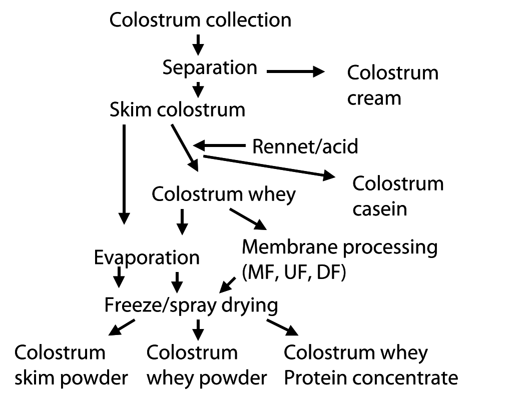


Table 5 Composition of a commercial colostrum product with 22% IgG.

Component	Amount
Moisture (%)	5
Protein (%)	75
IgG (%)	22
Ash (%)	6
Lactose (%)	10
Fat (%)	2
Lactoferrin (%)	0.3
Calcium (%)	1.5

3 Pakkanen & Aalto (1997)

Antimicrobial components

Colostrum is a rich source of antimicrobial compounds that can help in protection against infections. Antimicrobial components present in colostrum include lactoferrin, lactoperoxidase, lysozyme and immunoglobulins. Each of these components is available commercially in purified forms and discussed in more details in the later part of this chapter. Antibodies from colostrum in oral immunotherapy have aided treatment of various human infections, including those caused by antibiotic resistant bacteria[4] .

Immune-enhancing properties and intestinal benefits

One of the main reasons for hospital admission of infants and young children is infectious diarrhoea, usually caused by a rotavirus infection. Infants can also acquire rotavirus in hospital neonatal and paediatric wards; the infection can also be transmitted to adult members of the family. Colostrum has been successfully tried out in the protection against rotavirus and diarrhoea[5]. It has been suggested that infant formulas could be fortified with colostral immunoglobulins[6]. Colostrum may help protect the gastrointestinal tract against stomach cancers[7] and ulcers[8]. Colostrum has also been shown to prevent non-steroidal anti-inflammatory drug (NSAIDS)-induced gut damage. NSAIDS are given for the treatment of pain and are a common cause of gastritis.

Sports and performance applications

Colostrum appears to aid strength and speed in athletes, plus increase insulin, which has anabolic effects. Studies have shown that supplementation with bovine colostrum (20 g/d) in combination with exercise training for 8 weeks may increase bone-free lean body mass in active men and women[9].

Colostrum has been shown to enhance serum IGF-1, IgG, hormone and saliva IgA during athletes' training[10] . In clinical trials, IGF-1 is known to have strong anabolic effects on muscle tissue, as it is able to mimic most of the actions of growth hormones. IGF-I is of benefit to athletes, body builders and people concerned about weight because it can help burn fat and encourage lean muscle tissue.

10.3 Glycomacropeptide

Glycomacropeptide (GMP) is a hydrophilic peptide (amino acid residue 102 to 169) of κ-casein that provides stability to casein micelles in milk. When rennet acts on κ-casein during the manufacture of cheese, GMP is released into the whey. GMP makes up about 15% to 20% of the whey proteins. Recent advances in fractionation have allowed separation of GMP from cheese whey into commercial GMP-enriched ingredients. Due to the highly negative charge of GMP at low pH where whey proteins are positively charged, an ion exchange process can isolate GMP. When whey at pH 3 is contacted with a cation exchanger, the GMP is not adsorbed by the cation exchanger and may be concentrated and desalted by ultrafiltration. Alternatively, GMP from whey at pH less than 4 can be bound to an anion exchanger while the rest of the whey proteins are not bound. Pure GMP can then be eluted from the ion exchanger.

GMP is unique among some of the whey proteins in that it is a glycoprotein and, thus, has an oligosaccharide chain attached to it. It also is unique because it contains no phenylalanine, tryptophan or tyrosine. GMP also has high levels of the branched-chain amino acids, leucine, isoleucine and

[4] *Steven et al (1990)*
[5] *Davidson et al (1989)*
[6] *Seung et al (1995)*
[7] *Masuda et al (2000)*
[8] *Playford et al (2000)*
[9] *Antonio et al (2001)*
[10] *Mero et al (1997)*

valine. This composition of GMP gives it some unique characteristics that can be utilized in a variety of interesting applications. A small population has phenylketonuria (PKU), meaning they are unable to digest phenylalanine. GMP is one of the few amino-acid sources PKU patients can tolerate because the pure GMP does not contain phenylalanine.

Composition of a commercial GMP is shown in Table 6.

Table 6 Composition of a commercial GMP

Component	Amount
Moisture, %	5
Protein, %	80
GMP (% of total protein)	90
Sialic acid, %	4

GMP: Functionality and Applications

Published research has linked GMP with many physiological functions, including: promotion of bifidobacterial growth; suppression of gastric secretions; inhibition of bacterial and viral adhesion; modulation of immune-system responses; and binding of cholera and *E. coli* enterotoxins. In simpler terms, GMP offers potential benefits to intestinal health, appetite control, reduced dental caries, enhanced immunity and protection against diarrhoea.

Some of the bioactive properties of GMP are

- Anti-inflammatory[11]
- Toxin binding[12]
- Inhibition of bacterial and viral adhesion[13]
- Immune modulation and protection against diarrhea[14]
- Prebiotic effect[15]
- Source of amino acids for population suffering from phenylketoneuria (PKU)

Suggested applications of GMP are

- Dental care products such as toothpaste and mouthwash for prevention of dental caries and remineralisation
- Supplements and diets for PKU sufferers
- Prebiotic for probiotic supplements and foods
- Sports nutrition products as source of branched chain amino acids
- High protein diets for weight control

10.4 Lactoferrin

Lactoferrin is an iron-binding glycoprotein present in colostrum, milk and whey. Lactoferrin exists as a single peptide chain with a molecular weight of 77,000. It is folded into two globular units with each unit able to bind 1.4 mg of iron per gram of protein. Bovine lactoferrin is somewhat similar in structure to the human form, having approximately 70% of the same amino acids. The iron-binding ability of lactoferrin is responsible for many biological functions such as bacteriostatic effect, growth-promoting effect on certain cell lines, and prevention of lipid peroxidation and promotion of iron absorption in the body. Lactoferrin is one of few proteins in whey that are positively charged at pH 7.0 (isoelectric point of approximately pH 7.9) while most other proteins are negatively charged. This feature of lactoferrin has been exploited in commercial isolation of lactoferrin. Using cation based resins and selective salt solutions; lactoferrin can be separated from other positively charged proteins

[11] *Daddaoua et al. (2005)*
[12] *Kawasaki et al. (1992)*
[13] *Nesser et al. (1988)*
[14] *Otani et al. (1995)*
[15] *Azuma et al. (1985)*

attached to the resin. Further concentration of lactoferrin is carried out using ultrafiltration and spray drying. When reduced to its purest form, it is pink in colour. Commercially, lactoferrin is available in a range of protein concentrations. Due to the low amount present in milk and whey, the cost of separation is high and therefore, ingredient cost is high.

Table 7 shows the composition of a commercial lactoferrin powder.

Table 7 Composition of a commercial lactoferrin product

Component	Amount
Moisture (%)	5
Protein (%)	95
Lactoferrin (% of total protein)	90
Iron (%)	13
Ash (%)	1
Fat (%)	<1
Lactose (%)	<1

Lactoferrin: Functionality and Applications

Lactoferrin can provide several physiological functional (bioactive) properties, which are mainly derived from its ability to bind iron. Each molecule of lactoferrin can bind two atoms of iron. The main bioactive properties of lactoferrin include antibacterial and antiviral properties, antioxidant properties, immune modulation, and ability to carry iron.

Antibacterial and Anti-viral Properties

Lactoferrin inhibits the growth of pathogenic bacteria and fungi, due to its ability to bind large quantities of iron. Lactoferrin binds iron very strongly, thus rendering this essential nutrient unavailable to support microbial growth. Lactoferrin also disrupts bacterial digestion of carbohydrates, further limiting their growth. In addition, the action of pepsin in the stomach converts lactoferrin into lactoferricin, which has broad-spectrum activity against pathogenic bacteria and yeast. Lactoferrin also has the ability to bind to parasites and the outer membrane of Gram-negative bacteria, making the cell wall more permeable and, thus improving the efficiency of antibiotics.

Additionally, segments of the lactoferrin molecule can exert a direct bactericidal effect on certain strains of bacteria and is also thought to inhibit the attachment of bacteria to the gut wall, therefore reducing the probability of infection. Anti-viral effects of bovine lactoferrin against several types of viruses have been reported; lactoferrin appears to achieve this effect by inhibiting virus absorption and its penetration into cells.

Antioxidant Properties

Lactoferrin can be used as a natural antioxidant and may reduce the susceptibility to aging processes and disease. Lactoferrin provides protection against oxidative damage by scavenging excess iron, which catalyzes the undesired formation of free radicals from hydrogen peroxide produced as a result of microbial respiration, thus allowing the cell's own peroxidase to harmlessly break down the hydrogen peroxide.

Immune Modulation

Lactoferrin contributes to the defence against pathogens by activation of cells involved in the anti-inflammatory response during the course of microbial infection, thus enhancing the self-immunity.

Iron transport and absorption

Lactoferrin is an excellent iron carrier and increases the bioavailability of iron.

Commercial lactoferrin is suitable for applications in health supplements, functional foods and drinks, infant formulas, cosmetics and oral care products, as well as for animal feed. Examples of potential markets for lactoferrin are supplements for the elderly or immune-compromised patients; supplements for recovery from gastrointestinal infections; products used to stimulate the body's immune system to help deal with toxic environments, disorders or treatments; and prophylactic products for travellers' diarrhoea. Lactoferrin can be used in a number of food applications such as

- Sports nutritional formulations
- Infant formula
- Yogurt
- Meat applications
- Chewing tablets or gums
- Antioxidant in cosmetics

Lactoferrin can be added in the range 10-100 mg per 100 g of product. This broad application range requires knowledge on effective incorporation of this bioactive component based on the prediction of its properties during processing, storage and consumer use.

10.5 Lactoperoxidase

Lactoperoxidase [EC 1.11.1.7] is an enzyme present in colostrum and milk, with a molecular weight of approximately 77.5 kDa. Bovine colostrum and milk contain about 11-45 mg/L and 13-30 mg/L lactoperoxidase respectively[16]. In whey, lactoperoxidase constitutes approximately 0.5% of whey proteins[17]. The biological significance of lactoperoxidase is its involvement in the natural host defence system against invading microorganisms. Separation of lactoperoxidase from whey is based on the same principle as used for isolation of lactoferrin. Lactoperoxidase is positively charged at the normal pH of whey (isoelectric point in the pH range 9.0-10.0) and can be bound to cation exchange resins and fractionated from the rest of the whey proteins.

Lactoperoxidase inactivates or kills a wide spectrum of microorganisms through an enzymatic action. This reaction involves two cofactors, hydrogen peroxide and thiocyanate ions, which together with lactoperoxidase constitute the lactoperoxidase system (LP system). Activation of the enzyme results in the formation of hypothiocyanite ions, which are responsible for the antimicrobial action. The mechanism of the LP system can be described by the following reaction:

$$\text{Glucose} + H_2O + O_2 \xrightarrow{\text{Glucosxoidase}} H_2O_2 + \text{Glucuronate} \xrightarrow{LP+SCN^-} HOSCN/OSCN^-$$

The reaction of LP system relies on the production of short-lived intermediary oxidation products of the thiocyanate ion (OSCN-) that reacts with bacterial cytoplasmic membranes, as well as impairs the function of metabolic enzymes. As addition of H_2O_2 is not permitted in certain countries, in situ development of H_2O_2 is carried out by the addition of glucose oxidase (a permitted additive). The source of thiocyanate ion can be either naturally present (as in the case of animal tissues and plant), or added as sodium or potassium thiocyanate.

Commercially, lactoperoxidase is isolated from either skim milk or whey using an ion-exchange

[16] *Korhonen (1977)*
[17] *de Wit & van Hooydonk (1996)*

process similar to that used for isolation of lactoferrin. The basic principle underlying the process is the fact that lactoperoxidase has an isoelectric pH in the alkaline range (9.0-9.5) which means that it is positively charged at the normal pH of cheese whey (6.0 – 6.6) while rest of the proteins are negatively charged. This difference in pH is used to adsorb lactoperoxidase to an anion exchange column that is subsequently separated from other proteins. Gross composition of a commercial lactoperoxidase is shown in Table 8.

Lactoperoxidase: Functionality and Applications

Lactoperoxidase when used in the form of LP system has a broad spectrum of antibacterial activity, having a bacteriostatic effect against Gram-positive bacteria and a bactericidal effect against Gram-negative microorganisms, *e.g. Pseudomonads, Coliform, Salmonella and Listeria*[18]. The following are the examples of potential applications of lactoperoxidase:

Table 8 Composition of a commercial lactoperoxidase

Component	Amount
Moisture (%)	6.8
Protein (%)	91
LP (% of protein)	83
LP activity (ABTS method)	270
Ash (%)	2

- Use of LP system to improve yield of aquaculture by bactericidal effect on fish pathogens[19]
- Application of lactoperoxidase together with LP system activating ingredients (thiocyanate and hydrogen peroxide) in toothpaste formulations to protect against oral streptococci[20]. Activation of salivary peroxidase antimicrobial system in toothpaste and mouth rinse reduces acid formation by oral microorganisms and clinical studies have shown that plaque accumulation, gingivitis and early carious lesions and aphthous lesions may all be reduced by appropriate applications of the applied enzyme preparations[21].
- Promising results have been obtained when activating components are included in calf feed with the aim of activating the LP system in the intestinal tract[22] .
- Using LP system to protect contamination of *Campylobacter jejuni* in poultry during slaughter[23].
- Lactoperoxidase can be used improve the shelf life in meat products by creating conditions that allow activation of the LP system
- Lactoperoxidase can be used successfully for controlling lactose fermentation and acidity development during storage of yogurt[24]
- Application of the LP system for preservation of cosmetics showed a broad-spectrum antimicrobial activity against bacteria yeasts and moulds[25]

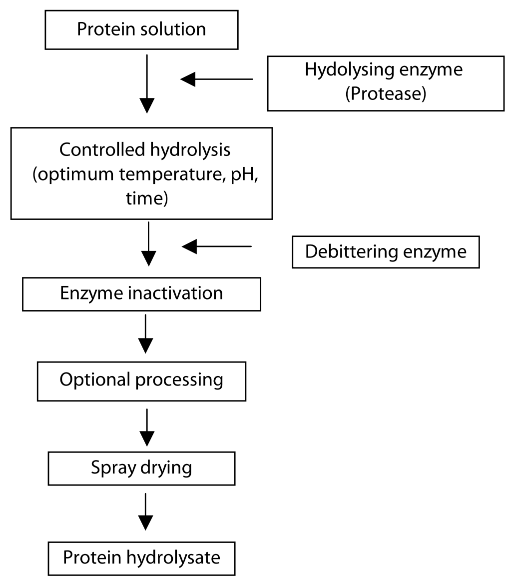
10.6 Casein and Whey Protein Hydrolysates

The enzymatic hydrolysis process produces protein ingredients designed for nutritional, dietetic and medical foods. Hydrolysed milk protein is a highly purified ingredient, hydrolysed under controlled conditions to obtain unique functional and nutritional properties. Both casein and whey proteins can be hydrolysed to produce protein hydrolysates with variations in the degree of hydrolysis. During enzymatic hydrolysis, casein and whey proteins are broken down into peptides of different sizes, and free amino acids. Specific enzymes are used that allow a good control over the size and functionality of peptides formed during hydrolysis. Enzymatic protein hydrolysates containing short chain peptides with characteristic amino acid profiles and defined molecular size are used in specific formulations such as those used for feeding hospitalised patients.

[18] *Reiter & Harnulv (1984)*
[19] *Kussendrager & van Hooydonk (2000)*
[20] *Reiter & Harnulv (1984)*
[21] *Hoogendoorn (1985)*

A general process for manufacture of protein hydrolysates is shown in Figure 3.

Figure 3 A general process for manufacture of milk protein hydrolysate



For manufacture of protein hydrolysates, milk proteins (casein, caseinate, milk protein concentrate, lactalbumin, whey protein concentrate, whey protein isolate) are first dispersed and solubilized in water and the pH and temperature are adjusted to the desired levels (generally to the optimum temperature for the enzyme). An appropriate enzyme is then added to the protein solution (substrate) at a certain enzyme: substrate ratio that optimises the enzymatic reaction. Under controlled conditions, the enzyme cleaves the peptides bonds and produces the desired level of protein hydrolysis. The hydrolysed protein is optionally processed through steps such as clarification, flavour reduction, concentration, and subsequently is spray dried.

Enzymatic hydrolysis of protein causes several changes in protein structure that affect the functional properties of protein. These changes include:

- Decrease in molecular weight due to breakdown of long polypeptides into smaller peptides, and increase in the number of peptides
- Decrease in the pH when hydrolysis is carried out at neutral to basic pH due to the release of H^+
- Increase in pH when hydrolysis is carried out at acidic pH due to the consumption of H^+
- Increase in the solubility due to increase in NH_3^+ and COO^- contents of proteins
- Increase in the number of hydrophobic residues due to destruction of the aggregated (globular) structure of protein

There are a number of variables that need to be considered and controlled during the manufacture of high quality protein hydrolysate. The first consideration is the selection of appropriate substrate, *i.e.* the protein, and most commonly, either whey protein concentrate or whey protein isolate is used, as these result in hydrolysates which are of high quality and have bland flavour. Casein is also used as a substrate for specific applications. Selection of an appropriate enzyme is the next consideration and is one of the most critical steps in the development of high quality protein hydrolysate. Considerable efforts go into selecting an approved, food-grade enzyme, and also in the desired amount (enzyme/substrate ratio) required for hydrolysis. Hydrolysis of protein results in a decrease in the pH of the protein solution and therefore regular pH adjustment is needed during manufacture. If a low-sodium hydrolysate is desired, potassium hydroxide is used for pH adjustment, otherwise sodium hydroxide is used. Throughout the process, pH, time and temperature are monitored and controlled which helps in producing high quality, nutritional and functional protein hydrolysates.

[22] *Reiter et al (1981)*
[23] *Borch et al (1989)*
[24] *Nakada et al (1996)*
[25] *Guthrie (1992)*

A common way of differentiating between protein hydrolysates is the assessment of the degree of hydrolysis (DH) where the higher value reflects higher level of hydrolysis. Users of protein hydrolysates need an understanding of the desired attributes, and selection should be based on flavour, degree of hydrolysis, required bioactivity, and nutritional composition.

The bitter taste of protein hydrolysates is a major barrier to their use in food and health care products. The intensity of the bitterness is proportional to the number of hydrophobic amino acids in the hydrolysate. The presence of a proline residue in the centre of the peptide also contributes to the bitterness. The peptidases that can cleave hydrophobic amino acids and proline are valuable in debittering protein hydrolysates. Aminopeptidases from lactic acid bacteria are available under the trade name Debitrase. Carboxypeptidase A has a high specificity for hydrophobic amino acids and hence has a great potential for debittering. A careful combination of an endo-protease for the primary hydrolysis and an aminopeptidase for the secondary hydrolysis is required for the production of a functional hydrolysate with reduced bitterness.

Commercial milk protein hydrolysates are available in a range of degrees of hydrolysis and molecular weight profiles. Table 9 shows approximate composition and functional properties of commercial hydrolysates.

Table 9 Approximate composition
and potential functionality and applications of milk protein hydrolysates

	Whey Protein or Casein Hydrolysate			
Degree of hydrolysis	<5	6-10	11-20	>20
Protein (%)	80-92	80-92	80-92	80-92
Amino nitrogen (%)	1-2	1-3	1-4	3-10
pH, 5% solids	6.0-7.6	6.0-7.6	6.0-7.6	6.0-7.6
Fat (%)	0.1-3.5	0.1-3.5	0.1-1.0	0.1-1.0
Lactose (%)	0.1-3.0	0.1-3.0	0.1-1.0	0.1-1.0
Ash (%)	2.0-4.0	3.0-4.0	3.0-4.0	3.0-5.0
Major differences	Improved physical functionality (solubility, emulsification, foaming, etc.)	High levels of medium chain peptides, high solubility and heat stability	High levels of short to medium chain peptides, reduced protein allergy, high heat stability, low lactose and low fat, reduced allergenicity	High levels of di- and tri-peptides and free amino acids, high heat stability, low lactose and low fat, reduced allergenicity
Potential food applications	Dry and liquid beverages, infant formula, sports nutritional products	High protein beverage powders, powdered diet supplements, infant, sports and enteral nutritional formulations	Hypoallergenic infant, sports and enteral formulations, high protein formulations	Medical and clinical nutritional formulations, hypoallergenic infant and sports nutritional formulations, lactose-free formulations

Protein hydrolysates: functionality and applications

Milk protein hydrolysates can be used for the following bioactive or physiologically functional properties.

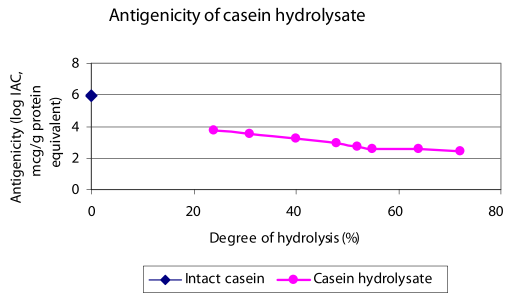
- Reduced allergenicity and antigenicity
- Increased protein absorption
- Release of bioactive peptides

Reduced allergenicity

Due to the differences in the protein composition of human and cow milk, feeding of cow milk to newborn babies can cause allergic reactions. Hydrolysis of cow milk proteins into smaller peptides reduces the risk of allergenicity and allows the use of hydrolysate as a substitute for human milk protein in infant formula. Milk protein hydrolysates are also suitable for replacement of intact proteins in adult nutritional formulations where reduced allergenicity is needed. The antigenicity of a protein, *i.e.* its ability to induce an allergic reaction, is related to the size of protein, amino acid sequence, and presence of secondary and tertiary structures. The antigenicity of hydrolysates can be measured by an enzyme-linked immunosorbent (ELISA) inhibition assay that measures the amount of immunologically active protein. Intact casein shows a high value for immunologically active casein (IAC), at 10^6 µg/g protein equivalent (Figure 3). Increasing the degree of hydrolysis can decrease this value from 106 to 103 µg/g or below, as seen for casein hydrolysate in Figure 4.

Food applications that can benefit from reduced allergenicity are infant formula, adult nutritional formulations, isotonic sports, enteral formulations and medical nutritional formulations.

Figure 4 Allergenicity of casein and casein hydrolysate[26]



Increased protein absorption

Depending on the degree of hydrolysis, type of enzyme and conditions during hydrolysis, a range of peptides can be obtained during hydrolysis. The decrease in the peptide size generally leads to an increase in absorption of peptides. Milk protein hydrolysates containing mostly di- and tripeptides are absorbed more rapidly than free form amino acids and much more rapidly than intact proteins. This is desirable for athletes who want to maximise the amino acid delivery to muscles, and to the patients with impaired absorption system.

Release of bioactive peptides

Hydrolysis of milk proteins may produce biologically active peptides that are usually buried inside the aggregated structures of protein molecules. Milk protein hydrolysates for example, contain several biologically active peptides such as antihypertensive peptides. The antihypertensive effect of several peptides has been related to the inhibition of the angiotensin-converting enzyme (ACE). ACE activity results in blood pressure increase via conversion of angiotensin I to angiotensin II, which is a vasoconstrictive peptide, and via degradation of bradykinin, which is a vasodilatative peptide. Inhibition of ACE, e.g. by peptides in milk protein hydrolysates, results in a decrease in blood pressure.

10.7 Milk Minerals

Calcium and phosphorus are the major minerals required for the growth and development of bones and teeth. Calcium deficiency is far too common in diet, and awareness of this deficiency has led to calcium fortification of a range of food products including breakfast cereals and fruit juices. Although consumers consider milk and dairy products to be the richest sources of calcium, many have limited their consumption to reduce fat in their diets, or because of their intolerance to lactose. Milk minerals are a rich source of calcium used for calcium fortification of food and beverage products. Commercial milk mineral complex is obtained from cheese whey after removal of proteins, which are converted into protein concentrates, and lactose, which is dried into lactose powder. A typical composition of a commercial milk mineral product (milk calcium) with 24% calcium is shown in Table 10.

Table 10 Typical compositions of milk minerals with 24 % calcium

Component	Amount per 100 g
Moisture (free & bound) (g)	10.0
Protein (g)	5.0
Fat (g)	1.0
Lactose (g)	5.0
Ash (g)	78.0
Sodium (g)	0.5
Potassium (g)	0.15
Calcium (g)	24.0
Magnesium (g)	0.8
Phosphorus (g)	13.7
Phosphorus as phosphates (g)	39.0
Chloride (g)	0.20
Iron (mg)	11.0
Copper (mg)	0.1
Manganese (mg)	1.0
Zinc (mg)	48
Iodine (ug)	20

Milk Minerals: Functionality and Applications

Milk minerals are a natural milk calcium complex product manufactured from milk and whey. Calcium in milk minerals is a highly bioavailable calcium phosphate which is a natural milk calcium complex. Dietary calcium has been linked to osteoporosis and bodily functions such as regulation of cell function, nerve conduction, muscle contraction and blood coagulation. Milk minerals are rich in calcium and milk calcium has been suggested to have the following bioactive functional properties

- Prevention of osteoporosis and growth of healthy bones and teeth[27, 28]
- Blood pressure and cardiovascular disease control [29,30]
- Lower effect on hypertension[31]
- Prevention of colon cancer[32]
- Control of weight gain and obesity[33,34]

Suggested applications of milk minerals include:

- Dairy products such as recombined milk, flavoured milk, yogurt and cheese
- Nutritional and functional foods such as sports and adult nutritional beverages, weight loss products and sports bars
- Bakery products such as breads and cakes
- Confectionery products
- Breakfast cereals
- Convenience foods such as soups, sauces and frozen desserts
- Food supplements such as capsules and tablets

27 *Cadogan et al. (1997)*
28 *Murphy et al. (1994)*
29 *McCarron & Reusser (1999)*
30 *Miller et al. (2000)*
31 *Hatton & McCarron (1994)*
32 *Holt (1999)*
33 *Zemel et al. (2000)*
34 *Davies et al. (2000)*

FAQ

Colostrum

1. *What is colostrums and how is it different from normal milk?*

   Colostrum is the first milk produced by the cow during the first 24-36 hours after calving and serves as the first natural food for a newborn calf. Colostrum is not only a source of nutrients such as fat, protein, carbohydrate, vitamins and minerals; it also contains several biologically active componets that are present in minute quantities in normal milk. The most important bioactive components of colostrum are growth factors and antimicrobial factors that help in providing prevention from infections.

2. *Which calves could benefit from supplementation of diet with colostrum?*

   Colostrum supplementation is advised for calves whose mother dies during birth or would not allow immediate nursing. Calves that are too weak to stand and suckle immediately after the birth could benefit from high amounts of immunoglobulins and other growth factors from colostrum.

Glycomacropeptides (GMPs)

1. *Why is GMP promoted as a "weight control" ingredient?*

   Research has shown that GMP stimulates synthesis and release of the hormone cholecystokinin (CCK) in the duodenum. The two important physical events triggered by CCK during digestion are the release of the pancreatic enzymes and the contraction and emptying of the gall bladder/hepatic bile duct. The pancreatic enzymes are critical for the complete digestion of fats, proteins and carbohydrates and therefore the full nutritional realization of food. CCK has the effect of slowing the overall digestive process by slowing intestinal contractions, thus giving the digestive enzymes more time to work on their respective substrates resulting in more complete absorption of a given digestive loading. In fact, there is interest in GMP isolated by itself as an appetite suppressant for inclusion with other foods, because by slowing digestion one perceives the "full" feeling longer (satiety effect) following a meal, possibly discouraging between- meal snacking. This process is likely to have an effect as a "weight control" agent in diet.

2. *What is PKU and why is GMP suitable for PKU patients?*

   Phenylketonuria (PKU) is a rare, metabolic disorder that is inherited from ancestors. People with PKU cannot utilize the essential amino acid phenylalanine and its derivatives due to the absence of the enzyme needed for utilization of phenylalanine. Consequently, a phenylketonuric person consuming a normal diet would accumulate high levels of phenylalanine, which may cause toxicity to the central nervous system and possible brain damage. Such persons are recommended special low-phenylalanine diets that provide adequate protein. High quality glycomacropeptide (GMP) is an ideal ingredient for phenylketonurics, as it contains negligible levels of phenylalanine.

Lactoferrin

1. *How much lactoferrin can be added in food formulations?*

   The addition of lactoferrin to food products may be based on the amount of lactoferrin or the desired level of iron. The desired level of iron could vary from as little as 1 mg/100 mL for infant formula to as high as 7-mg/100 mL for a sports formulation.

2. *How can lactoferrin be used in improving shelf life of meat products?*

Recently, the USDA approved the use of activated lactoferrin on fresh beef. Activated lactoferrin, or lactoferricin, is a pepsin hydrolysate of lactoferrin. Lactoferricin has enhanced antimicrobial action in comparison to lactoferrin. This activated form has been shown to protect fresh beef against *E. coli* 0157:H7, *Salmonella, Campylobacter* and more than 30 types of other pathogenic bacteria. The activated lactoferrin prevents pathogenic bacteria from attaching to the surface of the meat and also prevents their growth.

3. *What is the best method for lactoferrin addition to acidified beverages such as drinking yogurt and sports drinks?*

One of the important properties of lactoferrin is its suitability for low pH environment. Lactoferrin is stable at low pH and can be added to drinking yogurt after preheat treatment, after fermentation, or through mixing with the fruit preparation. In fruit yogurt, lactoferrin can be added after the heat treatment of milk together with the starter or with the fruit preparation.

4. *What are the main bioactive properties of lactoferrin?*

The main bioactive properties of lactoferrin are derived from its ability to bind iron. These properties include:

Improved bioavailability of iron: lactoferrin carries iron efficiently and helps in absorption of iron in the body.

Antioxidant properties: lactoferrin can be used as a natural antioxidant that can prevent oxidative damage to body tissues by controlling the production of free radicals.

Antibacterial property: This property is an effect of the depletion of iron in the environment, which limits the growth of bacteria. Action of pepsin in stomach converts lactoferrin into lactoferricin that has broad applications against pathogenic bacteria and yeasts. Also there are reports suggesting that lactoferrin interferes directly with bacterial cell surface thereby killing sensitive organisms.

Antiviral properties: Potentially, lactoferrin can inhibit the absorption of viruses to mammalian cells thereby preventing viral infection of cells.

Immunomodulatory properties: During the course of microbial infection, lactoferrin provides anti-inflammatory.

5. *What are the major applications of lactoferrin?*

Potential food applications of Australian lactoferrin powders include functional foods, beverages, sports and infant formulations, health supplements and animal feed. In food applications, lactoferrin can provide several health benefits such as antiviral and antibacterial effects, immune enhancement and antioxidation properties. Lactoferrin powder can also be used in cosmetics and oral care products, exploiting the antibacterial and antiviral benefits.

- Sports and infant formulations
- Chewing gum
- Mouthwash and toothpaste
- Veterinary and feed specialties
- Natural preservative in foods

Lactoferrin can be added in the range 10-100 mg per 100 g of product. This broad application range requires knowledge on effective incorporation of this bioactive component based on the prediction of its properties during processing, storage and consumer use.

6. *How does heat treatment such as pasteurization affect the activity of lactoferrin?*
Like other whey proteins, lactoferrin is sensitive to high temperature heat treatment. However, formulation containing lactoferrin can be pasteurised at normal pasteurization temperature *i.e.* 72°C for 16 s with less than 5% loss of bioactivity. Although pasteurisation causes minimal reduction in the activity, excessive heat treatment during processing of food products can reduce the activity of lactoferrin.

Lactoperoxidase

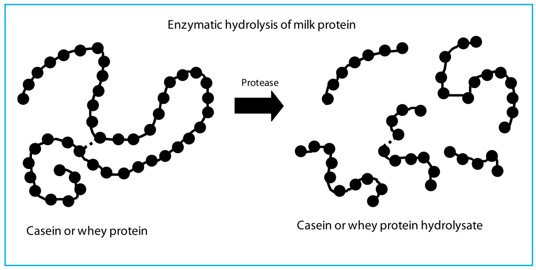
1. *How do I use lactoperoxidase for preservation of meat?*
Lactoperoxidase provides an anti-bacterial, preservative effect when used in combination with thiocyanate ion (SCN-) and hydrogen peroxide (H_2O_2). In combination, three ingredients form a system called lactoperoxidase system (LP System). The resultant product of the oxidation reaction is hypothiocyanite ion (OSCN-) that inhibits bacterial metabolism via the oxidation of essential sulphydryl groups in proteins. The preservative effect of the LP System involves use of three ingredients:
   - Lactoperoxidase powder at enzyme concentration in the range 1-20 mg/kg of meat
   - Sodium or potassium thiocyanate ion at a concentration in the range 5-40 mg/kg meat (as thiocyanate ion)
   - A source of hydrogen peroxide (H_2O_2) (*in situ* production using glucose oxidase – glucose oxidase is an approved processing aid in some countries) at a concentration in the range 5-50 mg/kg meat

Protein hydrolysates

1. *What is enzymatic hydrolysis of milk proteins and how is it carried out?*
Enzymatic hydrolysis involves breakdown of protein molecules into smaller peptides and amino acids through the action of a protease or a peptidase as seen below.

For manufacture of whey protein hydrolysate, a dispersion of whey protein concentrate or isolate is adjusted to temperature and pH that are optimum to the hydrolyzing enzyme. The enzyme is then added and allowed to react with protein for a specified time period. Sometimes more than one enzyme is added to optimize the hydrolysis for flavour and peptide size. After completion of hydrolysis the enzyme is deactivated, usually via heat treatment, and the milk protein hydrolysate is pasteurized. Subsequent treatments of the hydrolysate may include filtration, clarification, concentration and spray drying.

2. *What are the benefits of protein hydrolysate and peptides over whole protein?*
Protein hydrolysate and peptides are produced by enzymatic hydrolysis of casein or whey protein. The hydrolysis breaks the peptide bonds at specific locations and produces low molecular weight fragments with altered functionality and health benefits. There are three main benefits of using milk protein hydrolysates and peptides over whole protein:



- The digestibility of proteins is improved which helps people with impaired digestive functions in providing essential amino acids
- The allergenicity associated with whole protein is reduced, which is particularly beneficial for infants who consume infant formula, or adults who are allergic to proteins.
- The overall absorption of amino acids is improved, as the amino acids are already digested in hydrolysates and peptides. This is of particular interest to sports people who are at risk of negative nitrogen balance, and need to get fast-absorbed amino acids

3. *Why do some protein hydrolysates taste bitter, and how is bitterness reduced in commercial hydrolysates?*

A major barrier in the wide acceptance of protein hydrolysates is the unpleasant bitter flavour of some products. Bitterness results from the content of oligopeptides, which are formed by endoproteinases during the hydrolysis of native protein.

The bitter taste only develops from a certain degree of hydrolysis onwards, when the peptides have molecular weight between 1,000 and 5,000 Daltons and high content of hydrophobic amino acids (leucine, isoleucine, proline, valine, phenylalanine, tyrosine and tryptophan). Almost all peptides containing these amino acids tend to be bitter, with intensity proportional to the number of hydrophobic amino acids and the size of the peptide. Depending on their share in the total protein, one can predict the tendency to bitter peptide formation during hydrolysis. As caseins contain more hydrophobic amino acids than whey proteins, hydrolysates from casein result in bitterness even at a low degree of hydrolysis.

Commercially, protein hydrolysates with little or no bitterness have been manufactured. Methods tried for removing bitterness include adsorption to active carbon, binding to ion exchange resins, plastein reaction or masking, but most have been discarded for technical or economic reasons. More success has been achieved with exopeptidases that attack the protein molecule only at the N- (aminopeptidases) or C-terminal end (carboxypeptidase), and split off small peptide fragments or amino acids. Aminopeptidases such as DebitraseTM, remove single or pairs of amino acids from the N-terminal of a peptide chain rendering the peptides free from bitterness (see the Figure at right).

During hydrolysis, letting proteinase and aminopeptidase act at the same time can reduce bitterness. In this case, the process is conducted beyond the degree of hydrolysis at which the bitter point would have been reached with proteinase alone. In addition, a two-step process can be used to reduce the bitterness in the hydrolysate. In the two-step process, the conventional proteinase is allowed to act in the first step at which the bitter point is exceeded. In the second step, the aminopeptidases are given the opportunity to breakdown the bitter peptides. Although proteinases with natural exopeptidase activities already shift the point of unpleasant bitterness very noticeably, the pure aminopeptidases will shift that point much

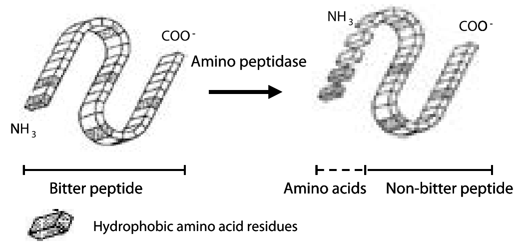
[35] *Pawlett D and Bruce G (1996)*

further.

4. *What can be done to improve the emulsifying properties of protein hydrolysate?*

As the process of hydrolysis breaks down the large macromolecules of protein into smaller polypeptides, the amphiphilicity of protein is reduced thereby reducing the ability to emulsify fat. Stable emulsions such as infant and adult nutritional formulations with protein hydrolysate, can be manufactured by appropriate manipulation of emulsifying conditions and by the use of appropriate emulsifiers. Often a combination of the two is required to make stable emulsions that can withstand high temperature treatment.

Figure Debittering effect of an aminopeptidase



5. *What is ACE-I activity and how can protein hydrolysate and peptides help in hypertension?*

Angiotensin converting enzyme (ACE) is a key enzyme involved in the regulation of blood pressure. The ACE inhibitors (ACE-I) work by blocking (inhibiting) the enzyme that converts the inactive form of angiotensin (angiotensin I) in the blood to its active form (angiotensin II). Angiotensin-II is very potent vasoconstrictor and leads to high blood pressure (also called hypertension). Hypertension is considered to be the most important cause of human deaths in affluent countries. Hypertension affects over 80 per cent of diabetics and is one of the primary risk markers for metabolic syndrome. Protein ingredients, such as hydrolysates and peptides with ACE-I activities, help in lowering hypertension and risk of related diseases.

6. *What is the importance of branched chain amino acids (BCAAs), and which protein products provide high amounts of BCAAs?*

The branched chain amino acids (BCAAs) are leucine, isoleucine and valine. BCAAs are considered essential amino acids because human beings cannot survive unless these amino acids are present in the diet. These amino acids are particularly useful for atheletes and sports people in general. BCAAs are needed for the maintenance of muscle tissue and appear to preserve muscle stores of glycogen (a storage form of carbohydrate that can be converted into energy). BCAAs also help prevent muscle protein breakdown during exercise. During sustained exercise, muscle BCAAs are used for energy and NH3 production. The subsequent increase of free tryptophan to BCAA ratio is thought to increase the tryptophan availability for serotonin synthesis. This can cause sleep and could increase the mental effort necessary to maintain athletic activity. BCAA supplementation before and during exercise may therefore delay fatigue and improve athletic performance. Research suggests that regular supplementation with branched chain amino acids can prevent central fatigue by preventing tryptophan from entering the brain. However, more research is needed to support such findings further. Whey protein products originating from acid whey contain higher amounts of BCAAs than those from cheese whey unless cheese whey is largely free from GMP.

[36] *Kun et al. (2001)*

Milk minerals

1. *What are the advantages of using milk calcium over commercial calcium salts such as calcium carbonate and calcium phosphate?*

   There are several sources of calcium available in the market including those from non-dairy sources. Milk calcium is a 100% natural source of calcium derived from milk. In addition to calcium, milk calcium may contain protein and other nutrients such as other minerals that are not available from non-dairy calcium salts. The flavour of milk calcium is superior to other calcium salts. The absorption of dairy calcium is considered superior to other sources since it is present with other minerals such as phosphorus, which are essential for bone metabolism. Milk calcium contains a calcium: phosphorus ratio of approximately 1.7 that is considered optimal for bone absorption (optimal range 0.2-2.0).

2. *Is the milk calcium more bioavailable than other calcium salts?*

   Several clinical studies have been carried out on bioavailability of dietary milk calcium. While milk calcium is bioavailable, studies have not found it significantly higher than the bioavailability of calcium from other sources. Bioavailability of calcium is influenced by the several factors including the level of calcium intake, vitamin D status, phytates, oxalates, caffeine, lipids, phosphopeptides, proteins, lactose and phosphorus. A review on calcium and bone health showed a positive effect of dairy calcium on bone health and the prevention of osteoporosis[36]. The flavour of milk calcium is generally superior to other calcium salts.

3. *How can we avoid sedimentation of milk minerals in liquid beverages such as a nutritional beverage?*

   Two strategies can be used to optimise the use of milk minerals in liquid beverages:

   - Using micronised milk minerals and controlling viscosity. The sedimentation of particles in a beverage is governed by the movement of particles and can be roughly predicted by the Stokes Law, according to which the rate of movement of particles is directly proportional to the diameter of particles and the density difference between the particle and the surrounding medium, and inversely proportional to the viscosity of the liquid. Thus by reducing size (by micronisation) and increasing viscosity (using a stabiliser), the rate of separation of milk minerals can be slowed down.
   - Using appropriate hydrocolloid stabilisers that create a weak three-dimensional network and a yield stress in the formulation. The yield stress needs to be just sufficient enough to hold the minerals, as too much yield stress may impart an undesirable appearance (gel-like structure) to the beverage.

Glossary

ACE - I

Angiotensin converting enzyme (ACE) is a key enzyme involved in the regulation of blood pressure. The ACE inhibitors (ACE-I) work by blocking (inhibiting) the enzyme that converts the inactive form of angiotensin (angiotensin I) in the blood to its active form (angiotensin II). Angiotensin-II is very potent vasoconstrictor and leads to high blood pressure (also called hypertension). Hypertension is considered to be the most important cause of human deaths in affluent countries.

Antimicrobial

Antimicrobials are biologically active components that protect against bacterial infections and enhance immunity. Antimicrobial components of milk include growth factors, lactoferrin, lactoperoxidase and lysozyme.

Antioxidant

In biological systems, the normal processes of oxidation (plus a minor contribution from ionizing radiation) produce highly reactive free radicals. These can readily react with and damage other molecules and body cells. An antioxidant is a chemical that prevents the oxidation of other chemicals. Many of the vitamins act as antioxidants.

Bioactivity

The physiological functional role of a food component is called bioactivity. Examples of bioactivity include anti-hypertensive activity of peptides from milk, and antibacterial and immune enhancing properties of lactoferrin.

Casein hydrolysate

Peptides of casein obtained by enzymatic hydrolysis of casein or caseinate.

Colostrum

Colostrum is the first milk produced by a cow after the birth of a calf. Colostrum is a rich source of antibodies, growth factors and nutrients for the suckling neonate, and may provide passive immunity to the newborn against various infectious microorganisms, particularly those that affect the gastrointestinal tract.

ELISA

ELISA, enzyme-linked immunosorbent assay is a sensitive laboratory method used to detect the presence of antigens or antibodies of interest in a wide variety of biological samples. An ELIZA method can be used to measure the antigenicity of milk proteins and hydrolysates.

Functional food

Functional foods refer to foods and food components that provide health benefits beyond basic nutrition. Functional foods may be naturally present (e.g. broccoli), dietary supplements (e.g. vitamins and minerals) or fortified (e.g. health drinks).

Growth factors

Growth factors are bioactive proteins present in colostrum, milk and whey. Growth factors are key regulators of a variety of cellular functions and are involved in the control of tissue growth and repair. Extensive research has identified a number of applications for their use in clinical medicine and biotechnology. Commonly identified growth factors are insulin-like growth factors-1 and 2 (IGF-1 and IGF-2), transforming growth factors – β1 and β2 (TGF-β1 and TGF-β2) and epidermal growth factor (EGF)

Hydrolysis

Enzymatic hydrolysis involves breakdown of protein molecules into smaller peptides and amino acids through the action of a protease or a peptidase. Hydrolysis of protein improves its functional properties and releases bioactive peptides.

Lactoferrin

Lactoferrin is an iron-binding glycoprotein present in colostrum, milk and whey. The iron-binding ability of lactoferrin is responsible for many biological functions such as bacteriostatic effect, growth-promoting effect on certain cell lines, and prevention of lipid peroxidation and promotion of iron absorption in the body.

Lactoperoxidase

Lactoperoxidase [EC 1.11.1.7] is an enzyme present in colostrum and milk, with a molecular weight of approximately 77.5 kDa. Bovine colostrum and milk contain about 11-45 mg/L and 13-30 mg/L lactoperoxidase respectively. The biological significance of lactoperoxidase is its involvement in the natural host defence system against invading microorganisms.

Milk minerals

Milk minerals are obtained from cheese whey after removal of proteins that is converted into protein concentrates and lactose, which is dried into lactose powder. Milk minerals are a rich source of calcium used for calcium fortification of food and beverage products.

Peptide

Peptides refer to segments present in protein molecules formed by joining amino acid residues. The link between one amino acid residue and the next is an amide bond, and is sometimes referred to as a peptide bond.

PKU

Phenylketonuria (PKU) is a rare, metabolic disorder that is inherited from ancestors. People with PKU cannot utilize the essential amino acid phenylalanine and its derivatives due to the absence of the enzyme needed for utilization of phenylalanine. Consequently, a phenylketonuric person consuming a normal diet would accumulate high levels of phenylalanine, which may cause toxicity to the central nervous system and possible brain damage.

Prebiotic

Prebiotics refer to ingredients that promote the growth of probiotic bacteria. Examples of prebiotics are oligosaccharides such as fructo-oligosaccharides or inulin.

Probiotic

Probiotic refers to a substance containing beneficial live microorganisms that claims to be beneficial to humans and animals, e.g. by restoring the balance of microflora in the digestive tract. Examples of probiotic bacteria are acidophilus and Bifidobacteria.

Whey protein hydrolysate

Peptides of whey proteins obtained by enzymatic hydrolysis of whey proteins.

References

Abd El-Salam MH, Ei-Shibiny S and Buchheim W (1996). Characteristics and potential of the casein macropeptide. International Dairy Journal 6, 327-341.

Antonio J, Sanders M and Van Gammeren D (2001). The Effects of Bovine Colostrum Supplementation on Body Composition and Exercise Performance in Active Men and Women. Nutrition 17, 243-247.

Azuma N, Yamauchi K and Mitsouka T (1985). Bifidius growth-promoting activity of a glycomacropeptide derived from human k-casein. Agricultural and Biological Chemistry 48, 2159-2162.

Borch E, Wallentin C, Rosen M and Bjorck L (1989). Antibacterial effect of the lactoperoxidase/thiocyanate/hydrogen peroxide system against strains of Campylobacter isolated from poultry. Journal of Food Protection 52, 638-641.

Cadogan J, Eastell R, Jones N and Barker M E (1997). Milk intake and bone mineral acquisition in adolescent girls: randomised, controlled intervention trial. British Medical Journal 315, 1255-1260.

Daddaoua A, Puerta V, Zarzuelo A, Suárez MD, Sánchez de Medina F and Martínez-Augustin O (2005). Bovine Glycomacropeptide Is Anti-Inflammatory in Rats with Hapten-Induced Colitis. Journal of Nutrition 35, 1164-1170.

Davidson GP, Whyte PB, Daniels E, Franklin K, Nunan H, McCloud PI, Moore AG, Moore DJ (1989). Passive immunisation of children with bovine colostrum containing antibodies to human rotavirus. Lancet. 2(8665): 709-712.

Davies K M, Heaney R P, Recker R R, Lappe J M, Barger-Lux J, Rafferty K & Hinders S (2000). Calcium intake and body weight. Journal of Clinical Endocrinology and Metabolism 85, 4635-4638.

de Wit JN and van Hooydonk ACM (1996). Structure, functions and applications of lactoperoxidase in natural antimicrobial systems. Netherlands Milk & Dairy Journal 50, 227-244.

Foley JA and Otterby DE (1978). Availability, storage, treatment, composition and feeding value of surplus colostrum: A review. Journal of Dairy Science 61, 1033-1060.

Guthrie WG (1992). A novel adaptation of a naturally occurring antimicrobial system for cosmetic protection. SOFW-Journal 118, 556-562.

Hatton DC and McCarron DA (1994). Dietary calcium and blood pressure in experimental models of hypertension. A review. Hypertension 23, 513-530.

Holt PR (1999). Dairy Foods and Prevention of Colon Cancer: Human Studies. Journal of the American College of Nutrition 18, 379S-391S.

Hoogendoorn H (1985) Activation of the salivary peroxidase antimicrobial system: clinical studies. In The Lactoperoxidase System, Chemistry and Biological Significance, pp. 217±227 [KM Pruitt and JO Tenovuo, editors]. New York: Marcel Dekker.

Kawasaki Y, Isoda H, Tanimoto M, Dosako S, Idota T and Ahiko K (1992). Inhibition by lactoferrin and k-casein glycomacropeptide of binding of cholera toxin to its receptor. Bioscience, Biotechnology and Biochemistry 56, 195-198.

Kilara A and Panyam D (2003). Peptides from milk proteins and their properties. CRC Critical Reviews in Food Science and Nutrition 43, 607-633.

Korhonen H (1977). Antimicrobial factors in bovine colostrum. Journal of the Scientific Agricultural Society of Finland 49, 434-447.

Korhonen H (2002). Technology options for new nutritional concepts. International Journal of Dairy

Technology 55, 79-88.

Kun Z, Greenfield H, Xueqin D and Fraser DR (2001) Improvement of bone health in childhood and adolescence. Nutrition Research Reviews 14, 119-151.

Kussendrager KD and van Hooijdonk A. C. M. (2000). Lactoperoxidase: physico-chemical properties, occurrence, mechanism of action and applications. British Journal of Nutrition 84, Suppl 1, S19-S25.

Mahmoud MI, Malone WT and Cordle CT (1992). Enzymatic hydrolysis of casein: effect of degree of hydrolysis on antigenicity and physical properties. Journal of Food Science 57, 1223.

Masuda, C, et al. 2000. Chemopreventive Effects of Bovine Lactoferrin on N-Butyl-N-(4-hydroxybutyl)nitrosamine-induced Rat Bladder Carcinogenesis. Japanese Journal of Cancer Research Vol. 91. 582-588.

Mattila-Sandholm T and Saarela M (2003) Functional Dairy Products. Woodhead Publishing Ltd, Cambridge.

McCarron DA & Reusser ME (1999). Finding Consensus in the Dietary Calcium-Blood Pressure Debate. Journal of the American College of Nutrition, Vol. 18, No. 90005, 398S-405S.

Mero A, Miikkulainen H, Riski J, Pakkanen R, Aalto J, Takala T (1997). Effects of bovine colostrum supplementation on serum IGF-1, IgG, hormone, and saliva IgA during training. Journal of Applied Physiology. 83: 1144-1151.

Miller G D, DiRienzo D D, Reusser M E, and. McCarron D A (2000). Benefits of Dairy Product Consumption on Blood Pressure in Humans: A Summary of the Biomedical Literature. Journal of the American College of Nutrition 19, 147S – 164.

Murphy S, Khaw K-T, May H, Compston JE (1994). Milk consumption and bone mineral density in middle aged and elderly women. British Medical Journal 308, 939-41.

Nakada M, Dosako S, Hirano R, Ooka M and Nakajima I (1996). Lactoperoxidase suppresses acid production in yogurt during storage under refrigeration. International Dairy Journal 6, 33-42.

Neeser JR, Chambaz A, Vedovo SD, Prigent MJ & Guggenheim B (1988) Specific and nonspecific inhibition of adhesion of oral actinomyces and streptococci to erythrocytes and polystrene by caseinoglycopeptide derivatives. Infection and Immunity 56, 3201-3208.

Nielsen PM (1997) Functionality of protein hydrolysates. In Food Proteins and Their Applications (Eds Damodaran S and Paraf A) pp 443-472. Marcel Dekkar, Inc, New York.

Otani H, Monnai M, Kawasaki Y, Kawakami H & Tanimoto M (1995) Inhibition of mitogen-induced proliferative responses of lymphocytes by bovine k-caseinoglycopeptides having different carbohydrate chains. Journal of Dairy Research 62, 349-357.

Pakkanen R and Aalto J (1997) Growth factors and antimicrobial factors of bovine colostrum. International Dairy Journal 7, 285-297.

Playford RJ, Macdonald CE and Johnson WS (2000). Colostrum and milk-derived peptide growth factors for the treatment of gastrointestinal disorders. American Journal of Clinical Nutrition 72, 5-14.

Pawlett D and Bruce G (1996). Debittering of protein hydrolysates. In Industrial Enzymology (Ed Godfrey T and West S) pp 177-186, MacMillan Press Ltd, London

Reiter B and Harnulv G (1984). Lactoperoxidase antibacterial system: Natural occurrence, biological function and practical applications. Journal of Food Protection 47, 724-732.

Reiter B, Fulford RJ, Marshall VM, Yarrow N, Ducker MJ and Knutsson M (1981) An evaluation of the growth promoting effect of the lactoperoxidase system in newborn calves. Animal production 32, 296-306.

Ruiz, L.P. (1994). Antibodies from milk for the prevention and treatment of diarrheal disease. Proceedings of IDF Seminar Indigenous Antimicrobial Agents of milk - Recent Developments, Uppsala, Sweden, pp. 108-121.

Seung, Chun Baik and Jae, Hyun Yu (1995) Separation of immunoglobulin from Holstein colostrum and its immunological response. Foods and Biotechnology 4, 117-121.

Reference Manual for US Whey and Lactose Products. US Dairy Exports Council

Steijns JM (2001) Milk ingredients as neutraceuticals. International Journal of Dairy Technology, 54, 81-88.

Stephan W, Dichtelmuller H and Lissner R (1990) Antibodies from colostrum in oral immunotherapy. J Clin Chem Clin Biochem 28, 19-23.

Walzem RL, Dillard CJ and German JB (2002) Whey components: Millennia of evolution create functionalities for mammalian nutrition: what we know and what we may be overlooking. Critical Reviews and Food Science and Nutrition 42, 353-375.

Zemel MB, Shi, H, Greer B, DiRienzo D and Zemel PC (2000). Regulation of adiposity by dietary calcium. FASEB Journal 14, 1132-1138.

DAIRY AUSTRALIA
Delivering for the dairy industry

11

Whey Products and MPC

Content

259 11.1 Introduction

259 11.2 Whey Products - Overview of Manufacture and Composition

262 11.3 Functional Properties and Applications of Whey Protein Products

267 11.4 Lactose – Composition and Uses

267 11.5 Lactose Properties and Applications

269 11.6 Whey Products – Applications and Usage Levels

269 11.7 Milk Protein Concentrate – Overview of Manufacture and Composition

271 11.8 Functional Properties and Applications of MPC

272 11.9 MPC Products - Applications and Usage Level

273 FAQ

280 Glossary

283 References

11.1 Introduction

Whey products and milk protein concentrates (MPCs) are now well-established dairy ingredients marketed for their nutritional, physical-functional and physiological-functional properties. Due to the availability of a diversified range of dairy ingredients, the selection of an appropriate ingredient has now become a challenge that requires considerable interaction between the manufacturer and the user of the ingredient. Good understanding of physico-chemical properties of ingredient components and processing conditions used during the manufacture of ingredients can provide helpful guidelines in identifying potential functionality for the dairy ingredient. However, this alone does not guarantee an optimum functional performance in a food application. Optimisation of the functional performance in a food application also requires additional knowledge of the constituent ingredients of food application and potential interactions with the components of the dairy ingredient. If dairy ingredients were selected simply on the basis of the type of powder or a perceived functionality, there are likely to be variations and inconsistent functional performance in food products. This chapter simplifies some of the issues in relation to understanding the functionality and applications of whey products and MPCs.

11.2 Whey Products - Overview of Manufacture and Composition

Whey is the casein- and fat-free co-product from cheese or casein manufacture. In the past, manufacturers focusing on the cheese and casein products found it difficult to dispose of and utilise the whey. Some manufacturers simply dumped the whey creating environmental pollution, while others either fed it to pigs or sprayed it on farmland. Although manufacturers knew that whey was a rich source of nutrients, they simply did not know how to cost-effectively extract nutrients with the constituents being in too small quantities to handle by the available technology. Over years, researchers have established, not only the new methods for manufacture of a range of dried whey ingredients, but have also demonstrated their significant health and nutritional benefits.

11.2.1 Whey – Sources, Compositional Differences and Product Processing

The source of the whey is one of the most important factors affecting the composition, processing, and functionality of whey products. In the dairy industry, available sources of whey can be grouped into two broad categories:

- Sweet whey
- Acid whey

Sweet whey is obtained during the manufacture of rennet cheese (such as cheddar and mozzarella) and rennet casein, while acid whey is obtained during the manufacture of acid casein (mineral, lactic acid casein or some fresh acid cheese varieties such as cream and cottage cheese). The major differences between sweet and acid whey are in the pH and the proportion of minerals (Table 1). The pH of the sweet whey is higher than that of the acid whey. The acid whey contains

Table 1 Compositional differences (approximate) between sweet and acid whey

Constituent	Sweet Whey	Acid Whey
Total solids (%)	6.6	6.5
Water (%)	93.5	93.5
Fat (%)	0.04	0.04
Protein (%)	0.60	0.60
Lactose (%)	4.80	4.90
pH	6.2	4.6
Lactic acid (%)	0.05	0.40
Ash (total minerals) (%)	0.50	0.78
Calcium (%)	0.04	0.12
Phosphorus (%)	0.04	0.06
Sodium (%)	0.05	0.05
Potassium (%)	0.16	0.16
Chloride (%)	0.11	0.11

higher amounts of minerals than sweet whey as the acidification removes colloidal calcium phosphate and other minerals from the casein micelle into the whey. It is vital to have an understanding of the compositional differences between sweet and acid whey as this can significantly affect the functionality of whey products such as whey protein concentrate (WPC).

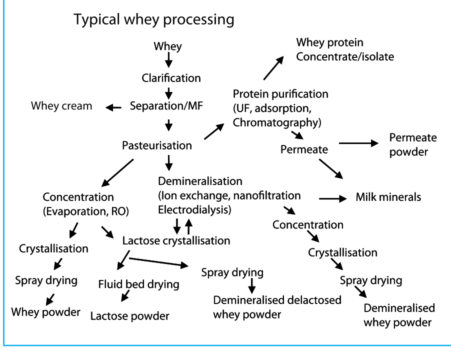


Figure 1 Typical processing of whey during manufacture of whey products

11.2.2 Whey Processing

Whey is a rich source of functional and nutritional components and thus can be processed into a range of ingredients. Figure 1 shows typical processing protocols for whey products. Typically, whey is clarified to remove casein/cheese curd particles, and the bulk of the fat is removed as whey cream using centrifugal separation. Microfiltration can be used to further decrease the fat content as fat adversely influences the functional properties of whey. Clarified whey is pasteurized and subsequently converted to a range of whey products with varying protein, lactose and mineral concentrations. Process-induced modifications, such as preheating and drying conditions, and salt levels, are employed to develop ingredients with functionalities tailored to specific food applications. Further modifications during drying, such as agglomeration and lecithination, are also commonly used to improve handling and dispersibility of dry ingredients.

11.2.3 Whey Protein Ingredients

For nutritional and functional reasons, protein is one of the most valuable components in whey and thus a range of protein ingredients is commercially available from whey. Table 2 shows the approximate composition of major whey protein ingredients. Generally, for each whey protein ingredient, several variations are available depending on the desired functionality in a food system. For example, WPC80 might be available as high heat stable, high gelling, and high emulsifying forms. It is often wise to discuss the desired functionality and food application with the supplier of dairy ingredients.

Table 2 Approximate compositions of whey protein ingredients.

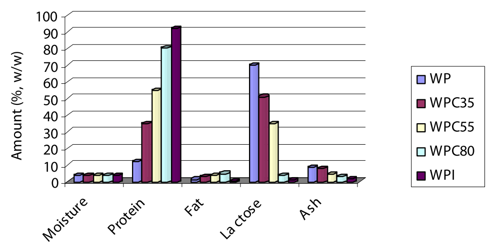
	Amount per 100 g						
Attribute	Whey powder	Demineralised whey powder (40% de-mineralization)	WPC35	WPC55	WPC80	WPI Chromatography	WPI Micro-filtration
Moisture (g)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Protein (g)	12.0	12.5	35	55	80	90	90
Fat (g)	1.5	1.0	3.0	4.0	5	0.5	0.2
Lactose (g)	70.0	77.5	51	35	4	1	0.5
Ash (g)	8.5	6.0	8.0	4.5	3.2	3.7	1.6
Sodium (mg)	780	425	430	500	130	700	230
Potassium (mg)	1470	680	1720	500	480	1100	590
Calcium (mg)	420	180	1180	450	400	150	490
Phosphorus (mg)	930	550	500	350	270	300	240
Chloride (mg)	360	210	220	400	290	50	50

Figure 2 compares the major constituents of whey protein products. As the protein concentration increases, there is a corresponding decrease in lactose and ash (minerals) contents. The fat content of WPC generally increases as the protein content increases. This is because the process of ultrafiltration used for protein concentration also retains the fat globules in whey. In WPI, the fat content is extremely low because either the additional step of microfiltration is used to remove fat globules, or proteins are separated by chromatography where the fat globules are not retained.

11.2.4 Whey Powders

The simplest of the whey products are the whey powders that are manufactured by spray drying of concentrated and crystallised whey. High ash content of whey powders imparts salty taste and can make whey powder unsuitable for a number of applications such as infant formula. Using the processes of ion-exchange, electrodialysis and nanofiltration, demineralised whey powders have been manufactured that provide cost-effective alternatives for standard whey powders. Typically, demineralised whey powders have 40%, 70% or 90% demineralization of whey (see the typical composition of 40% demineralised whey powder in Table 2). Other modifications to whey powders include removal of lactose only (delactosed whey powder), or removal of both lactose and minerals (delactosed and demineralised whey powders).

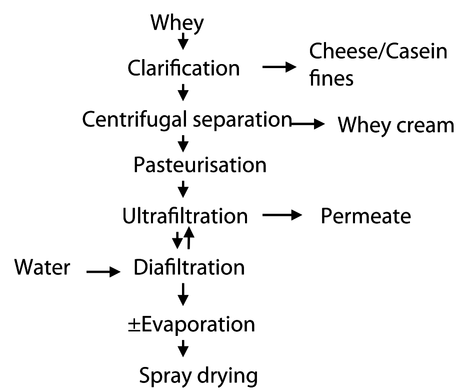
Figure 2 Comparison of major constituents of whey protein products.



11.2.5 Whey Protein Concentrate

Whey protein concentrates (WPCs) are preferred over whey powders where protein-enriching applications are needed or where specific functionality is desired. WPCs contain proteins in the range 35 - 80% and correspondingly reduced amounts of lactose and minerals. WPCs are manufactured either by ultrafiltration/diafiltration or by ion exchange chromatography. A simple process flow diagram for manufacture of WPC is shown in Figure 3.

Figure 3 Major steps used in the manufacture of WPC

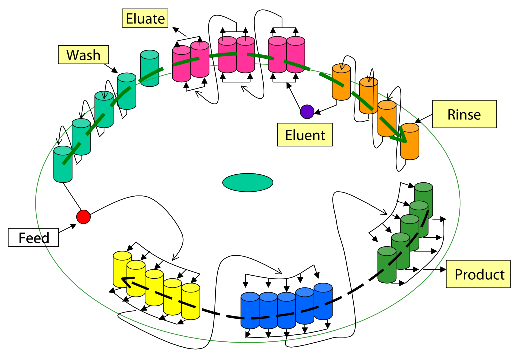


Ultrafiltration uses semi-permeable membranes to separate whey components based on selective molecular weight and structure. In the process, the whey is contacted with the membrane under an applied pressure. The applied pressure forces the water and the smaller molecules (minerals and lactose) through the membrane (permeate) while retaining whey protein molecules (retentate). For 80% WPC, the retentate is diluted with water (termed as diafiltration) and further concentrated through ultrafiltration.

11.2.6 Whey Protein Isolate

When protein content of WPC is above 90%, the products are generally known as whey protein isolates (WPIs). Whey protein isolate is commonly manufactured by either (a) ion exchange followed by concentration and spray drying or (b) microfiltration followed by ultrafiltration and spray drying. In the manufacture of WPI by ion exchange, the pH of clarified whey is lowered to 3.0-3.5 and passed through ion exchange resins where most of the proteins are adsorbed which are subsequently eluted and the pH is readjusted. The protein solution is then concentrated by evaporation, ultrafiltration or reverse osmosis and spray dried. Ion exchange process is generally carried out using a batch process. Recently, a similar but continuous ion exchange chromatographic separation process has been adopted by some companies. Continuous chromatographic method allows separation of component of mixtures down to the molecular level. A simple flow diagram for a continuous ion exchange (ISEP) separation is shown in Figure 4.

Figure 4 A simple flow diagram for continuous ion exchange chromatography (ISEP)[1]



In the process whey passes through a vertical column filled with a solid sorbent and depending on the degree of attraction between the separating molecules and the sorbent, molecules migrate at different rates and are physically separated and collected.

In the microfiltration process, whey is pressure driven through ceramic membranes or polymeric filters where these act as "molecular sieves". This is followed by ultrafiltration and spray drying. Microfiltration process is a continuous process and removes virtually all the fat in whey. The major difference between the ion exchange and the microfiltration processes is that the WPI produced using ion exchange method does not contain glycomacropeptide (GMP) originally present in sweet whey. Other differences are in the amounts of individual proteins and mineral contents.

11.2.7 Selection of Whey Protein Ingredient

Whey protein ingredients are suitable for a range of food applications. The selection of a suitable protein ingredient is based on a number of factors such as the price, availability and suitability of the ingredient. One of the easiest ways to select protein ingredient is based on the composition of the ingredient, where the requirements for protein, lactose or minerals determine the suitability of the ingredient. The other, a more appropriate way of selecting a protein ingredient is based on the desired functional performance in the food product. An understanding of the functional properties of whey proteins is important in maximizing the performance of the whey protein ingredient.

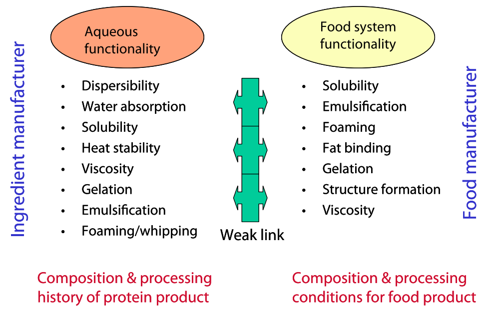
11.3 Functional Properties and Applications of Whey Protein Products

The term "functional properties" refers to those physico-chemical properties that determine the performance of the ingredient in water (aqueous functionality) or in food systems (food system

[1] *From Calgon Carbon Corporation*

functionality). Functional properties of whey proteins are governed by intrinsic factors such as amino acid composition, protein structure, level of denaturation and aggregation and the surface charge. Other factors such as milk composition, processing conditions, and environmental factors such as temperature, pH and ionic strength also play important roles in determining the functionality of protein ingredients. Figure 5 summarises the relationship between "aqueous functionality" and "food system functionality".

Figure 5 Relationship between functional properties of whey protein ingredients in water ("aqueous functionality") and food products ("food system functionality")

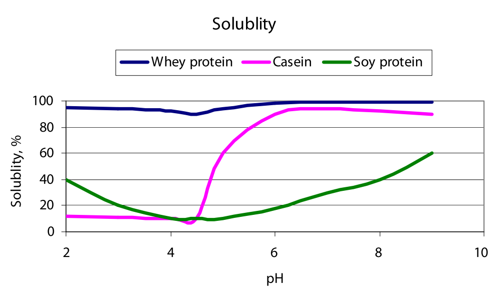


Functional properties in water ("aqueous functionality") primarily reveal the effects of the source of protein, processing history and the composition of protein ingredients and form quality yardsticks for the manufacturer of protein ingredients. On the other hand, similar properties when measured in food products reveal additional influences of the composition and processing conditions of the food product. The link between the "aqueous functionality" and the "food system functionality" is generally "weak" as the food products contain many ingredients and processing parameters that modify the functional properties of whey proteins. The interpretation of the results of functionality testing becomes increasingly difficult with increasing complexity of a testing approach. It is well recognized that the results of functionality testing in aqueous systems do not necessarily predict the functional behaviour of the protein in commercial food systems. Due to the complexity of food applications and the costs involved, it is difficult for manufacturers to test protein ingredients in real food systems. To bridge this functionality gap, model food systems containing essential ingredients of the final food products are generally employed. Testing of protein ingredients in model foods systems helps in prediction of the performance of the protein ingredients in the final food product and thus aid in the ingredient development and selection. Appendix 1 summarises the selection criteria for whey protein products based on functionality and food application.

11.3.1 Solubility

Whey protein products are highly soluble at room temperature and at low ionic strength. One of the advantages of whey protein products over casein products is their solubility at the entire pH range for food products (Figure 6). This is partly due to the small molecular size of proteins and the presence of a range of proteins with varying isoelectric pH values (isoelectric pH varying from 4.5 to 5.5). Heating whey proteins above their denaturation temperature causes aggregation of proteins with little or no effect on the solubility (as the aggregates are too small to sediment at low gravitational forces) as long as the protein concentration is low.

Figure 6 Solubility of whey proteins at different pH values

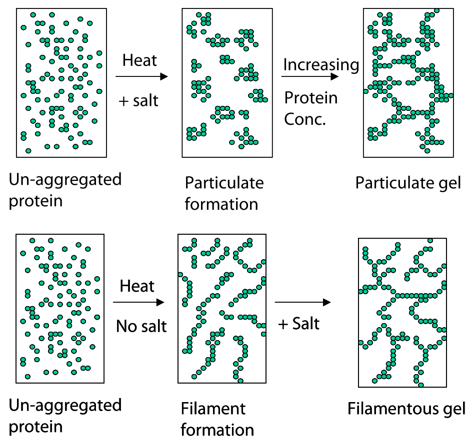


Food products where solubility is important are dry and instant beverages such as powdered nutritional beverage and powdered soups. Good solubility of whey protein products is also useful when mixed with other ingredients in the formation of liquid beverages and emulsions, such as recombined milk and infant formula. In general, well-manufactured whey protein products have excellent solubility in water.

11.3.2 Water Binding and Viscosity

Proteins bind water through their hydrophilic amino acids and the ease of access to these in the protein structure determines the water binding ability of a protein. Due to the high water binding properties, whey proteins have ability to enhance viscosity of the food system. Viscosity is one of the most important functional properties of whey proteins that help in providing mouth-feel and stability to liquid and semi-solid food systems. Viscosity of whey proteins decreases as the temperature of protein solution increases from room temperature to around 60°C. The viscosity of whey protein solution starts increasing as the temperature of heating increases above the denaturation temperature of whey proteins (approximately 78°C). This is due to the increased water binding due to the unfolding of protein molecules. The increase in viscosity is also dependent on concentration and pH - at low pH and protein concentration the increase in viscosity is limited.

Figure 7 Development of protein gels[2]



The viscosity related functionality of whey proteins is important in semi-solid foods such as soups, gravies, sauces and salad dressings. Although all whey protein products are suitable for viscosity development, protein products with high protein contents such as WPC 55 and WPC 80 are recommended.

11.3.3 Gelation and Structure Formation

Heat-induced, non-reversible gelation or gel formation is an important property of whey proteins for applications such as meat binding. Gelation properties of whey proteins are dependent on protein concentration, the pH of the protein solution, and the ionic strength (e.g. salt) (Figure 7).

At low protein concentration (4-6% protein), whey proteins produce soft and clear gels. Increasing the protein concentration increases the gel strength and the turbidity of the gel. At low pH, whey proteins produce weak and turbid gels. Increasing the pH to neutral level increases the gel strength, elasticity, and transparency of the gel. It is also important to select WPCs with little or no fat as the presence of fat adversely affects the gel formation and clarity of the whey protein gel. A texture analyser can be used to measure the gelling properties of whey proteins.

[2] *based on Bryant and McClements (1998)*

Food products that can benefit from gelation and structure building properties of whey proteins are meat products such as ham, surimi, and sausage and dairy products such as yoghurt and processed cheese. In yoghurt, whey proteins are especially useful in improving viscosity, gel strength and reducing syneresis (separation of free liquid). Preheating of milk for yoghurt manufacture denatures whey proteins and leads to casein-whey protein interactions and when casein is gelled due to the reduction in pH (formation of yoghurt structure), whey proteins help in strengthening the gel network and binding the free water. Other food products where the gelation properties are useful include desserts and pasta products. Optimum results for gelation and structure building are obtained when high protein products such as WPC80 and WPI are used in the formulation. Heating beyond the denaturation temperature of whey protein is needed to accomplish the desired gel structure.

11.3.4 Emulsifying Properties

Whey proteins are amphiphilic in nature meaning that they are able to anchor at the oil-water interface thereby lowering the interfacial tension and providing stability to the interface. This surface-active property of whey proteins allows them to form emulsions where the proteins adsorb at the oil-water interface and envelop the oil droplets providing them stability against oxidation, coalescence, and oiling off. Further rearrangement and unfolding of protein structure at the interface can further enhance the emulsifying ability of whey proteins. Excessive heat induced denaturation and aggregation of whey proteins results in lowering the emulsifying properties. Two commonly used methods for assessing emulsifying properties of whey proteins are emulsifying capacity and emulsion stability. The amount of oil that can be used to make a visibly stable emulsion is termed as emulsifying capacity while the time that the emulsion remains stable is known as the emulsion stability.

Food products that require emulsification of oil include beverages such as infant and enteral formula, convenience foods such as salad dressing and mayonnaise, and dairy products such as recombined milk, ice cream, and yoghurt. For manufacture of recombined milk products, whey protein products are often reconstituted (solubilized) in water at room temperature rather than at high temperatures preferred for milk powder and milk protein concentrates. Whey protein products suitable for emulsifying properties are WPC35, WPC55, WPC80 and WPI.

11.3.5 Foaming and Whipping Properties

The amphiphilic nature of whey proteins is also responsible for their high foaming and whipping properties. The foaming and whipping ability of whey proteins are improved by increasing protein content and impaired by the presence of small fat globules in whey. Heating of WPC generally enhances the foam stability of proteins. Other factors that affect the foaming and whipping properties of whey proteins are the pH and the ionic strength. Low pH and high ionic strength impair the foaming properties of whey proteins while slight denaturation improves the foaming properties. The foaming properties of WPCs can be measured by whipping a fixed amount of protein solution and measuring the volume expansion (foaming capacity) and time until the collapse of the foam (foam stability).

High foaming and whipping properties of whey proteins allows them to replace egg white in certain food applications such as cakes. Other foaming applications of whey proteins include ice cream and whipped topping.

11.3.6 Coating and Film Formation

The ability of whey proteins to form a transparent, bland, and flexible film allows them to be used as barriers against oxygen, moisture, aroma, and oil transport between two or more food products or between the food product and the atmosphere. Current demands for long shelf life foods and desire to recycle the packaging have led to increased demand for bio-films such as produced by whey proteins. Food applications that could benefit from coating properties of whey proteins are nuts, fruits and cakes. High protein ingredients such as WPC80 and WPI are suitable for coating and film formation.

11.3.7 Binding and Adhesion Properties

Whey proteins provide adhesion properties to meat products, batters, and fish products resulting in homogeneous products. Binding and adhesion properties are enhanced by heat-induced gelation of whey proteins. In bakery products such as bagels, whey proteins can provide surface glazing and binding of seeds thereby enhancing the appearance. Recommended whey protein ingredients are WPC55, WPC80, and WPI.

113.8 Browning Properties

Browning is an important property in baked goods and caramel products. Whey protein products, due to the presence of lactose, have excellent maillard type browning characteristics. Whey protein products such as whey powder, demineralised whey powder, WPC35 and WPC55 are suitable ingredients for browning applications.

11.3.9 Low pH Stability

Whey proteins have an advantage over casein protein where the functionality of proteins is needed at an acidic pH. At low pH, caseins tend to precipitate while whey proteins remain soluble and functional. Major applications of low-pH beverages are sports drinks and isotonic beverages. High protein WPCs are suitable for low pH applications. WPI is recommended for use where the clarity of the beverage is important. It is important to select whey protein ingredient free from fat as the fat globules can lead to cloudiness in beverages.

Table 5 Comparison of lactose grades and their applications[3]

	Edible	Refined Edible	US Pharmacopeia
Appearance	Yellow	White	White
Appearance of solution	Slight yellow/turbid	Colourless opaque	Clear, colourless, odour-less
Acidity	pH 4.5-7.0	pH 4.0-6.5	pH 4.0-6.5
Specific rotation	54.2-55.1	-	54.8-55.5
Lactose (%)	Min 99.0	Min 99.5	Min 99.7
Protein (%)	<0.5	<0.3	-
Free moisture (%)	<0.5	<0.5	-
Applications	Confectionery, bakery, meat and dairy products, dry beverages, fermentation	Infant foods, Adult nutritional products	Tablet wet granulation, direct compression, capsules, inhalation products

[3] *Rajah & Blenford (1988)*

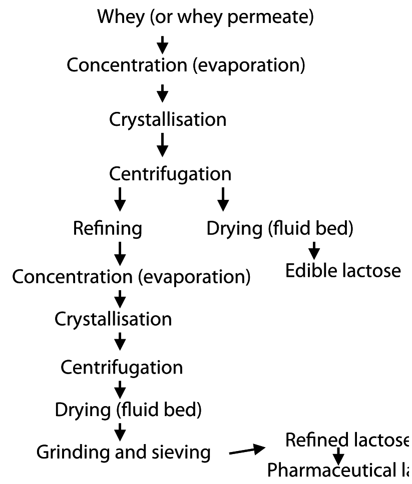
11.4 Lactose – Composition and Uses

Lactose, also known as milk sugar, is a unique carbohydrate present in mammalian milk (human and cows). Cheese or acid whey is a rich source of lactose, forming almost 70% of weight on solids basis. There are two basic methods for removal of lactose from whey:

- Removal from concentrated whey without removal of proteins
- Removal from concentrated whey from which the protein has been removed by ion exchange or ultrafiltration

A simple process for manufacture of lactose is shown in Figure 8.

Figure 8 A process flow diagram for manufacture of lactose from whey or whey permeate



Clarified cheese whey is concentrated by two-stage evaporation from approximately 6% solids to 30% solids in the first stage and from 30 to 60% solids in the second stage. The concentrated whey is slowly cooled to approximately 12-15°C, seeded with very fine lactose crystals. During this process, lactose crystallises from the solutions to form alpha lactose, which is decanted (centrifuged) to yield raw lactose and mother liquor. The raw lactose is washed further, decanted and dried to produce creamy edible lactose. This is further refined by decolourising and recrystallising lactose to produce refined or pharmaceutical grade lactose. Lactose powder can be supplied with selected particle size distribution achieved by selected grinding and sieving. Different grades of lactose and their applications are shown in table 5.

Table 6 Typical composition of a commercial edible grade lactose powder.

Component	Amount per 100 g
Moisture (free) (g)	0.20
Protein (g)	0.20
Lactose (alpha monohydrate) (g)	99.0

Typical composition of a commercial edible grade lactose powder is shown in Table 6.

11.5 Lactose Properties and Applications

Crystal forms

The two isomeric forms of lactose, i.e., alpha and beta, exist in crystalline forms. Usually alpha-lactose crystallises as a monohydrate where the crystals are very hard and non-hygroscopic, while anhydrous beta lactose crystallises into fine crystals. Lactose can also exist in an amorphous, glassy form as a mixture of alpha and beta lactose. It is important to have an understanding of the relative proportion of crystalline and amorphous forms of lactose in commercial lactose and milk powders, as these may affect the functional properties of powders.

Solubility

Compared to other sugars, lactose has a low solubility and the solutions can be supersaturated easily. For example at 30°C, only 20 g of alpha lactose can be dissolved in water compared with 69g of sucrose before the occurrence of super saturation. The beta form of lactose is considerably more soluble than the alpha form.

Sweetness

Lactose possesses a clean sweet taste without any aftertaste noticed for some artificial sweeteners. Although the sweetness character of lactose is similar to sucrose, the intensity of sweetness is only 30% of that of sucrose. The sweetness of lactose is dependent on the concentration and temperature of solution; higher the concentration or the temperature, higher the sweetness. Lactose can also be combined with other sugars that can result in synergistic effects in food products.

Moisture sorption

Moisture sorption characteristics of lactose affect its stability, quality attributes, and its control; together with the water activity it may affect many chemical reactions. Commercial lactose powders may contain up to 20% amorphous lactose and water activity of around 0.3. When high amounts of amorphous lactose are present, it leads to increase in moisture sorption, and can affect the properties like caking in lactose containing powders.

Browning

Lactose and lactose-containing powders, such as whey powder, are commonly used for their browning properties and development of a characteristic flavour. The browning reaction in lactose-containing products is induced by either (a) caramelisation or (b) Maillard reactions. The caramelisation occurs at high temperatures (150-175°C) and consists of a succession of dehydration, condensation and polymerisation reactions. The resulting water-insoluble compounds are called melanines that appear brown in colour. The Maillard reactions are induced when proteins or amino groups are present in the powder. The Maillard reactions can occur at low temperatures (such as the storage temperature of lactose) and result in condensation of lactose and amino groups into series of re-arrangements and finally into insoluble melanines.

Applications

Lactose is widely used by the food industry (e.g. infant formula, bakery, confectionary, meat and dairy applications) and pharmaceutical industry (tablets granulation and compression, capsules, inhalation and injectable products). Lactose being a reducing sugar helps in providing controlled browning in food products such as bakery and confectionery goods giving them characteristics golden colour.

A number of new products have been derived from lactose, which offers a range of opportunities for lactose. These include hydrolysed lactose with improved solubility, lactitol (sugar alcohol of lactose) as sugar substitute for bakery and confectionary products, lactulose (isomerization of glucose moity) for medical and infant formulations, lactobionic acid as acidifying and complexing agent for metal ions and fermented lactose products such as alcohol, lactic, propionic and citric acid.

Table 7 Whey products – applications and recommended usage levels

Application	Ingredient Usage Level (%, w/w)						
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI	Lactose
Dairy							
Recombined milks (including chocolate milk)	2-4	2-4	2-3	2-3	1-2	1-2	3-6
Ice creams	2-3	2-3	1-3	1-2	1-2	0.5-2	2-6
Yoghurts	2-5	2-5	2-5	2-4	1-3	1-3	2-4
Processed cheeses	3-6	3-6	1-3	1-3	1-2	0.5-2	-
Bakery & confectionery							
Breads	3-6	3-6	2-5	2-3	1-2	1-2	2-4
Cakes	2-4	1-5	4-6	3-5	2-4	2-6	8-10
Biscuits	3-6	3-6	3-5	3-5	2-4	1-3	4-6
Chocolates	1-5	1-5	1-5	2-3	1-2	1-2	3-7
Desserts	2-5	2-5	1-4	1-4	1-3	1-2	-
Meat products							
Sausages	3-5	3-5	3-5	2-5	2-4	1-3	-
Surimi	3-5	3-5	3-5	2-5	2-4	1-3	-
Convenience							
Sauces	2-5	3-6	5-8	5-8	2-4	2-4	-
Soups/gravies	2-5	3-6	2-5	2-4	1-3	1-2	-
Salad dressings	2-6	2-6	2-5	2-4	2-3	2-3	-
Nutritional products							
Infant formulae (liquid)	6-8	6-8	4-6	3-5	2-4	1.5-3	-
Enteral formulae (liquid)	-	-	-	-	1-2	0.5-2	-
Sports drinks	-	-	-	-	4-20	2-15	4-7
Sports bars	2-5	2-5	2-8	2-15	2-20	2-20	-
Dry mixes (including dry nutritional beverages)	40-60	40-60	30-50	30-50	20-30	15-20	15-40

WP- whey powder, DWP – demineralised whey powder

11.6 Whey Products – Applications and Usage Levels

Usage levels of whey products in food applications will depend on several factors such as type of application, desired nutritional and functionality requirements, and intended processing conditions. Table 7 below is provided as a guideline only.

11.7 Milk Protein Concentrate – Overview of Manufacture and Composition

Milk protein concentrate (MPC) products refer to spray dried concentrated milk protein products that contain both casein and whey proteins.

The generic term MPC refers to milk protein concentrate manufactured by

- Blending of casein (caseinate) and whey protein (whey powder or WPC)
- Co-precipitation of casein and whey protein, or
- Ultrafiltration and spray drying of skim milk

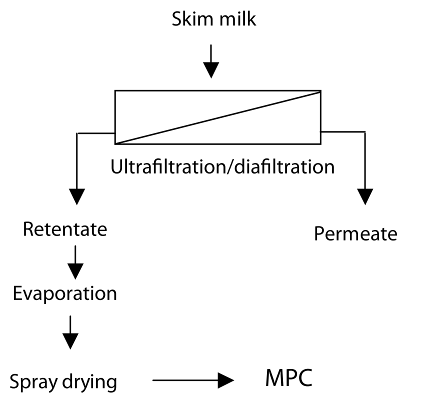
Table 8 Comparison of manufacturing methods of MPC

	MPC by Blending	MPC by Co-precipitation	MPC by Ultrafiltration
Raw ingredient	Casein (e.g. caseinate) and whey products (e.g. WPC)	Skim milk	Skim milk
Process	Dry or wet blending	Heat precipitation of low pH skim milk with or without calcium and resolubilisation to neutral pH	Ultrafiltration with or without diafiltration
Casein/WP ratio	Variable	80:20	80:20
State of casein micelle	Micelle dissociated to casein aggregates	Micelle dissociated	Mostly native micellar casein
State of whey proteins	Mostly undenatured	Denatured	Mostly undenatured
Casein whey protein interaction	No interactions	Casein whey protein interactions through disulphide bonds	Little or no interaction between casein and whey protein
Calcium concentration	Low	Medium for hi-calcium co-precipitate	Medium to high

MPC products made by the three methods show considerably different functional properties, and are suitable for a range of food applications (see Table 8). The blending of proteins is carried out either in a dry or a liquid form to obtain MPC with specific protein, lactose, and mineral profile. When MPC is made by dry blending proteins (e.g. caseinate and WPC), the product has less homogeneous functionality than the products made by co-precipitation or ultrafiltration. In the co-precipitation process, skim milk is heated (80-85°C at pH 6-6.4) in the presence or absence of added calcium, followed by acidification which results in casein-whey protein interaction and dissociation of casein micelles. The proteins are resolubilised by adjusting pH to 7.0.

In Australia, MPC generally refers to the product manufactured by ultrafiltration. The process of UF involves use of semi-permeable membranes with cut-off molecular weight of over 10,000 Daltons to concentrate proteins (Figure 9). The production of MPC with protein content above 65% generally requires an additional step of diafiltration. Diafiltration involves dilution of retentate with water that enables further concentration of proteins via ultrafiltration.

Figure 9 Simplified process diagram for milk protein concentrate



Similar to WPC, MPC is often referred to by the amount of protein present, i.e. MPC 56 referred to milk protein concentrate with 56% protein. Typical compositions of commercial milk protein concentrates are shown in Table 9.

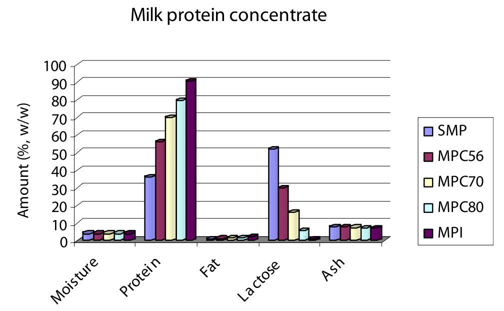
A comparison of the gross composition of MPCs is given in Figure 10. As seen in Figure 10, with increase in protein concentration, there is a corresponding decrease in lactose concentration. Although the total amount of minerals does not change significantly, the type of minerals changes as the protein concentration increases. There is a gradual increase in the amount

Table 9 Typical compositions of milk protein concentrates.

	Amount per 100 g				
Attribute	SMP	MPC56	MPC70	MPC80	MPI
Moisture (g)	4.0	4.0	4.0	4.0	4.0
Protein (g)	36	56	70	80	90
Fat (g)	0.8	1.2	1.3	1.7	2.5
Lactose (g)	52	30	16	5.5	0.9
Ash (g)	8	7.6	7.5	7.3	7.1
Sodium (mg)	450	400	200	120	30
Potassium (mg)	1640	1000	800	380	200
Calcium (mg)	1250	2000	2100	2200	2200
Phosphorus (mg)	1050	1200	1400	1400	1400
Chloride (mg)	600	550	350	80	50

of colloidal minerals (due to the increase in the casein micelle concentration) and a decrease in the serum minerals.

Figure 10 Comparison of major components of MPC



11.8 Functional Properties and Applications of MPC

MPCs are valuable protein ingredients that are suitable for a range of food applications. Appendix 2 summarises the selection criteria for milk protein concentrates based on functionality and applications.

Solubility

The solubility of MPCs depends on the protein concentration, temperature, and the amount of applied shearing during mixing. As the protein concentration of MPC increases, the solubility is slightly reduced but this can be easily overcome by dissolving MPC at high temperature and under vigorous mixing conditions. Homogenisation of high protein MPC greatly improves the solubility. High protein MPCs, with improved solubility are also commercially available.

Good solubility of MPCs is important for their application in dry and liquid nutritional beverages (such as infant and enteral formulations), dairy products (such as recombined milk, ice cream, yoghurt and cheese) and other dry mixes (such as soups and gravies). Due to the presence of casein micelles and their ability to rennet, MPCs are preferred for fortification of cheese milk. Good solubility at room temperature is an important attribute while using MPC for cheese milk extension. Poorly soluble MPCs may result in a defect called "nugget" formation if not processed appropriately during cheese manufacture. Under normal mixing conditions, MPC56 provides an excellent ingredient for extending milk solids but high protein MPCs with improved cold-water solubility can also be used.

Water binding and viscosity

MPCs have high water binding capacities. As the amount of protein increases the amount of bound water also increases. For protein concentrates with high solubility, the increase in protein content also increases the viscosity of the protein dispersion. Water binding and viscosity properties of MPC are useful in several food products including meat emulsions, soups and gravies.

Gelation and structure formation

Fortification of cheese milk (cheese milk extension) is an important application for MPC. The presence of casein micelles in MPC is considered particularly useful during rennetting as the micelles behave similar to that in cheese milk and thus help in rapid cheese curd formation. The gelation related functionality of MPC is useful in enhancing the firmness of rennet gel during the manufacture of cheese. Good dispersibility and solubility remains an important criterion for use of MPC in cheese milk extension as the casein micelles in MPC need to be rennetted by the enzyme and if they are poorly soluble, undesirable textural attributes, such as "nuggets" formation is noticed in the cheese. Such cheese also does not ripen well. Preferred MPCs for cheese milk extension are MPC56 and MPC70, as these generally possess desired functional properties such as casein micelle hydration, solubility and rennet gel formation.

Heat stability

Dispersions made from MPCs are very heat stable and formulations containing MPC can be retorted (121°C for 16 min) or UHT treated. High heat stability of MPCs makes them particularly useful for manufacture of liquid nutritional beverages such as infant and enteral formulations. For nutritional formulations, MPCs with low or no lactose are generally preferred. Examples of commercial products that can benefit from high heat stability of MPCs are recombined UHT milk, UHT and retort infant and enteral formulations.

Emulsifying properties

Milk proteins in MPC have excellent emulsifying properties that aid in the formation of oil-water emulsions such as enteral formula and nutritional beverages. In low-lactose or lactose-free, protein-based enteral and other nutritional beverages, MPC85 or MPI can be successfully used. Such formulations possess good heat and emulsion stability when subjected to high heat treatment such as UHT or retort sterilisation. Recommended food application using emulsifying properties of MPCs are recombined dairy products, infant formulation, and nutritional beverages needing oil-water emulsification.

Foaming and whipping properties

MPCs have excellent foaming and whipping properties derived from the presence of casein micelles and whey proteins in the ratio similar to that present in milk, and provided the prerequisite of good solublity is met. MPCs can be successfully used for foam and foam stabilization in the manufacture of products such as ice cream, whipped topping, and angel cakes.

11.9 MPC Products - Applications and Usage Level

Usage levels of MPCs in food applications will depend on several factors such as type of application, desired nutritional and functionality requirements and intended processing conditions Table 7 below is provided as a guideline only.

Table 10 MPC products – applications and recommended usage levels

Application	MPC56	MPC70	MPC80	MPI
Dairy				
Recombined milks (including chocolate milk)	4-6	4-6	3-5	2-4
Cheese milk extension	0.8-1.0	0.7-0.9	0.6-0.8	0.5-0.7
Ice creams	1-2	1-2	0.5-1.5	0.5-1.5
Yoghurts	2-5	2-5	1-3	1-3
Processed cheeses	2-5	2-5	2-4	1-3
Bakery & confectionery				
Breads	2-3	1-3	1-2	1-2
Cakes	3-5	2-5	1-3	1-3
Biscuits	3-5	1-3	1-2	1-2
Chocolates	2-3	1-2	1-2	1-2
Desserts	2-3	2-3	1-2	1-2
Meat products				
Sausages	2-4	2-3	1-2	1-2
Surimi	2-5	2-4	1-2	1-2
Convenience				
Sauces	2-4	2-3	1-2	1-2
Soups/gravies	1-4	1-4	1-2	1-2
Salad dressings	1-2	1-2	-	-
Nutritional products				
Infant formulae (liquid)	3-5	2-4	1-2	1-2
Enteral formulae (liquid)	-	3-6	2-5	2-4
Sports drinks	-	2-8	1-6	1-6
Sports bars	2-8	2-8	1-6	1-6
Dry mixes (including dry nutritional beverages)	15-30	15-30	8-15	4-10

FAQ

Composition and manufacturing

1. *What are the different whey proteins present in milk?*

   Milk contains approximately 3.5% protein and whey proteins represent approximately 20% of the total protein in milk. Of the total whey proteins, approximate amounts of individual proteins are: β-lactoglobulin – 50%, α-lactalbumin – 20%, bovine serum albumin – 6%, immunoglobulins – 11% and other proteins (including lactoferrin, proteose peptone, *etc.*) – 13%.

2. *What are the major nutritional benefits of using whey proteins in diet?*

   Whey proteins have the several nutritional properties such as

   - Having one of the highest protein efficiency ratios of 3.5 (casein – 2.5, soy – 1.8, wheat – 0.75) .
   - Being slow to digest, providing quality peptides and amino acids in the intestine.
   - Having high levels of essential amino acids compared to other sources of protein.
   - Being rich in sulphur-containing amino acids like cysteine which enhances immune

function and antioxidant status.
- Being rich in branched chain amino acids, leucine, isoleucine and valine, which prevent the degradation of muscle cells during heavy exercise.

3. *What are the major differences between WPI manufactured via microfiltration/ultrafiltration and ion exchange chromatography?*

Although the gross composition of WPI manufactured by microfiltration is similar to that manufactured by the ion exchange/chromatography, subtle differences are present. During the ion exchange process, protein molecules are removed from liquid whey through chemical binding to specially developed resins. The bound protein is removed by pH adjustment and subsequently concentrated via ultrafiltration. The ion exchange process results in slight chemical modifications to the protein, where some calcium is replaced by sodium during the binding/release process. Most of the whey proteins are captured with the exception of glycomacropeptides (GMP).

In the microfiltration process, particulate materials such as residual fat, microbial debris and denatured protein, are removed via a MF membrane of diameter less than 1 um before concentration of proteins using the ultrafiltration process. The MF process produces WPI that is different from the ion exchange WPI in that there is no chemical modification to the protein and GMPs are retained in the WPI. If no pH adjustment is used and the process is carried out under mild temperatures, the WPI is almost completely free of denaturation. Physical functional properties of WPI from MF can be optimised via controlled denaturation of whey proteins and manipulation of ionic strength.

4. *How do I know which WPC/MPC is appropriate for my food application?*

Commercially available WPC/MPC contain a range of protein concentration and consequently vary in minerals and lactose contents. If WPC/MPC is added to food on a solids basis, there will be large differences in functionality due to the differences in protein content. Appendices 1 and 2 can be used as a general guideline for selecting an appropriate WPC/MPC, but it is more appropriate if the final selection is made based on the desired protein content and desired functionality. For example, if gel formation were the key requirement, whey protein products with high amounts of proteins would be more suitable than MPC. However, if heat stability and good emulsifying properties are desired, MPC may be the preferred option.

5. *What are the advantages of using MPC over SMP?*

MPCs contain both casein and whey proteins almost in the same proportion as present in skim milk (i.e. 80% casein and 20% whey proteins). Therefore, proteins in MPC have similar functional properties to those in SMP. MPCs can be used to replace SMP for recombined milk type applications where the products requires low lactose, as MPCs contain considerably lower amounts of lactose than SMP. Although prices of dairy ingredients fluctuate considerably depending on market forces, in general, on protein basis, the amount of MPC required is lower than SMP thus giving cost savings.

6. *What are the differences between MPC and caseinates - sodium and calcium? Can MPC be used to replace caseinates in food applications?*

The major differences between MPC and caseinates are in the state of the casein and the amount of whey proteins. The caseins in MPC are present in the form of casein micelles whereas in sodium caseinate, caseins are in "random coil" aggregates. In calcium caseinate they are present as calcium-linked large aggregates (sometime called artificial micelles). MPC also contains whey proteins in the same proportion as present in milk, whereas caseinates contain no whey proteins. In most applications caseinates can be replaced by MPCs.

Functional properties

1. *What are the major functional properties of whey proteins?*

   In addition to the high nutritional value of amino acids, whey proteins possess excellent water binding, gelation, whipping and foaming properties. In the native form, whey proteins have globular structures that are formed through the intra-molecular disulphide bonds. By heating above the denaturation temperatures, globular structures are unfolded and the functional properties are improved. Whey proteins possess adequate emulsion forming properties and excellent emulsion stabilising properties.

2. *How does the source of whey proteins affect the functional properties of WPC?*

   Whey proteins are generally extracted from two major sources, sweet whey (obtained from cheese or rennet casein), and acid whey (obtained from acid casein and sometimes from cottage or cream cheese). Sweet whey contains considerably less amount of minerals such as calcium than acid whey, which affects the functional properties of WPCs. Another major difference between sweet and acid whey is in the amount of glycomacropeptides (GMP), which are present in sweet whey but absent in acid whey. Due to the high calcium content, WPC from acid whey may have poor heat stability but is more suitable for gelling-type applications. On the other hand WPC obtained from sweet whey possesses higher heat stability than that from acid whey, but possesses poor gelling properties. It should be noted that this "rule of thumb" might not apply if WPCs of similar compositions are obtained by appropriate processing of the whey.

3. *Whey proteins are soluble in the entire pH range of food products while caseins tend to precipitate near its isoelectric point, why?*

   Whey proteins contain a range of proteins such as β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulins, etc. with varying molecular size and isoelectric pH. The proteins in whey have smaller molecular size (10-20 nm) compared with casein micelles (e.g. 30-300 nm) and contain more uniform electric charge distribution than casein proteins. The combination of these properties allows whey proteins to show high solubility under the normal measurement conditions.

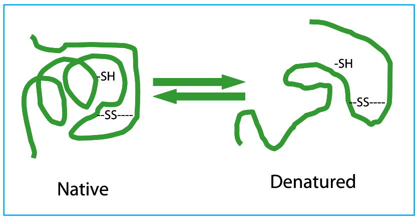
4. *What is the caking problem in whey powders and how can it be minimised?*

   The caking of whey powder is principally related to the hyg roscopic and crystallisation properties of lactose. If conditions arise within the final package of whey powder that promote further lactose crystallisation, the whey powder becomes "caked" by the formation of a linked crystall structure throughout the powder mass. Actions that minimise the risk of caking are

   - Maximum crystallisation of the lactose prior to spray drying
   - Formation of small, uniformly sized crystals during the crystallisation step

- Use of packaging that prevents up-take of moisture by whey powder
- Storage at low uniform temperature

5. *What is denaturation of whey proteins and what is its significance?*
Denaturation of whey proteins refers to the change in the native configuration of protein into an unfolded state. Denaturation can be defined as any modification of secondary, tertiary, or quaternary structure of the protein molecule, excluding breakage of covalent bonds. Denaturation is therefore a process by which hydrogen bonds, hydrophobic interactions, salt linkages are broken and the protein is unfolded. Such a change may be induced by change in environmental conditions such as heating above a certain temperature, change in pH, ionic strength, radiation, and high pressure or shearing. Depending on the extent of change in the environmental conditions, the denaturation can be reversible or irreversible. Denaturation of whey proteins results in loss of its biological activity and alters functional properties. In whey proteins, buried sulphydryl groups (-SH groups) are exposed during the denaturation and become active sites for interaction with other sulphydryl groups leading to aggregation of proteins. Pre-denaturation helps in improving the heat stability of whey proteins, and therefore manufacture of commercial heat-stable WPCs sometimes requires preheating during manufacture. Controlled denaturation of whey proteins improves functional properties such as emulsification, gelling and foaming. However, extensive denaturation can lead to aggregation, insolubilisation or gelation of whey proteins that can adversely affect the functional properties.



Ingredient application

1. *What are the major applications of whey powders?*
Whey powders are prepared by concentration and drying of sweet (e.g. cheese) or acid (e.g. casein) whey, and contain relatively low amounts of proteins and high amounts of lactose. Whey powders are very cost-effective nutritional ingredients suitable for a range of bakery, confectionary, and convenience food products. Demineralised whey powders are suitable where low saltiness is desired. Currently, two levels of demineralisation, 40% and 90% are available.

2. *What are the major applications of different WPCs?*
WPCs are manufactured by the ultrafiltration process and contain proteins levels from 35% to 85%. WPCs are versatile food ingredients and applications range from nutritional fortification to targeted functionality such as gel formation. In most commercial WPCs, the whey proteins are in the undenatured state, which means by heating during application, high quality gels can be formed. WPC is suitable for many food applications such as infant formulation, bakery, confectionary, and health and nutritional products. Health, sports and nutritional products generally require WPC with high protein/low lactose concentrations.

3. *What are the advances or disadvantages of using whey proteins over other proteins in food applications?*

One of the major advantages of whey proteins over caseins is the solubility over the entire pH range. Caseins tend to precipitate near the isoelectric point whereas whey proteins remain soluble. Therefore, for applications such as fruit juice and acid beverages, whey proteins provide better functionality than caseins. One of the potential disadvantages of whey proteins is their poor heat stability. Heating whey proteins over the denaturation temperature causes unfolding (denaturation) and disulphide bond-mediated aggregation that is followed by protein precipitation or gelation. However, appropriate manipulation of processing conditions can overcome the poor heat stability of whey proteins. The main factors that determine the heat stability of whey proteins are protein concentration, temperature of heating, pH and ionic strength. Whey proteins are more susceptible to heat-induced aggregation and visible precipitation at high protein concentrations, pH near the isoelectric point (pH 4.5-5.5), high ionic strength (such as calcium concentration), and high temperature (above 80°C).

Protein	Biological Value
WPI	159
WPC	104
Egg	100
Fish	83
Beef	80
Chicken	79
Casein	77
Soy	74
Wheat	54
Pulses	49

Compared with proteins from other sources such as soy and other plant proteins, whey proteins are nutritionally superior and provide many functional properties that are difficult to achieve using plant proteins. One of the measures of protein quality is the measurement of biological value (BV). BV measures the amount of protein (or more precisely - the nitrogen) retained in the human body per gram of protein absorbed. Comparison for BV is generally made with the BV of an egg that has a BV of 100. Table below compares the BV of protein from various sources.

Another major advantage of using whey proteins is that they provide the highest value of branched chain amino acids (leucine, isoleucine and valine), which are valued for muscle building and recovery.

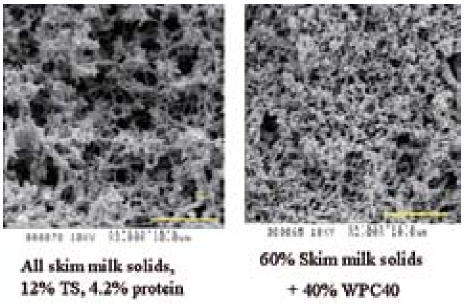
4. *What is heat-induced gelation of whey proteins and what factors influence this property?*

Heat-induced gelation of whey protein refers to the property of producing gel upon heating which contributes towards the structure and texture of food products. The heat-mediated gelation of protein-water systems has been described as a two-stage process. In the first stage, the denaturation of the native protein occurs while in the second stage protein-protein interaction occurs resulting in a three-dimensional protein network that forms the final gel structure. The strength and texture of whey protein gels are influenced by intrinsic factors such as the composition and concentration of the proteins and by extrinsic factors such as heating temperature, pH, ionic strength and the presence of other food components, for example, lipids, sugars, starches, etc. Heating above certain temperature results in activation of buried sulphydryl groups through unfolding of the protein. This leads to the formation of new intermolecular disulphide bonds that are required for the formation of a highly ordered gel structure. Changes to heating conditions affect the gel's macroscopic and microscopic structural attributes, by changing the rates and mechanisms of denaturation and aggregation. The macrostructure of protein gels is largely dependent on the protein concentration and at any given temperature, a critical concentration is needed for formation of the gel network. The ionic strength and the pH influence the gelation reactions by affecting the balance of polar and non-polar residues and interaction between protein-protein residues. Protein-protein interactions are generally favoured where the net change of protein is minimum, i.e. pH values near the isoelectric point. High ionic strength tends to reduce electrostatic repulsion between proteins due to the shielding of ionisable groups by mobile salt ions. Combination of protein concentration, temperature, pH and ionic strength is used to control the heat-induced gelation of whey proteins. When the pH is near the isoelectric point and the ionic strength low, randomly aggregate gels are formed by hydrophobic interaction. When pH is away from the isoelectric point and at low ionic strength, electrostatic-repulsive forces hinder the formation of random aggregates and hence linear polymers are formed.

5. *What are the benefits of using whey proteins in yoghurt?*

Whey proteins are mainly used to improve the texture of yoghurt. In set yoghurt, whey proteins can improve water binding and reduce syneresis during transport and storage. In stirred style yoghurt, whey proteins improve viscosity and mouthfeel. Whey proteins (e.g. WPC 80) are added to the yoghurt milk before the heat treatment to allow their denaturation and their interaction with casein micelles. The recommended levels of fortification are 2 to 4%. Overall, the addition of WPC to yoghurt improves its texture and water binding properties. A comparison of yoghurt with 12% total solids and 4.2% protein with or without WPC is shown in Figure below. It is obvious that the addition of WPC resulted in a fine stranded structure, and reduced the void volume that could lead to whey separation.

Figure Effect of addition of WPC on microstructure of yoghurt



6. *How do we ensure heat stability of WPC in the manufacture of UHT milk?*

One of the issues with WPCs that sometime needs attention is the inadequate heat stability of whey proteins. When whey proteins are heated above the denaturation temperature (approximately 78°C), unfolding of the globular structures occurs which exposes the buried sulphydryl groups in whey proteins that may form disulphide bonds with adjoining molecules. Depending on the temperature, protein concentration, pH and ionic strength, high temperature heating, such as UHT, can lead to the formation of insoluble protein precipitates. The key factors to control during the manufacture of UHT milk are the pH and the availability of free calcium ions. Too low pH can enhance the protein instability while too high free (ionic) calcium can lead to aggregation of whey proteins and ultimately precipitation of protein. Selecting a WPC with low calcium can help as well as the use of phosphate salts to bind free calcium in the UHT formulation. Heat stable WPCs are available and can be satisfactorily used in UHT applications.

7. *Which types of beverages applications are suitable for WPC and WPI?*

WPC or WPI can be use as the source of proteins in most beverages such as sports formula, infant nutrition, enteral formula, fruit juice, and drinks, soy beverages. In soy beverages such as soymilk, whey proteins can provide sulphur-containing amino acids that are limiting in soy proteins. Whey proteins also enhance the flavour of soy beverages. WPC or WPI is suitable for both acidic and neutral pH beverages. Careful selection of WPC or WPI is needed when the beverage needs to be heated at high temperatures.

8. *Which types of whey protein ingredients are suitable for clear beverages?*
The cloudiness in beverages is due to the colloidal particles in whey protein ingredients. The most suitable type of whey protein ingredient for clear beverage is WPI with little or no fat or lipid content. WPIs with undenatured protein and low lipid contents are suitable for both neutral pH and low pH beverages and can also be combined with fruit juices.

9. *What are the advantages of using WPC in sports nutrition?*
Among all protein sources, whey proteins contain the highest concentration of branched chain amino acids (BCAAs), leucine, isoleucine and valine. BCAAs are suggested to provide safe nutritional support for athletes and individuals seeking optimal lean muscle mass. BCAAs are also considered essential amino acids because human beings cannot survive unless these amino acids are present in the diet. For athletes, BCAAs are needed for the maintenance of muscle tissue and appear to preserve muscle stores of glycogen (a storage form of carbohydrate that can be converted into energy). BCAAs also help prevent muscle protein breakdown during exercise.

During sustained exercise, muscle BCAAs are used for energy and NH3 production. The subsequent increase of free tryptophan to BCAA ratio is thought to increase the tryptophan availability for serotonin synthesis. This can cause sleep and could increase the mental effort necessary to maintain athletic activity. BCAA supplementation before and during exercise may therefore delay fatigue and improve athletic performance. Research suggests that regular supplementation with branched chain amino acids can prevent central fatigue by preventing tryptophan from entering the brain. However, more research is needed to support such findings further. Whey protein products originating from acid whey contain higher amounts of BCAAs than those from cheese whey unless cheese whey is largely free from GMP.

10. *What are the major functional properties of lactose in food applications?*
Lactose can provide the following applications in food products:

- Reduction in the overall sweetness of the product since the sweetness of lactose only 30% to that of sucrose.
- Can be used as a carrier of flavour and enhancement of flavour in food products.
- Source of nutrition and energy, especially in infant formulae.
- Browning and characteristic golden crust in bakery products and caramelisation in confectionery products.
- Source of fermentable sugar for yoghurt and other fermented products.

11. *What are the main applications of MPC?*
The rapidly expanding capability of membrane separation technology has resulted in the generation of milk protein concentrates (MPCs) with varying levels of proteins. Due to the relatively unaltered structure of the protein components, these products are increasingly

expanding into the dairy and nutritional foods areas. MPCs can be used as replacement ingredients for skim milk powders, caseinates or whey protein concentrates. Compared with skim milk powders, MPCs have less lactose and higher amounts of protein, with casein/whey protein ration being similar to skim milk powder. Milk protein concentrates are particularly suited to use in recombined white cheeses, cream cheese spreads, and fresh cheeses such as fromage frais and lebneh. In recombined cheeses, the use of MPC 56 also eliminates the need for whey drainage and disposal as carried out in the traditional cheese making process, due to the high protein/low lactose composition of the product. Thus these products can be produced on existing recombining equipment without the need for specialised cheese making equipment. Water usage at the reconstitution stage is also reduced. MPCs are also suitable for nutritional drinks or special diet formulations (e.g. enteral formulations) where elevated protein levels are desirable.

12. What factors influence the functionality of MPCs in cheese application?

The main factors affecting the functionality of MPC in cheese milk are the solubility and hydration of MPC. Poor solubility of MPC in cheese milk can lead to formation of dry, gel-like particles in the cheese matrix. Therefore, it is important that MPCs with high solubility are chosen for this application. Adequate hydration of casein micelles from MPC allows the micelles to take part in the rennet-induced gelation and cheese structure formation. Solubility of MPC at room temperature can be improved by heating or homogenisation of MPC dispersions.

Glossary

Cheese milk extension

Cheese milk extension refers to boosting solids and increasing the cheese yield by the addition of protein powders. MPC56 and 70 are generally preferred for cheese milk extension as the casein micelles in these powders are easily rennetted into cheese curd.

Denaturation

Denaturation refers to the changes in the conformation of the native state of whey proteins. In the native state and under specified temperature, pH and ionic strength whey proteins possess certain conformation (e.g. secondary and tertiary structures) and biological activity. Alterations in the environmental conditions, such as heating, change in pH or ionic strength leads to the unfolding of the native structures. This state is called the denatured state of whey proteins. When proteins are denatured, their biological activity is reduced and changes occur in their functional properties.

Dispersibility

Dispersibility refers to the ability of a powder to disperse into individual particles upon coming into contact with water or a liquid food product.

Dispersibility of protein powders can be enhanced by agglomeration (recirculation of fine powder particles to form agglomerates during spray drying), and further enhancement by coating the agglomerates with lecithin (instantising).

Emulsion

An emulsion refers to dispersion or suspension of two immiscible liquids such as oil and water. Food emulsions can be oil-in-water such as milk or water-in-oil such as butter. An emulsion is intrinsically unstable due to the difference in the surface tension of the dispersed (e.g. oil) and the continuous phase (e.g. water). Milk proteins have the ability to form stable emulsions due to their ability to adsorb at the oil-water interface and reduce the interfacial tension.

Emulsification

The process of formation of an emulsion is termed as emulsification. Emulsification is usually carried out by mechanical means such as a homogeniser.

Emulsifying capacity

Emulsifying capacity refers to the maximum amount of oil that can be emulsified in an aqueous dispersion containing a fixed amount of protein before the inversion or breakdown of emulsion.

Emulsion stability

Emulsion stability refers to the amount of oil separation from an emulsion measured over a fixed time of storage after emulsion formation.

Foaming ability

Foaming ability refers to the maximum amount of foam that can be made by whipping a fixed amount of protein before the breakdown of the foam. To form a foam efficiently, proteins need to unfold and adsorb rapidly at the interface.

Foam stability

The time required for foam to breakdown is interpreted as its foam stability.

Gelation

Gelation is the ability of protein powders to develop a three-dimensional network. Heating, changing pH or ionic strength, can induce gelation in WPC dispersion while MPC can be gelled by rennet or by reduction in pH.

GMP

Glycomacropeptide – also known as caseinomacropeptide (CMP) or caseino-glycomacropeptide (CGMP) – hydrophilic peptide fraction of kappa casein released in whey during the action of rennet on casein micelle.

Heat stability

The ability of protein products to withstand high temperature heat treatment is referred to as the heat stability. MPCs are very heat stable can be heated for more than an hour at 121°C. WPCs containing native whey proteins are less heat stable but their heat stability can be controlled by controlling protein concentration, pH and ionic strength during heating.

Hydration and water binding

Hydration and water binding or water uptake of proteins are interchangeable terms used in the food industry. Hydration generally refers to ability of protein powder to absorb and bind water when coming in contact with water.

Membrane filtration

Membrane filtration process refers to fractionation of proteins using polymers and ceramic filters. The separation is based on molecular weight or molecular size. Membrane filtration is a pressure-driven, cross-flow or tangential flow process. Four major membrane filtration processes are: reverse osmosis, nanofiltration, ultrafiltration and microfiltration. WPC and MPC are generally manufactured using the ultrafiltration process.

MPC

Milk protein concentrate refers to protein powders obtained by ultrafiltration of skim milk. MPC contains caseins and whey proteins in almost similar ratio to that present in skim milk, i.e. 80% casein and 20% whey proteins. Similar to skim milk powder, the caseins in MPC are present as casein micelles. The protein content in MPC varies from 56 to 85%. MPC can be used as replacement for skim milk powder.

MPI

Milk protein isolate – refers to membrane–derived (ultrafiltered milk), milk protein concentrate with protein content of more than 90%.

Permeate

The low molecular weight "materials" or "components" passing through membrane filters during the manufacture of WPC and MPC is known as permeate. Permeate mostly contains all the lactose and minerals.

Physical functional properties

Physical functional properties refer to the characteristics of protein ingredients that contribute to physical properties such as viscosity, gelation, foaming and emulsification in water (aqueous functionality) or in food products (food system functionality).

Physiological functional properties

Physiological functional properties refer to the biological activity or bioactivity of proteins.

Retentate

During the process of membrane filtration, the concentrated protein material retained in the membrane is termed as retentate. Retentate is spry dried to manufacture WPC and MPC.

Solubility

Solubility of protein powders refers to the ability of the particles to uptake water and disintegrates into lowest particle or molecular state. Solubility of proteins relates to surface hydrophobic (protein-protein) and hydrophilic (protein-solvent) interactions with water. Among all the functional properties, solubility is considered an important pre-requisite for certain functionalities such as emulsification and foaming.

Viscosity

Viscosity refers to the resistance of a solution to flow and visually it refers to the thickness of the solution. Viscosity of protein solutions is related to the concentration of proteins and the availability of hydrophilic amino acids. Viscosity is important in providing physical stability of dispersions and emulsions and contributes to the mouthfeel of food products.

WPC

Whey protein concentrate – refers to whey protein product manufactured by concentrating whey proteins by membrane processing (such as ultrafiltration) or ion exchange chromatography. WPCs are differentiated based on their protein contents and the protein content in WPC varies from 35% to 85%.

WPI

Whey protein isolate – refers to a whey protein concentrate with protein content over 90%. WPI is relatively free from lactose and a suitable ingredient for sports, infant nutrition, functional foods and nutraceuticals.

Whey

The yellowish green liquid obtained during manufacture of cheese, rennet casein and acid casein. Whey obtained during the manufacture of cheddar or Mozzarella cheese or rennet casein is termed as "sweet" while that obtained during the manufacture of acid casein, cream or cottage cheese is termed as "acid" whey. Whey contains whey proteins, lactose, minerals and very small amounts of fat.

Whey proteins

The proteins present in whey are known as whey proteins. Whey proteins are also called serum proteins. When casein is removed from milk by acid or rennet, the solution contains the whey proteins. The major whey proteins are β-lactoglobulin and α-lactalbumin, together representing nearly 70% of the total whey protein. Other whey proteins are bovine serum albumin, lactoferrin and proteose peptone.

References

Bryant CM and McClements DJ (1998). Molecular basis of protein functionality with special consideration of cold-set gels derived from heat denatured whey. Trends in Food Science and Technology 9, 143-151.

Dairy Processing Handbook (1995). Tetra Pak Processing Systems AB, Lund, Sweden.

De Wit (1998). Nutritional and functional characteristics of whey proteins in food products. Journal of Dairy Science, 81, 597-608.

Fox PF (2001) Milk proteins as food ingredients. International Journal of Dairy Technology, 54, 41-55.

Harper WJ (1989). Functional properties of whey protein concentrates and their

relationship to ultrafiltration. IDF special issue 9201. 77-108.

Huffman LM and Harper WJ (1999). Maximising the value of milk through separation technologies. Journal of Dairy Science, 82, 2238-2244.

Kinsella JE (1984). Milk proteins: physico-chemical and functional properties. CRC Critical Reviews in

Food Science and Nutrition, 21, 197-262

Mulvihill DM (1999). Production, functional properties and utilization of milk protein products. In Advanced Dairy Chemistry – 1: Proteins (Ed Fox PF), pp. 369-404. Elsevier Applied Science, London.

Rajah KK and Blenford DE (1988). The ALM Guide to Lactose Properties and Uses. Association of Lactose Manufacturers, The Hague, The Netherlands.

Reference Manual for US Whey and Lactose Products. US Dairy Exports Council.

Appendix 1a Selection of whey protein products for dairy and confectionary products based on functional properties and food applications

Functional Property	Whey Protein Product						Dairy				Bakery & Confectionary			
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI	Recombined milk	Ice cream	Yoghurt	Processed cheese	Bread	Cake	Biscuits	Chocolate
Bulking agent	◆	◆	◆											
Flavour enhancement	◆	◆	◆	◆			■	■	■		■	■	■	■
Nutrition enhance-			◆	◆	◆	◆	■	■	■	■	■	■	■	■
High protein				◆	◆	◆	■	■	■	■	■	■	■	
Low lactose					◆	◆								
Low minerals					◆	◆								
Dispersibility	◆	◆	◆	◆	◆	◆	■	■	■	■				
Solubility	◆	◆	◆	◆	◆	◆	■	■	■	■				
Clarity						◆								
Water binding			◆	◆	◆	◆		■	■	■	■	■	■	
Fat binding				◆	◆	◆				■		■	■	
Viscosity				◆	◆	◆			■	■	■	■	■	
Gelation					◆	◆			■	■	■	■		
Heat stability		◆	◆	◆	◆	◆	■			■				
Low pH stability	◆	◆	◆	◆	◆	◆			■	■				
Emulsification			◆	◆	◆	◆	■	■	■	■				
Foaming			◆	◆	◆	◆		■						
Whipping			◆	◆	◆	◆						■		
Film formation				◆	◆	◆						■		
Crystallisation	◆	◆												■
Browning	◆	◆	◆	◆										
Adhesion				◆	◆	◆					■	■		

Appendix 1b Selection of whey protein products for meat, convenience and nutritional products based on functional properties and food applications

Functional Property	Whey protein product						Meat products				Convenience			Nutritional products				Dry mixes
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI	Desserts	Chopped meat Chopped meat	Sausage	Surimi	Sauce	Soup/ gravy	Salad dress-ing	Infant for-mula	En-teral for-mula	Sports drink	Sports bar	
Bulking agent	◆	◆	◆															■
Flavour enhancement	◆	◆	◆	◆			■				■	■	■	■				■
Nutrition enhancement			◆	◆	◆	◆	■	■	■	■	■	■	■	■	■			■
High protein				◆	◆	◆	■	■	■	■			■	■	■	■	■	■
Low lactose					◆	◆									■	■	■	■
Low minerals					◆	◆									■			■
Dispersibility	◆	◆	◆	◆	◆	◆					■	■	■	■	■			■
Solubility	◆	◆	◆	◆	◆	◆	■				■	■	■	■	■			■
Clarity						◆										■		
Water binding			◆	◆	◆	◆	■	■	■	■	■	■	■					
Fat binding				◆	◆	◆	■	■	■	■							■	
Viscosity				◆	◆	◆	■	■	■	■	■	■	■					■
Gelation					◆	◆	■	■	■	■								
Heat stability		◆	◆	◆	◆	◆	■					■		■	■			
Low pH stability	◆	◆	◆	◆	◆	◆					■		■			■		
Emulsification			◆	◆	◆	◆	■	■	■	■	■	■	■	■	■			
Foaming			◆	◆	◆	◆												
Whipping			◆	◆	◆	◆	■											
Film formation				◆	◆	◆												
Crystallisation	◆	◆																
Browning	◆	◆	◆	◆			■											
Adhesion				◆	◆	◆		■	■								■	

WP – whey powder, DWP – demineralised whey powder

Appendix 2 Selection of milk protein concentrate based on functional properties and food applications

Functional Property	Milk Protein Product				Dairy					Bakery & Confectionary				Meat Products			Convenience			Nutritional Products			
	MPC 56	MPC 70	MPC 80	MPI	Recombined milk	Cheese milk extension	Ice cream	Yoghurt	Processed cheese	Bread	Cake	Biscuits	Desserts	Chopped meat	Sausage	Surimi	Sauce	Soup/ gravy	Salad dressing	Infant formula	Enteral formula	Nutritional beverages	Sports bar
Flavour enhancement	◆	◆			■		■		■	■	■	■	■	■	■	■	■	■	■				■
Nutrition enhancement	◆	◆	◆	◆	■		■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■
High protein		◆	◆	◆	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Low lactose			◆	◆	■				■	■	■	■	■	■							■	■	■
Dispersibility	◆	◆	◆	◆	■		■	■									■	■	■	■	■	■	
Solubility at 20°C	◆	◆			■	■	■													■	■	■	
Solubility at 45°C	◆	◆	◆	◆	■	■	■													■	■	■	
Solubility at 65°C	◆	◆	◆	◆	■	■	■	■												■	■	■	
Water binding	◆	◆	◆	◆				■	■	■	■	■	■	■	■	■	■	■	■				■
Fat binding		◆	◆	◆					■	■	■	■	■	■	■	■							■
Viscosity		◆	◆	◆				■	■				■										
Heat stability	◆	◆	◆	◆	■			■	■	■	■	■								■	■	■	
Emulsification	◆	◆	◆	◆	■		■		■								■	■	■	■	■	■	
Foaming	◆	◆	◆	◆			■				■												

DAIRY AUSTRALIA
Delivering for the dairy industry

12

Applications of Australian Dairy Ingredients in UHT Milk

Content

288 12.1 General outline of the UHT process

293 FAQ

317 Glossary

319 Referrences

12.1 General outline of the UHT process

Brief discussion on the principles of UHT processing.

12.1.1 UHT Processing Options

The aim of the UHT or Ultra High Temperature, or Ultra Heat Treatment process is to produce an end product with commercial sterility but which has undergone minimal chemical or organoleptic changes either as a result of processing or of storage.

The UHT process involves two main procedures:

- a continuous flow system for the sterilization of fluids, which is
- coupled with aseptic packaging.

The key points in this definition are "continuous sterilization", and "aseptic packaging".

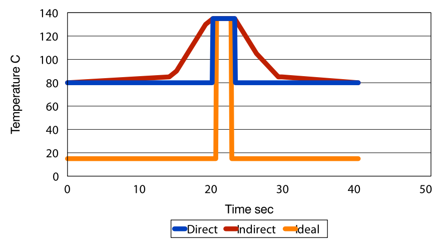
UHT processing can therefore be considered as being carried out in two streams:

- in stream one, the fluid is continuously sterilized
- in stream two, the container material is separately continuously sterilized

The final filling and sealing of the packs is then carried out under aseptic conditions.

The UHT process thus contrasts with the process of retort sterilization, in which the non-sterile fluid is filled into a non-sterile container, the pack sealed and then both the liquid and the pack are sterilized as one unit. The key factor involved in UHT processing (as far as the sterilization step is concerned) is rapid heating to a pre-defined temperature (generally of the order of 135 to 145ºC), holding for the minimum time to ensure sterility (generally 2 to 5 sec), and then cooling as rapidly as possible before aseptic packaging (these conditions contrast with those of in-can sterilization, generally of the order of about 120ºC for 20 minutes).

Figure 1 Ideal typical direct and indirect time/temperature processes for UHT sterilisation



Given the fact that the aim of the UHT process is to achieve sterilization of the product with minimal concurrent damage to physical, chemical or organoleptic properties of the product, ideally, the time/temperature curves for the sterilisation stage should be should be as shown by the orange curve in Figure 1. This curve shows very rapid heating from cold to sterilizing temperature, holding for the minimal time to ensure sterility, and then very rapid cooling.

Direct and indirect processing

The essential feature of UHT processing is that of rapid heating and cooling of the product to minimize chemical and organoleptic change. This is generally achieved in one of two ways:

- the "direct" process relies on direct contact of the product with steam, either by injection of steam into the product (steam injection) or by injection of the product into a chamber filled with steam (steam infusion). However, after sterilization the product is passed into a vacuum chamber operating under the precise conditions necessary to remove this amount of water from the product. The vacuum process also results in a very rapid cooling of the product from sterilization temperature to a temperature of about 75 to 80ºC.

- The "indirect" process relies on obtaining sterilization temperatures by heat transfer through a stainless steel interface, generally part of a tubular or plate heat exchanger. Regenerative heating and cooling of the product is an essential part of the system. Of necessity, longer heating and cooling times are required, compared to direct processing.

Both processes generally use an initial temperature for the UHT sterilisation of about 70 to 85ºC, in part to assist with regeneration of heat and also to assist in improving overall product quality. Typical curves for the indirect and direct systems are shown in Figure 1 for the red and blue curves respectively. Note that the overall shape of the direct system above its starting point of about 80ºC is similar to the Ideal Curve. It should be noted that, in general, the area under the curve is indicative of the heat damage done to the product, (in particular the proteins) as a result of heating. It is clear that the indirect system is inherently more severe than the direct system when compared at equal holding times and temperatures. This is due to the slower heating and cooling times involved in the indirect system.

Figures 2, 3, and 4 show a typical steam injection nozzle, an infusion system and an indirect system based on a tubular heat exchanger.

Figure A2 Steam injector for UHT processing*

** Figure courtesy of Tetra Laval (Tetrapak 1995)*

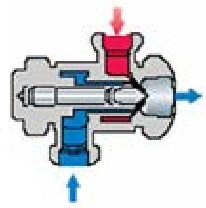


Figure A3 Steam infusion system for UHT processing*

** Figure courtesy of Tetra Laval (Tetrapak 1995)*

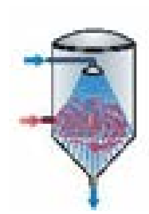
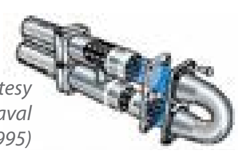


Figure A4 Tubular system for UHT processing*

** Figure courtesy of Tetra Laval (Tetrapak 1995) Homogenization*



Homogenization

The purpose of UHT processing is to manufacture a product which will keep for an extended period without refrigeration. Thus homogenization is essential to avoid the development of fat separation in the product. The homogenization of the product may occur either upstream or downstream from the sterilization head. If the homogeniser is located downstream from the sterilisation head, then it must be designed to ensure that it too can be sterilised appropriately and that during operation, it remains aseptic. Thus normal homogenizer valves, pumps and other components must undergo costly modification to ensure that they can be sterilised, and to ensure aseptic operation. However, to counterbalance this additional cost, it is generally accepted that that there is a gain in product quality achieved by location of the homogenizer downstream. In particular, downstream homogenization is believed to achieve a reduction in fat separation during storage, and to reduce sedimentation in the product (this may be due to dispersion of micro particles of burn-on from the sterilization section, or dispersion of denatured whey proteins). Downstream homogenisation is particularly seen as important for direct systems.

Aseptic holding tanks

In the past few years, most UHT plants have been installed with aseptic holding tanks as an integral part the plant. This vessel allows a balance of flow rates between the UHT processor and the packaging section, so as to prevent the need for recirculation of the product, should supply exceed filling capacity. Recirculation is very undesirable, as it results in increased heat treatment of a portion of the product. In such cases, the aseptic holding unit plays an important part in ensuring the final quality of the product. A typical aseptic unit is shown in Figure 5.

Figure 5 Tetra Laval Aseptic holding unit for UHT processing

** Figure courtesy of Tetra Laval (Tetrapak 1995)*

Fillers

There are many options available to processors for filling operations, including the use of laminates (either preformed or rolls), bags and plastic bottles. Selection of which system to use will be mainly determined by both market assessment and cost.

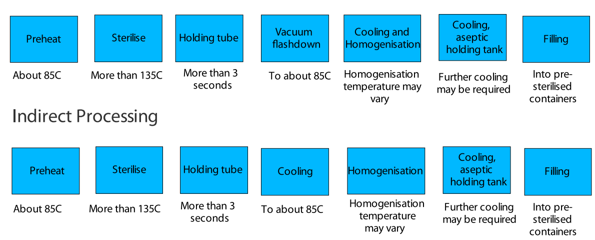
Unit processes

The main unit processes involved in UHT processing are shown in Figure 6 below, for direct and indirect processing. As mentioned above, the homogenizer may be placed either upstream or downstream of the sterilizing head (it is shown downstream in Figure 6). Also note that all operations from the sterilising head downstream must be sterilized prior to commencement of operation, and must remain sterile for the duration of the run. This sterilisation may be carried out either by pressurised hot water or by high pressure steam. The time and temperature conditions for this sterilisation step are set by the manufacturers. The aseptic holding tank, if fitted, is included in the Cool and Fill section.

Figure 6 Unit processes involved in UHT operations

Direct and Indirect UHT Processing Unit Operations

Direct Processing



12.1.2 The Effects of UHT Processing on Dairy Products

Changes in the physical and chemical characteristics of UHT milk evident immediately after processing

Effect of UHT processing on protein denaturation

The extent of protein denaturation in the product is important both in terms of functionality in formulated products and from the nutritional viewpoint. The extent of whey protein denaturation is generally greater in an indirect system than a direct system. The proportion of individual denatured whey proteins present also depends on the process used, both in terms of the sterilisation conditions and systems but also in terms of the preheating and cooling regimes.

Reflectance and sediment

In general, conventional retort sterilization and UHT processing both result in an increase in the opacity of milk. This is the result of an increase in the number of reflecting particles present in the milk as a result of denaturation and aggregation of whey proteins. Homogenisation also increases the opacity of milk. As the pH of milk is decreased, the reflectance of the resultant UHT milk initially rises, as would be expected. However its reflectance reaches a maximum at about 6.55, and then decreases very rapidly. The reduction in opacity corresponds to an extraordinarily rapid increase in sediment in the product. This sediment forms immediately after UHT processing, and is a heavy material which can be removed by centrifugation at only 100 g for a few minutes. Thus the milk is totally stable to UHT processing at pH say, 6.65, but at pH 6.50, the micellar stability of the milk is totally destroyed on UHT processing, and the product is unusable. Further, the sediment will cause rapid burn-on throughout the system, and cause complete plant blockage. Therefore if sedimentation in the product is to be avoided, it is essential that the pH of the raw milk be above about 6.65-6.70. A reduction in pH below this value, either by chemical means, or by addition of formulated components, or through the action of bacteria, can result in rapid sediment formation.

pH.

It is very difficult to make hard and fast comments regarding the effect of UHT processing on pH, as very many factors can influence such changes. However, some general comments can be made. Firstly the extent of such changes is small, generally less than 0.05 pH unit, and virtually always less than 0.1 pH unit. Secondly, milks processed by direct treatment have generally a higher pH than the same milk processed by the indirect method. The reason for this might be due to the effect of the differing time/temperature profiles (affecting the production of acids via the Maillard reaction), or the effect of the vacuum flashdown stage in direct processes resulting in removal of carbon dioxide from the system.

Freezing point

There has been ongoing controversy for many years regarding the effect of UHT processing on freezing point. The balance of evidence however seems to suggest that there is no significant change as a result of UHT processing, and any observed changes are more likely to be the result of dilution or concentration of the product. Such changes may occur with direct processing if the relationship between the vacuum in the flash down chamber is not set appropriately.

Flavour

The flavour of fresh UHT milk is generally acknowledged to be poor, with cooked flavours predominating. It is likely that these flavours are the result of release of sulphydryl groups in the product (the denaturation of whey proteins in particular during UHT processing can lead to the development of sulphydryl flavours in the milk). There is normally a rapid improvement in the flavour of the product in the first few days, as these groups become oxidized. The rate of such improvement is related to the availability of oxygen.

Contamination of the product

Clearly problems with contamination of the product are of major concern to manufacturers. Protocols must be enforced to ensure that any such problems are identified and programs maintained to ensure that the source of contaminants can be clearly identified and removed.

Changes in the Physical and Chemical Characteristics of UHT Milk Occurring during Storage

Storage-induced changes are affected to a very large extent by storage temperature. The rate at which most of these changes occurs is reduced as the storage temperature decreases. The major exception to this rule is the onset of age gelation which occurs most rapidly at about 27ºC. Age gelation is a common defect which limits the acceptable life of UHT milk by conversion of the product to a junket-like gel. It is not due to bacterial action, but rather to the action of proteolytic enzymes which survive UHT processing.

pH

The pH of UHT milk generally drops during storage. The rate of decrease in pH increases sharply with increased storage temperature. The change in pH is not necessarily related to the onset of age gelation, Typically, after 3 to 6 months, the pH of UHT milk might drop by 0.05 units on storage at 4ºC, 0.20 pH units at 15ºC and 0.5 pH units at 40ºC. The changes are approximately linear with time.

Acidity

The acidity of UHT milk also increases with time, the rate of increase being more rapid at elevated storage temperatures. Again the extent of development of acidity is not related to the onset of age gelation.

Flavour

The flavour of UHT milk during storage is controlled by storage temperature, storage time and oxygen content. The oxygen content of the milk will depend on the particular process employed for manufacture. However, in the longer term, the permeability of the container also plays a major role in oxygen availability.

Age gelation

Age gelation is one of the most common problems faced by UHT manufacturers. Age gelation is a purely physico-chemical process of coagulation, and the product remains sterile, even though it takes the form of a rennet-like gel. The onset of age gelation can occur as shortly as 2-3 weeks after manufacture, but may be delayed for well over a year with other samples. The time taken for the onset of age gelation is highly dependent on storage temperature. At temperatures of about 4ºC it can be delayed indefinitely; at 15ºC, useful retardation can be achieved. Maximum rate of gelation occurs at about 27ºC, and gelation is completely prevented by storage at or above 40ºC (of course, such samples suffer very badly from browning reactions).

Colour

The brightness of UHT milk generally decreases on storage, the rate of decrease depending greatly on storage temperature. The decrease in brightness is a function of development of Maillard browning reactions. *(Maillard browning occurs when reducing sugars such as lactose interact with the amino groups of amino acids during cooking or processing of food. Maillard reactions can affect many factors, including nutritional value (essential amino-acids loss, such as lysine), colour changes (brown pigments formation) and flavour.)* Storage at much above 30ºC leads to rapid development of darkening of the product within a few weeks.

Fat separation

In non-recombined or non-reconstituted products, fat separation is almost always the result of poor homogenizing conditions. This may be the result of inadequate homogenizing pressure, inadequate pressure in the second stage of the homogenizer, scratches on the homogenizer valves or leaking by-pass valves. In recombined or reconstituted products, fat separation can usually be overcome by addition of correct stabilizers.

Excessive nominated life of the product leading to market problems

Too often producers are pressured to accept "best by" dates which are perhaps a little optimistic for the market conditions. Such actions generally lead to problems with the long term marketing of the products, and such pressure should be resisted.

FAQ

UHT Processing

1. *Why does UHT processing give a better product than in-can sterilisation?*

The UHT process started from the fact, first noted at the start of the twentieth century, that biological reactions which lead to the destruction of bacteria have a higher thermal co-efficient than the chemical reactions which lead to undesirable changes in the product (such as the development of off flavours and loss of nutritive value). For example, a 10ºC rise in temperature of sterilization results in a increase in the rate of destruction *of Bacillus stearothermophilus* by a factor of about 10, whereas for the same temperature rise, the rate of browning increases by a factor of only about 3. *B. stearothermophilus* is a comparatively heat resistant organism, and the rate of destruction of more sensitive organisms, such as *B. subtilus* increases by a factor of about 30 for each 10ºC rise in temperature. Thus to achieve a similar degree of destruction of *B. stearothermophilus* through increasing sterilization temperature by 10ºC, a reduction of holding time by a factor of at least 10 is possible. However, the browning reactions at this increased temperature but reduced holding time, will be reduced to about 3/10 of the amount at the lower temperature.

The results of this effect are shown in Table 1.1 below

Table 1.1 Effect of temperature on chemical change

Temperature ºC	Time for Equal Bactericidal Effect	Chemical Change for Same Bactericidal Effect
115	1	100
125	.1	30
135	.01	9
145	.001	2.7

In essence therefore, by increasing sterilization temperature, and reducing holding time to obtain equal sterilization effect, the degree of concomitant chemical, physical and organoleptic damage in the product is very substantially reduced. The logical development of this is the UHT process, in which high temperatures and short times are employed to yield a product which is commercially sterile, but with comparatively little chemical, physical or organoleptic damage.

2. *What are the advantages of direct and indirect processing?*

The direct process.

The direct process relies on direct contact of the product with steam, either by injection of steam into the product (steam injection) or by injection of the product into a chamber filled with steam (steam infusion). Either method results in virtually instantaneous heating of the product to sterilizing temperature, through the latent heat of the steam. In both cases, a portion of the steam condenses in the product as a result of the heating process, with a dilution of the product at that stage by about 8 to 10% (depending on the initial temperature of the product). However, after sterilization the product is passed into a vacuum chamber operating under the precise conditions necessary to remove the same amount of water from the product. The vacuum process also results in a very rapid cooling of the product from sterilization temperature to a temperature of about 75 to 80ºC. For this reason, special attention must be paid to steam quality used in direct systems - culinary quality steam is absolutely essential.

There is one further aspect that has caused concern in some countries. The addition of water to milk is seen as adulteration, and illegal - although the same amount of water is removed by the vacuum process, the same molecules are not necessarily removed, and therefore the product contains some added water, which is against regulations. This aspect prevented the adoption of direct UHT processing for many years in some countries.

Indirect processing

Indirect UHT processing relies on obtaining sterilization temperatures by heat transfer by through a stainless steel interface, generally part of a tubular or plate heat exchanger. High pressure steam or hot water is generally used as the heating source. Regenerative heating and cooling of the product is an essential part of the system. Of necessity, longer heating and cooling times are required, compared to direct processing.

The Actijoule process is an interesting development where the heat transfer tube is electrically heated. It is currently used for manufacture of milk and milk products.

Which system is preferable?

There are many factors to be considered, and there are certainly no simple straight-forward answers – much depends on the particular product, market and manufacturing environment. Some factors which might be considered include:

- UHT direct systems are more complex, and in general require more control equipment.
- Direct systems require a special steam supply.
- Direct systems are more expensive, in both operating and capital costs.
- Direct systems can handle viscous materials which can pose problems on some indirect systems (particularly those based on plate heat exchanger systems).
- Indirect systems can be very energy efficient – more than 85% regeneration is possible (direct systems are generally of the order of 40%.
- Indirect systems may face greater problems with burn-on in the heating, sterilization and cooling sections. Such deposits are formed from mixtures of heat denatured proteins and salts, and can limit running times to, say, 4 hours or less before it is necessary to have an intermediate clean. Direct systems can often run for more than 18 hours without such shutdowns.
- Direct systems can yield an oxygen free product . This may be of advantage for improved flavour or retention of some vitamins.
- Directly processed milks are more prone to age gelation than indirectly processed milks.

Of key importance also is the effect of each process on milk quality. This is very difficult to assess, as the basis for comparison is not clear - should they be compared at equal temperatures and holding times (inevitably favouring the direct system), or at some theoretical "equal sporicidal efficiency conditions". In general however, the direct system with its minimal heating and cooling times should give a product with less denaturation and vitamin loss. This would be expected to be reflected also as better flavour. However, in practice, the situation is very far from clear cut. It is fair to say that indirect manufacturers have made very great strides in improving their operations, and in many cases the flavour of their product is often comparable or superior to that of direct processes.

3. *What are the possible causes of contamination in UHT products?*

If contamination occurs in the product at an unacceptable level, it is vitally important to identify and rectify the source of the contamination. In general, it is very rare for resistant spores to survive UHT treatment (although there have been some recent cases in Europe). In general, the sources of contamination nearly always involve post-sterilisation contamination.

Whilst it is often difficult to immediately identify the source of the contamination, an indication of the likely source may often be obtained by evaluation of the type(s) of organisms involved. It has been suggested that contamination with non-heat resistant spores such as *B.cereus* suggests that the plant has not been cleaned or sterilised effectively. In such cases the sterilising process has eliminated vegetative organisms, but has not been sufficient to eliminate spores of moderate heat resistance. Such contaminants can arise through a contaminated down stream homogeniser. Regular changes in homogeniser seals should be considered as a means of reducing contamination problems.

Other studies have suggested that spores (such as *B. stearothermophilus*) trapped under seals have enhanced heat stability, and may survive UHT sterilisation processes. More recently some manufacturers have encountered problems with contamination by *Fusarium oxysporum*, which can lead to flavour defects and blowing of packs. Generally it is believed that the cause of such difficulties is through contaminated air near the filling machines. It is also important that air filters on aseptic tanks are well maintained.

A further area which can cause concern is the development of pinholes in heat exchangers, leading to contamination of the product by cooling water and the contaminants therein. This problem can generally be recognised by the wide range of water based contaminants in the product.

Overall, some of the most likely causes of contamination include:

- Downstream homogeniser
- Filling machines
- Aseptic tanks
- Seals
- Pinholes

The key to overcoming problems with contamination are therefore:

- Ensure that protocols are in place to identify contamination problems as early as possible
- Identify the contaminant(s) present
- From the heat resistance of the organisms, identify likely areas of contamination
- Take preventative action

It should be emphasised that ***the sources of contamination nearly always involve post-sterilisation contamination***. There are many examples of manufacturers increasing the severity of the treatment of UHT products in response to overcoming isolated problems with bacterial contamination. This more intense heat treatment results in greater denaturation, which is undesirable. This so-called "Process Creep" is a very poor response to such difficulties, and manufacturers should be on guard against it.

4. *What is the importance of oxygen in the product?*

The level of oxygen in the product can have important implications regarding changes in flavour occurring on storage and on the loss of vitamins occurring during processing and storage.

Oxygen in the product can occur as the result of oxygen entering via:

- the raw milk
- the aseptic holding tank
- the head space of packs
- permeation through the packaging material

The effect of oxygen on the product is determined in part by the storage temperature of the product.

Processing systems

Packaging systems vary in the amount of air which they included in the package. Many systems, particularly the form-fill-seal systems which seal below the liquid level, claim to have minimal oxygen in the packaging. Other systems which fill into preformed packs can result in head spaces of more than 50 mL. It should be noted that even in systems which claim to have minimal head space in the packs, there will be perhaps 5 to 8 mL of air present, perhaps through air entrapment during the packaging operation. Clearly the variations in the amount of oxygen present will have a significant impact on flavour changes during storage.

Milk is normally saturated with oxygen, but in the direct process, the oxygen is stripped during the vacuum flash down process, and the product at that stage is free of oxygen. In a packaging system such as certain TetraBrik machines, there is little opportunity for the product to come in contact with oxygen (provided an aseptic tank is not used), and there is little head space in the pack - thus it is possible in these systems to obtain a nearly oxygen-free product which will remain in that form for an extended period depending on the permeability of the packaging material.

It is claimed that oxygen-free products have the advantage of retaining oxygen-labile vitamins for longer (these can be lost in a few days in an oxygen containing product), and perhaps lead to somewhat improved flavour after extended storage (although they may show poorer initial flavour). It should be noted that the differences in flavour as the result of differing oxygen content are only comparatively minor.
Indirect systems (with no vacuum flashdown), those that use aseptic holding tanks and those packaging systems which include a high head space volume will lead to products with a high oxygen content. High oxygen contents in the product can lead to earlier development of stale/oxidised

flavour during storage.

Filling systems

Amongst the form/fill seal operations, various plastic materials are used in roll forms, with a web thickness of up to 1.5 mm for cups. Lids are usually of thermoplastic lacquered aluminium foil. The packaging material base and lid foils are, for example, immersed in peroxide and dried, and all filling and sealing operations are carried out in a sterile air tunnel at slightly above atmospheric pressure. The seal is formed by heat sealing of the lacquered aluminium web onto vacuum formed cups. The advantage of such systems is the wide range of shapes which can be filled, virtually to customers requirements. However, many of these systems are highly permeable to oxygen, which can lead to a degradation in organoleptic quality during storage. Metal cans are of course impermeable to oxygen, but most paper/plastic laminate packs are at least in part permeable to oxygen. Laminates vary in their composition, and this is reflected in price. Many laminates contain a layer of aluminium to assist in the prevention of oxygen contamination, but cheaper versions without an aluminium layer have been used in UHT operations from time to time to reduce costs. Naturally, the higher oxygen permeability will influence the rate of oxidized flavour development of products stored in these packs. Even in the case of aluminium foil laminates, oxygen permeability is possible through seams in some instances.

Flavour

The flavour of fresh UHT milk is generally acknowledged to be poor, with cooked flavours predominating. It is likely that these flavours are the result of release of sulphydryl groups in the product. There is normally a rapid improvement in the flavour of the product in the first few days, as these groups become oxidized. The rate of such improvement is related to the availability of oxygen. In general, the oxygen content of UHT milk decreases rapidly in the first few days, with a corresponding increase in acceptable flavour due to oxidation of sulphydryl groups. In practice, for samples stored at 2ºC, there appears to be some general preference for the flavour of low oxygen samples throughout a storage life of three months. At higher temperatures, such as 30ºC, high oxygen samples are initially preferred, but after a fairly short time (say three to four weeks) comments such as "oxidized" are often noted. Changes in flavour correlate well with changes in oxygen content and sulphydryl content of UHT milks.

Vitamins and oxygen

Vitamin C and folic acid are sensitive to oxygen content in the product, and losses of these vitamins can occur very rapidly when oxygen is available. Table 4.1 shows the effect of oxygen on vitamin losses for these materials.

Table 4.1 Effect of oxygen on ascorbic acid and folic acid contents of stored UHT milk

Vitamin	Oxygen Level (ppm)	Storage	Losses %
Ascorbic acid	0.1	60	20
	1-2	14	90
	8	7	100
Folic acid	0.1	60	0
	1-2	60	5
	8	14	100

The implications of the Vitamin C and folic acid losses are important with regard to label claims for these components in UHT products. Clearly even fortification will not help significantly, particularly if the product pack has a head space, as there is often more than enough oxygen present to destroy a considerable amount of Vitamin C and folic acid.

5. *What are the problems involved in sampling for contamination?*

In UHT processing, it has been suggested that, after incubation of all filled containers, not more than 1 sample in 5000 should show signs of contamination. After installation and commissioning of a UHT plant, intense assessment of the level of contamination occurring in products is vital to ensure that all parts of the plant are correctly installed and operating. This will involve assessment of many containers produced over a lengthy period.

After final authorization of the process and commencement of normal UHT operations and production, it is simply not possible to ensure that the required standard of less than 1 in 5000 packs contaminated is in fact met, without the testing of a significant portion of production. Clearly, incubation and testing of samples means that these samples cannot be used to produce income, and it is to the benefit of the company's overall profits if the amount of samples required for testing is reduced to a minimum consistent with safety and overall sampling policy. For example, a statistical analysis of operations has suggested that in order to ensure a 95% probability that the spoilage rate is less than 1 in 1000 (well above the recommended limit of no more than 1 in 5000), a random sample of 300 containers should be examined from a total output of 3000 to 8000 containers (between 10% and 3.75% of production).

For most companies, the statistical patterns used for selection of samples for contamination evaluation will have been recommended by the equipment suppliers. Often they include sampling of comparatively small numbers at regular intervals, somewhat higher samples being taken at near commencement and completion of production, and at other times, for example during reel changes and flying seal changes (as appropriate).

However such protocols can often only indicate whether gross contamination has occurred. For example, the normal protocols employed can identify, if the contamination rate increases from less than 1 in 5000 to say 1 in 50 or so. However, they often cannot identify if the contamination rate has increased by a factor of 2, 3 or even 10, to 1 in 2500, 1 in 800 or even 1 in 500.

Fortunately, most problems with contamination result in a very marked increase in contamination rates such that the protocols used in plants can readily identify that a difficulty has occurred. However, it should be borne in mind by operators that the protocols cannot be relied upon to detect changes of some significance other than those which lead to gross contamination in the product.

In routine operations, it has been suggested that random samples be taken at a rate of 50 per 3000 packs produced, with other suggestions involving sampling about 1% of production and others suggesting only 0.25%. Although these sampling regimes do not indicate precise spoilage rates, it is claimed that this problem is compensated by the accumulation of data and experience over time.

A further factor of importance is assisting determination of the cause of contamination is need to ensure that all samples are clearly labelled and coded. Evidence of the time of filling, the filling machine and the UHT plant employed is crucial in assisting assessment of contamination problems. Such coding is also important in evaluation of longer term problems such as age gelation and sedimentation in the product.

Nutritional

1. *What is the effect of UHT processing and storage on nutrition?*
   From the results of many feeding experiments, it can be concluded that from a nutritional view, UHT milk is comparable to pasteurized milk. The biological value, true digestibility and net protein utilization of the milk proteins are virtually unaffected by UHT treatment.

Milk protein

The first change which occurs on the heating of milk is denaturation, an unfolding of the more or less regular structure of the protein - this involves changes in the spatial distribution of the proteins, without a breakdown in the peptide bonds.

Denaturation per se has no negative nutritional significance, and in fact can improve digestibility and utilization of milk protein, as a result of the protein structure being somewhat loosened. Further, heat-treated milk is precipitated as a finer curd in the digestive tract, which improves enzymic activities.

Concern is sometimes expressed about the extent of loss of lysine (an essential amino acid in milk proteins) in UHT milk. Lysine loss is due to Maillard reactions, involving lysine and lactose. The resultant complex is resistant to digestive enzymes, and the lysine is not available for utilization. Pasteurization of milk results in a loss of about 1 to 2% of lysine; UHT treatment about 2 to 4%, with small non-significant differences between direct and indirect systems; short boiling gives a loss of about 5% lysine; sterilization 6 to 10% loss; and evaporation about 20% loss. Thus in UHT milk, by far the greatest proportion of lysine is available after processing. No loss of lysine occurs on storage of UHT milk at 2ºC or at ambient temperatures, whilst at 38ºC loss of about 25% occurs over a 6 month period.

Milk Fat

Under UHT conditions, there are no adverse effects on the nutritional properties of the milk fat. However, it should be noted that during the storage of UHT milk, there are hydrolytic reactions occurring which result in an increase in the free fatty acids present in the product. Free fatty acid development will occur only if the milk contained residual bacterial lipase, so that under normal conditions such action should not occur. However in cases where the milk does contain residual bacterial lipase, the extent of formation of free fatty acids is dependent on storage temperature, being very slow at refrigeration temperatures, but more rapid at elevated temperatures, to the point where organoleptic changes can be noted. Such problems can be severe, as even low concentrations of free fatty acids can lead to flavour and aroma problems.

Minerals

UHT treatment results in a decrease in the level of ionic calcium in the milk, as calcium ions and other minerals move into the casein micelle. This decrease in ionic calcium and phosphorus can be as high as 40%. In feeding trials, it has been found that calcium and potassium retention were higher in infants fed UHT milk than those fed pasteurized milk. Phosphorous retention did not differ significantly between the two groups.

Vitamins

Effectlof processing

The level of the heat stable fat soluble vitamins A, D, E and carotene, and of the heat stable vitamins of the B complex, riboflavin, pantothenic acid, biotin and nicotinic acid are little or unaffected by UHT processing, using either direct or indirect processing. Also, on subsequent storage, there is virtually no loss of these vitamins in light protected packaging. Similarly, a number of the water soluble vitamins are heat stable, such as riboflavin, nicotinic acid, pantothenic acid and biotin. There is a small loss of thiamine. Vitamin B12 and folic acid are both heat labile.

Influence of storage

The changes in the vitamin content of UHT milk have been considered under *FAQ 4. What is the importance of oxygen in the product?*

12.2.3 UHT product defects

1. What factors control fat separation in UHT products?

Summary

- Fat separation is generally caused by inadequate or inappropriate homogenisation
- Even a very small number of larger fat globules in milk (less than 1% of the total) can lead to major difficulties in fat separation on storage
- Homogeniser selection, valve design and maintenance are key factors in controlling fat separation
- Regular microscopic examination of homogeniser valves is recommended
- Use of additives (if permitted) to increase the viscosity of the aqueous phase can assist in controlling fat separation

Discussion

In general, fat separation in UHT milk is the result of inadequate or inappropriate homogenisation.

Why is fat separation such an important issue in UHT products? The simple reason is that, unlike pasteurised products, UHT products are required to retain their acceptability over a period of 6 to 9 months or even more when stored at temperatures perhaps as high as 25 to 30ºC. By comparison, pasteurised products generally only have to retain their acceptability for a period of two or three weeks, when stored under refrigeration temperatures. It is quite clear that for pasteurised products, while homogenisation is required to avoid fat separation, the efficiency of homogenisation need not be particularly high, as the refrigerated conditions of storage and the short time before consumption each reduce the likelihood of significant fat separation. However in the case of UHT milk, the lengthy period required for storage, coupled with the higher storage temperatures involved make fat separation one of the major issues associated with this product. To ensure adequate homogenisation in UHT operations, considerable care must be taken in homogeniser selection, design of homogeniser valves, homogeniser operation and maintenance.

In general, the rate of rising of fat globules in an ideal environment is governed by a number of factors as outlined below:

- ***The rate of rising of fat globules increases as the square of the globule diameter***. So, a globule with twice the diameter rises at four times the speed, one with three times the diameter rises at nine times the speed and so forth.

- ***The rate of rising is directly proportional to the difference between the density of the fat globules and the external liquid***. In the case of milk, when we homogenise we create a globule with a surrounding milk fat globule membrane (MFGM), a mainly proteinaceous material which is heavier than water. Fat globules of course are lighter than water, so together the resultant globule and membrane will be a little heavier than the pure fat, and the difference between the densities of the water and the globule/MFGM complex will be decreased. Thus, not only does homogenisation reduce the overall size of the globules (decreasing rate of separation) but also results in an effective increase in density of the globules, also reducing fat separation. Under extreme homogenising conditions, the density of the fat globule FGM complex can be greater than the plasma, and these fat particles will sink. Such an event only happens rarely.
- ***The rate of rising is inversely proportional to the viscosity of the liquid***. Thus an increase in viscosity through the addition of carrageenan or xanthan for example, will reduce fat separation.

However, these concepts reflect only an idealised situation. In practice of course, even with good homogenisation we will have a range of fat globule sizes in the end product. What is important in reducing fat separation is not only that the average size of the globules be below, say 0.5 microns, but that there are very few globules with a size much greater than this. It is of little value for example. if the average globule size is 0.5 micron, but 3 or 4 % of globules have a size of more than 1.5 microns. The influence of small numbers of globules on the fat separation rates is shown below.

For milk with all globules of 0.5 microns (Case 1), the rate of rising has been defined as 1.0. In Case 2, (milk with 99% of globules of 0.5 microns and only 1% of globules of size 1.5 microns) the 1% of globules of 1.5 micron size contain 22% of the total fat present, and these particles rise at 10 times the normal rate. These figures may be surprising at first, but they are the outcome of the relationship between the rate of rising of globules and the diameter of the particles. Certainly fat separation will be a problem with this sample. In Case 3, with 99% of globules of size 0.5 microns and 1% of size 2.5 microns, the 1% of globules contain 56% of total fat, and rise at 25 times the normal rate! Severe fat separation is likely. Even in Case 4, with 99.9% of globules of 0.5 microns and 0.1% of size 1.5, the larger globules represent 3% of total fat and rise at ten times the normal rate.

Table 1.1 Effect of fat globule size distribution on fat separation

Case Number	Particle Size (µ)	Number (%)	Volume (%)	Rising Rate of Largest Particles (Smallest =1)
1	0.5	100	100	1
2	0.5	99	78	1
	1.5	1	22	9
3	0.5	99	44	1
	2.5	1	56	25
4	0.5	99.9	97	1
	1.5	0.1	3	9

Thus, it can be seen that even very small amounts of larger globules can contain a very highly disproportionate amount of the total fat present, and these will rise at many times the normal rate. Careful and efficient homogenisation is therefore required.

For homogenisation of UHT milk, two stage valves are often used. One of the main reasons for use of this approach is to ensure that any clusters which are formed during the first stage of homogenisation are broken up by the second stage. However, from time to time, depending on the systems employed and the valves used, clusters may be encountered. These may be considered as single globules, and therefore will lead to major difficulties in fat separation.

Free fat in the product can lead to rapid and severe fat separation. (Free fat is caused by either coalescence of smaller particles in the product, or through inadequate recombination techniques leading to fat globule instability). In general this is not a problem with non-recombined products, and provided care is taken in the manufacture of recombined products, such difficulties should not be encountered.

Control of fat separation

- As indicated above, control of fat separation is dependent on efficient design and operation of the homogeniser. Even small invisible marks on the homogeniser valves can reduce homogeniser efficiency, allowing a greater number of larger globules to enter the product, A visible examination of the valve surfaces is not sufficient. A microscopic examination of the surface should be undertaken regularly, and the valves replaced or refaced as required. If products such as chocolate milks are used in the system, they may result in increased homogeniser valve wear, and increased attention to valve maintenance in such circumstances is essential.
- An increase in plasma viscosity can reduce fat separation. If permitted, the use of additives such as carrageenan, xanthan and the like that result in increased viscosity can help control fat separation.
- An occasional problem which has been encountered is milk entering the product which has bypassed the homogeniser, through for example a CIP bypass tube. An examination of the plant should be undertaken to ensure that such an option is not available.
- Laboratory evaluation of samples is not easy. As indicated above, very small amounts of larger globules can contribute heavily to fat separation, and these are not readily identified, even with modern methods. A useful means for routine examination is using a visual microscope to assess mean globule size. But in general, this will only indicate if there are major problems with the homogeniser. It is particularly difficult to assess the level of larger diameter globules when they are present in only small amounts.

2. What influences age gelation in UHT products?

Age gelation is a major problem to many UHT processors. It is a problem that currently is quite unpredictable, and one which leads to much concern on the part of manufacturers. The problem is a formation of a gel-like product from the original milk, which may occur anytime from about 6 weeks after manufacture to more than one year later - the product is still sterile, but resembles a rennet cheese curd/whey mixture in appearance.

The mechanism of age gelation is now generally accepted to primarily involve the action of proteolytic enzymes which survive the UHT process. These enzymes are produced either by:

- the action of proteolytic psychrotrophic micro-organisms (those which can continue to grow even at refrigeration temperatures) in the raw milk prior to UHT processing. On UHT processing, the organisms are destroyed, but the proteolytic enzymes may survive to a greater or lesser extent; and/or
- the action of the native milk enzyme, plasmin, present in freshly drawn milk from the udder. Again this enzyme can survive UHT treatment and cause age gelation in the product.

Evidence has shown that the rate of proteolysis which these enzymes initiate in UHT milk increases with temperature, and reaches a maximum at about 40ºC. This does not correlate well with the temperature of most rapid age gelation of about 27ºC. Further, age gelation does not always occur after a specific degree of proteolysis. Rather there seems to be a minimum level of proteolysis below which gelation will not occur. Above this level, gelation occurs only in some samples.

It should also be noted that the development of proteolysis will lead to bitterness in the milk, a useful sign of the possible close onset of age gelation. The bitterness is due to the presence of peptides in the milk caused by proteolysis of proteins.

Options for Control of Age Gelation

Selection of raw milk and processing options

Little can be done regarding the presence of plasmins in the raw milk, but steps can be taken to reduce the role of microbial enzymes in age gelation. The best way of controlling age gelation by such enzymes is by reducing as far as possible the presence of psychrotrophic bacteria in the raw milk. Thus, only the best quality fresh raw milk should be used for UHT processing.

It should be noted that only extremely small levels of the particular psychrotrophs are required to produce sufficient enzymes to initiate age gelation problems in the product. Thus, even a low level of psychrotrophs in the raw milk is no guarantee of performance - if they are of the type that produces heat resistant enzymes.

The best options for manufacturers to control age gelation is therefore to obtain the best raw milk possible, and to UHT process it as quickly as possible. In general, manufacturers should aim to get the milk from the cow into the carton within 24 hours. In the case of recombined products, again the aim should be to recombine and UHT process as quickly as feasible. This should be a prime aim of all UHT processors. Milks which have been stored at the farm (2 day pickup) or at the factory for more than a few hours should not be used for UHT processing. Checks should be taken on the level of proteolytic psychrotrophs in the raw milk used for processing.

Low temperature Inactivation (LTI)

Heating of the raw or UHT milk for 60 minutes at 55ºC will in general produce a worthwhile reduction in the extent of proteolytic activity in the product. However, a number of difficulties have been found in applying LTI in practice. These include the impracticability of holding large quantities of milk for one hour at 55ºC. For UHT packaged milk, this is not an option. For raw milk, the volumes would be considerable. More importantly however, proteases from different organisms show different inactivation temperatures, ranging from 50 to 65ºC. As these temperatures are quite specific, unless the properties of the contaminating enzymes are known for each batch, the LTI conditions selected would be ineffective. In practice, therefore LTI processing is of little commercial value.

Use of sodium hexa-metaphosphate

Age gelation can be controlled by addition of sodium hexa-metaphosphate (HMP) to UHT milk. It is believed that this compound interferes with the second stage of age gelation, preventing aggregation of the partially degraded casein micelles, after proteolysis has taken place. Thus, in samples treated with HMP, proteolysis continues, but gelation is prevented. Not only can the continuing proteolysis be measured chemically, but it is also evident from increased bitterness in the product. Thus, this approach does control age gelation well, but does not prevent the development of bitterness in the product.

It is reported that other phosphates such as sodium di-hydrogen phosphate and others are ineffective in control of age gelation. The reason for this is not known. Further there are variabilities in the effectiveness of HMP, depending on its source.

However the use of HMP to assist in the control of age gelation appears effective, provided that its addition is permitted by the regulatory authorities.

Assessment of Product Shelflife Prior to the Onset of Age Gelation

It would be useful if, after manufacture, we could assess the likely shelf life of the product before gelation occurs? Only a few options are available, none of which is very satisfactory.

Measurement of primary amino groups

The action of the protease in cleaving the caseins (and whey proteins) results in an increase in the level of primary amino groups present in the product (there will be of course a base level present from the terminal and other amino groups present in the unmodified milk proteins). Thus given time, an increase in the level of these groups can be observed in UHT milk which contain proteases. It should therefore be possible for manufacturers to store samples of UHT milk at say 28ºC for some weeks, then assess the increase in the level of primary amino groups in the product. This in turn would give an idea of protease activity, and in time, it should be possible to relate protease activity to likely shelf life. However, it should be borne in mind, as indicated above, that protease activity is not the only factor required for gelation to occur. At this stage, the factors controlling this mechanism are simply not well defined.

Even if such a system were developed satisfactorily, the warning that manufacturers would get is not great. The test would take at least four weeks, and possibly 8 to 12 weeks, and by this time the product is well and truly in the market place.

Measurement of viscosity

A simple indication of age gelation is viscosity. Typically the viscosity of UHT milk remains constant until about 6 to 8 weeks prior to gelation, when a rapid increase is observed. Even a slight increase in viscosity (from 2-3 cp to say 10 cp) is a good indication that age gelation is likely to occur within the next 2 months. Again however, the warning given to manufacturers is not great, and the method is not particularly useful from the marketing point of view.

Neither of these methods is very satisfactory (viscosity and assessment of primary amino groups) as they only give warning well after the product has been distributed.

Identification of Native or Bacterial Enzymes in UHT Milk

Recent work has been able to identify the source of the enzyme responsible for age gelation – whether it is caused by enzymes from psychrotrophic bacteria, or if plasmin is responsible. The methodology looks at the protein breakdown present in the product as the patterns differ depending on the enzyme present. Knowledge of the likely cause can be of benefit if bacterial enzymes are shown to be responsible, as some useful action to control gelation can then be taken. However if plasmin is responsible, little can readily be done except perhaps for increasing the severity of the heat treatment.

3. What factors can cause sedimentation in UHT products?

Summary

- Milks with a pH below about 6.60 to 6.70 can show extreme immediate sedimentation on UHT processing.
- Careful monitoring of raw milk pH is essential in UHT operations. The pH of the milk must be measured precisely to two decimal places. Milks with a pH below about 6.65-6.70 should be treated with suspicion.
- If immediate sedimentation is encountered on UHT processing, this can be addressed by adjustment of the pH with either alkali or di-sodium hydrogen phosphate (if permitted).
- Sedimentation which occurs during long term storage is not likely to be a significant problem.

Discussion

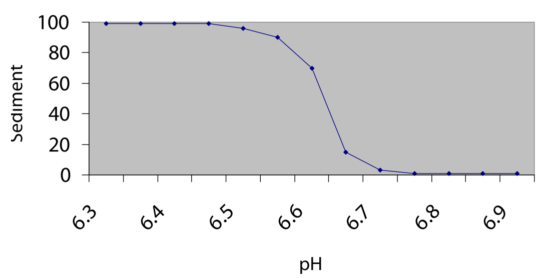
Sedimentation in UHT products is a major concern to consumers, as it detracts from the attractiveness and mouth feel of the product.
Sedimentation in the system can thus be of concern in two major areas:

- Sedimentation arising during or immediately after manufacture, and
- Sedimentation arising on storage.

Sedimentation which Occurs Immediately after M anufacture

In general, sedimentation arising during or evident immediately after manufacture can be recognised by the processing problems encountered as a result – in particular increased feed pressure in the system because of burn-on occurring in the hot sections of the plant. Such burn-on can also lead to less effective sterilising conditions and increased contamination.

Table 3.1 Effect of pH on sediment in UHT milk



Under the correct processing conditions, milk

Chap - 12

is generally quite stable to UHT processing, and the extent of any immediate sediment formation should be quite minor. However, if the pH of the milk is allowed to drop below about 6.70, the extent of sediment formation increases extremely rapidly. The effect of the raw milk pH on sediment formation may be seen schematically from the diagram below.

From the above, it may be seen that milk is extremely sensitive to pH when it comes to immediate sediment formation. The scale of 100% sediment on the vertical axis represents virtually all of the casein and most of the denatured whey protein being precipitated. Thus for pHs below about 6.5, milk is generally totally unstable to UHT processing, with virtually all of the proteins being precipitated as heavy sediment. For pH's much below 6.65, sediment formation changes from close to 0, to close to 100% within about 0.15 to 0.20 of a pH unit.

If milk of say pH 6.4 which shows virtually total instability to UHT processing has its pH altered to say 6.8 through the addition of sodium hydroxide, the milk will generally show no significant signs of instability on UHT treatment. Similarly, a milk of original pH 6.8 which passes through a UHT plant satisfactorily will sediment very severely when its pH is dropped to 6.5 prior to processing.

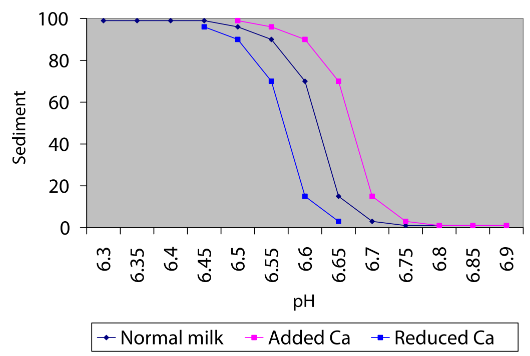
It is only the low pH of milk that is responsible for the instability, not the means of its occurrence. Changes due to addition of acid or through the development of lactic acid bacteria leading to a drop in pH lead to the same unstable outcome.

Such development of sediment in the product can have a catastrophic effect on both processing and product. Clearly, if the milk is of such a pH where total sedimentation occurs, this will rapidly lead to severe blockage of the plant, and possibly blown seals. In practice however, such major effects are very rare, given the care taken by the industry to ensure that milk is stored under refrigeration conditions and used quickly.

However, further difficulties can occur when the pH of the milk is just below the point at which initial instability and precipitation occurs. For example, if milk which is stable at say pH 6.70 is processed at say 6.67 then minor but important sedimentation may occur in the product, and the run time of the plant may be decreased to some extent. This problem does occur from time to time in the industry.

Further work has shown that this instability is closely related to the ionic calcium content of the milk, as shown in the diagram below. In this case, three samples have been examined for instability – one a normal milk, one with increased ionic calcium content, and one with reduced ionic calcium content. As may be seen, the milk with a high ionic calcium content shows the onset of instability at higher pH, whereas that with decreased ionic calcium shows the onset of instability at a lower pH than the control. Thus high calcium milks are less stable to UHT treatment than

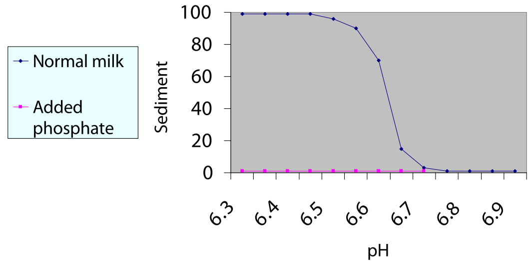
Table 3.2 Effect of pH on sediment in UHT milk



low calcium milks. This is the reason that UHT treatment of goat's milk, which is particularly high in ionic calcium, is very hard to process satisfactorily without special precautions.

When sufficient calcium sequestering agent is added to the milk, it will become quite stable to UHT processing. In the diagram below, the pH of the milk is adjusted with either disodium hydrogen phosphate or sodium di-hydrogen phosphate. As may be seen, the resultant milk is quite stable to UHT processing.

Table 3.3 Effect of added phosphate on the sediment in UHT milk



There are a number of precautions that can be taken to aid in ensuring that sedimentation is not a problem during UHT processing:

The pH of the raw milk must be measured precisely to 2 decimal places prior to treatment. The importance of measuring precisely to two decimal places cannot be overemphasised. As can be seen from the figures above, the performance of raw milks with pHs of, for example, 6.70 and 6.66 are very significantly different in terms of sediment formation on UHT processing. In general, most milk processing operations require pH measurement to only one decimal place. However greater precision is required for UHT milk. Experience will generally tell what is the minimum that should be accepted, but a good rule of thumb is that in general, milks with a pH much below 6.65-6.70 should be treated with suspicion.

Should milks of low pH or unexpectedly unstable performance be encountered, there are a number of options that may be employed:

- Adjust the pH carefully with alkali (if permitted). Such an action will result in a more stable milk to UHT processing. However, an investigation into why milk of an unexpectedly low pH was encountered should be initiated.
- Add di-sodium hydrogen phosphate to the milk (if permitted). This will both increase the pH of the milk, and increase the calcium sequestering level of the milk. Both of these actions will result in improved stability to sedimentation. The level of added phosphate will need to be determined on a case by case basis. It is also possible that the addition of these phosphates may make the milk more susceptible to age gelation.

It should be noted that the results above deal directly with single strength milk. Similar problems occur in recombined products, and the impact of this is discussed under FAQ 12.2.4.2.

Formulated products may or may not have similar problems – much will depend on the individual components and their impact on both pH and ionic calcium.

Sedimentation which Occurs during Storage

In general, most UHT milks develop a small amount of sediment on storage, but at a level not sufficient to be a problem. It has been suggested that this sediment is formed by the same mechanism which leads to fouling of the heat exchangers in the process, and that the sediment resembles fouling material which has not adhered to the plant surface. There seems to be some evidence that direct processing systems lead to somewhat greater sediment than indirect systems, but that increased homogenisation pressure decreases sedimentation. It has been suggested that the extent of sedimentation increases with the severity of heat treatment and the time and temperature of storage However, extreme homogenisation can lead to increased sedimentation, with the very small fat globules actually falling to the bottom of the container. This problem is rarely encountered however.. There is a further discussion of this aspect under the FAQ 12.2.3.1.

4. *What factors can control the development of off-flavours in UHT products?*

Off flavours in the product can develop from a number of sources. These can include:

- the action of enzymes which survive UHT treatment *(these can be either in the raw milk drawn from the udder, or produced by bacteria in the raw milk. Whilst the bacteria are destroyed in the UHT process, some enzymes are capable of withstanding UHT conditions).*
- chemical reactions in the milk between milk components, such as the Maillard reaction between proteins and lactose, which can lead to development of off-flavour and colour.
- the effect of the UHT process itself on the milk components *(such as the denaturation of whey proteins which can lead to the development of sulphydryl flavours in the milk).*
- the effect of the presence of oxygen, which can lead to the development of oxidised flavours in the milk, and
- the action of contaminating bacteria in the product.

Of course, we do not expect the latter to occur in a properly functioning UHT plant. Of the remainder, some will have an immediate impact, and others will become more noticeable during storage. For example, the off-flavours occurring as the result of UHT treatment will be immediately noticeable, but will often fade on storage, whereas many of the chemical and enzymatic reactions will develop during storage. As a general rule, the rate of development of unacceptable flavours is closely related to storage temperature.

There is very little that can be done in practice to reduce the effect of the UHT processing operation itself on UHT flavour. The requirements of sterility must be met, which requires a certain time/temperature relationship. The key matter is to ensure that the UHT processing conditions selected are not in excess of those required to ensure sterility of the product.

The flavour of fresh UHT milk is generally acknowledged to be poor, with cooked flavours predominating. It is likely that these flavours are the result of release of sulphydryl groups in the product. There is normally a rapid improvement in the flavour of the product in the first few days, as these groups become oxidized. Heat treatment can result in unfolding of the protein molecules and further reactions producing a range of sulphur containing products such as hydrogen sulphide, mercaptans, sulphides and di-sulphides. These all have pronounced flavours and even in small amounts have a significant impact on the flavour profile of the product. In raw milk there are no free sulphydryls, but about 2-3 μmol/g protein are present in fresh UHT milk. After a few days (in the presence of oxygen) the levels of free SH decrease to virtually zero.

The flavour of UHT milk during storage is controlled by storage temperature, storage time and oxygen content. As previously discussed, the oxygen content of the milk will depend on the particular process employed for manufacture. However, in the longer term, the permeability of the container and its original headspace will also play a major role in oxygen availability.

Important flavour changes can occur through the action of heat resistant proteases and lipases which survive UHT treatment. In the case of proteases, these can lead to development of bitterness in the product (in severe cases) after as little as 6 weeks storage at 25ºC. The effect is reduced substantially at refrigeration temperature. In the case of lipases, a number of exocellular lipases of certain *Pseudomonas* species are not inactivated by UHT processing. Thus fat cleavage occurs through the reactions of these enzymes. Again the extent of formation of free fatty acids is dependent on storage temperatures, being very slow at refrigeration temperatures, but much more rapid at elevated temperatures, to the point where organoleptic changes can be noted. Problems with heat resistant lipases can be severe, as even low concentrations of free fatty acids can lead to significant flavour and aroma problems.

Whilst it is very difficult to make any hard and fast rules, for samples stored at 2ºC, there appears to be some general preference for the flavour of low oxygen samples over the first three months of storage. At higher temperatures, such as 30ºC, high oxygen samples are initially preferred, but after a fairly short time (say three to four weeks) comments such as "oxidized" or "stale" are often recorded by graders. Changes in flavour correlate well with changes in oxygen content and sulphydryl content of UHT milks. It should also be noted that one of the best indicators of the near onset of age gelation is the development of bitterness in the product, which generally occurs three to four weeks before gelation.

In an ideal world, the best way to control development of off flavour is to store UHT milk under refrigeration temperature. Whilst this might lead to a somewhat longer period of noticeable cooked flavour in the product, it will extend the acceptable life of the milk considerably, the other factors which lead to off flavours will be significantly retarded.

So overall, to ensure better flavour in UHT milk:

- use the best quality raw milk
- manufacture as soon as possible after drawing milk from the cow
- use minimal processing conditions appropriate to meeting sterilisation requirements
- store at as low a temperature as possible – do not freeze
- store out of direct sunlight

5. *What influences the colour of UHT milk?*

Four major factors affect the colour of UHT milk:

- processing conditions
- raw milk quality
- storage conditions
- other processing operations such as lactose hydrolysis

There are a number of effects of processing temperature on the colour of milk. In general, milk becomes whiter in appearance when it is heated above about 65ºC – this is thought to be due to denaturation of the whey proteins resulting in an increase in the number of reflective particle present. So, in general, UHT milk is whiter than the original product immediately after manufacture (this is independent of the whitening effect also caused by homogenisation).

However, a browning reaction also occurs on heating of milk, and can continue when milk is stored, particularly at temperatures above about 35ºC. This reaction, the Maillard reaction, is the result of interactions between the lysine moiety of the milk proteins, and the lactose. The reaction is very complex, but will lead in time to development of brown colours in the product.

Raw milk quality can have an influence on milk colour, as the result of sediment formation in the product during processing (refer to FAQ 12.2.3.3). If the pH is below about 6.70-6.60, trace amounts of sediment may form in the product which will lead to a reduction in the reflective particles present, and a drop in perceived colour.

Storage conditions are particularly important in development of colour in UHT milks. For example, milks stored above 35ºC develop a noticeable brown appearance quite quickly. The effect is much less noticeable for samples stored below 25ºC.

Other processing operations can lead to increases in the colour development in UHT milks. Of particular interest are those which increase either the lactose or the reducing sugars in the product. In both cases, this will result in an increase in Maillard reactions. Particular care must be taken with lactose hydrolysed products (see FAQ C6). In general the higher level of reducing sugars in these products (glucose and galactose) will lead to a marked increase in browning. This is noticeable if the hydrolysis is carried out prior to UHT processing, and can lead to a noticeable brown colour in the initial product. Also on storage at elevated temperatures, browning occurs in these products much more rapidly than in conventional UHT milk.

Thus, the best way of ensuring reduced problems with colour development in UHT milk is to:

- use the best quality raw milk
- manufacture as soon as possible after drawing milk from the cow
- use minimal processing conditions appropriate to meeting sterilisation requirements
- store at as low a temperature as possible – do not freeze
- store out of direct sunlight

6. What influences the manufacture of lactose hydrolysed products?

Lactose hydrolyzed UHT milks offer two market advantages over unhydrolyzed products:

- Lactose hydrolyzed products are sweeter than unhydrolyzed products. Lactose hydrolysis involves cleaving the di-saccharide of milk, lactose, into its two component mono-saccharides, glucose and galactose. Each of these sugars is noticeably sweeter than lactose. Complete hydrolysis of the lactose in milk results in an increase in sweetness equivalent to the addition of about 1.5% sucrose. Such an increase in sweetness can be beneficial, as formulated products containing hydrolyzed milks may require less addition of sugar to reach the desired level of sweetness. This can reduce costs and calorific content - one aspect helping profitability, the other assisting marketing.

- A significant percentage of the world's population suffer from lactose malabsorbtion. Normally, digestion of lactose involves cleavage of the di-saccharide into glucose and galactose in the gut by the action of an enzyme, β-galactosidase. The resultant mono-saccharides are then absorbed and metabolized by the body. However, much of the population of the world loses the ability to secrete sufficient β-galactosidase to effectively digest their normal intake of milk after the age of about 10 years. This results in a marked decrease in the ability of this segment of the population to properly digest lactose after this age. Thus, when lactose malabsorbers ingest lactose-containing products, a significant amount of the lactose passes undigested into the lower intestine, where it is fermented, leading to production of gas, an increase in osmotic pressure and a flow of fluid into the bowel. This in turn leads to feelings of discomfort, bloating, and in severe cases stomach cramps and diarrhoea. Lactose intolerant populations include most of those of South East Asia, Japan, black Africans, African Americans, Native American Indians and Australian Aborigines.

Lactose hydrolysis of UHT milk can really only be effectively carried out by the use of the enzyme β-galactosidase. This enzyme has been available commercially for some years. In one option, the raw milk is hydrolyzed by the addition of the enzyme, and the hydrolyzed milk then subjected to UHT sterilization. It is not however the most desirable methodology. It suffers from the considerable disadvantage that it is the hydrolyzed product which is subjected to the UHT processing conditions. As the mono-saccharides glucose and galactose are much more reactive than the original lactose, the UHT product will have suffered considerably from Maillard browning reactions occurring during manufacture. These reactions lead to the development both of off-flavours in the product, and also an immediate noticeable browning of the product.

A preferable option involves injection of sterile beta-galactosidase enzyme solution in very low quantities into the UHT sterilized milk prior to aseptic packaging. The process may use injection into an aseptic holding tank, or into the pack itself prior to sealing. In these circumstances, the hydrolysis takes place over a period of say 10 days after manufacture, in the sterile pack. Self evidently, the amount of enzyme required can be reduced very substantially compared to the process described earlier, as the reaction can take place over a much longer period - there is no concern regarding bacteriological growth in the product. Operational costs are thus considerably reduced. Further, the enzyme is added after heat processing, so that there is no excessive browning of the product occurring during sterilization.

An important concern is the freedom of the enzyme preparation from protease contamination. Cheaper enzymes often contain significant levels of protease, which can lead to the development of bitterness in the product (and in some cases gelation) on extended storage. Operators using such systems should ensure the high quality of the enzyme used in the process.

7. *What is the role of heat stability and alcohol stability tests in evaluation of milks for UHT processing?*

Heat stability

The "heat stability" test is commonly used for the evaluation of milks to be used for the manufacture of milk powders with particular functional properties. The test involves sealing milk into a bottle or tube, and immersing it into an oil bath operating at say 140ºC. The time taken in minutes until visible sediment or coagulation in the milk is noted. The test is also used by some UHT plants for selection of milks for UHT processing.

However, the heat stability of milks tested in this manner does not show any sharp change in coagulation time as a function of pH between say 6.70 and 6.60. Yet, as discussed under FAQ 12.2.3.3, a small difference in pH at this level can result in a sudden increase in the total sediment present in the product. Thus, the use of heat stability as a means of selection of milks for UHT processing is seriously flawed – it does not indicate if the pH of the milk is too low for effective manufacture without sediment formation. At best, it may be said that:

- If the milk fails the heat stability test, it should not be used for manufacture of UHT milk.
- However, if the milk passes the heat stability test, it may or may not be satisfactory for UHT manufacture.

Heat stability tests do not give any indication of the effective storage life of UHT milk.

Alcohol stability

The alcohol stability test is widely used in the dairy industry for selection of milks. The test involves adding various amounts of alcohol to milk, and noting when coagulation occurs. There remains some uncertainty about the value of alcohol stability as a useful test within the industry. Work has indicated that alcohol stability is a crude measure of pH – a decrease in pH results in a decrease in alcohol stability. It has been suggested by some that therefore the test is of little value. However recent work has suggested that there are some benefits to be gained from a knowledge of the alcohol stability of milk.

Recent work on fouling has indicated that the use of a combination of alcohol stability, pH and ionic calcium in the milk could allow assessment of UHT plant run times – a very important economic factor.

If however, alcohol stability is being used by UHT operations as an indicator of the general acceptability of milk for UHT processing, it alone is not likely to be of immediate value.

12.2.4 Recombining

1. *Recombining and reconstitution – what is the difference?*

   It is important that a clear differentiation be made between the terms "recombination" and "reconstitution".

   "Recombination" is defined as the process in which previously separated components of milk, principally skim milk powder (SMP) and anhydrous milk fat (AMF), are brought together again in a water phase, along with any additional ingredients and necessary stabilizers, to form the desired end product. Because the ratio of AMF to SMP can be varied, a wide range of products can be manufactured by recombination, each having its characteristic ratio of fat to solids-not-fat. The composition and characteristics of the products made by recombining are normally similar to those of the equivalent products made by traditional manufacturing methods.).

There are two obvious benefits to manufacture by recombining:

(i) the separate components may be stored for extended periods without the need for refrigeration, allowing simple export and storage.
(ii) the total mass involved in export is reduced by a factor of more than 7 (in the case of milk) by removal of water.

"Reconstitution" is defined as the process of addition of water only to milk powder to produce a product of similar total solids to the normal liquid milk equivalent. Whole milk powder is the usual powder used for reconstitution, resulting in a product similar in composition to fresh milk, but skim milk powder may also be reconstituted to give a product similar to freshly separated liquid skim milk.

Because reconstitution does not accommodate the variation of the fat to SNF ratio by addition of AMF and/or SMP, the range of products that can be produced by reconstitution is limited.

2. *What are the principles involved in the manufacture of UHT recombined products?*
In essence, recombining involves the separation of milk into components which can at a later date be recombined into products very close to those made by traditional manufacturing methods. There are two obvious benefits:

(i) the separate components may be stored for extended periods without the need for refrigeration, allowing straightforward export and storage, and
(ii) the total mass involved in export is reduced by a factor of more than 7 (in the case of milk) by the removal of water.
The main raw material involved in reconstitution is whole milk powder, and the raw materials involved in recombining are skim milk powder and anhydrous milk fat (AMF).

The major UHT market in much of South East Asia is for a product which has added sugar - generally levels of about 3% are desirable. In South East Asia, the sales of sweetened UHT milk are about 50% of the UHT white milk market.

Factors Involved in Selection of Raw Materials

Powder

The selection of powder to be used in recombined UHT milk is critical to the satisfactory processing of the product and its storage characteristics. Milk powders for recombining are generally divided into three categories, high heat, medium heat and low heat. These terms refer to the heat treatment given to the milk prior to spray drying, and not to the stability of the recombined product to heat. Milk for low heat powder might for example be preheated at 72ºC for 15s, for medium heat powder at 73-75 for 1-3 min, and for high heat powder at 80-85ºC for 30 min.
The preheat treatment used in powder manufacture does not appear to have any significant impact on the storage properties of the UHT processed product, either in terms of flavour or the onset of age

gelation (there may be marginal flavour benefits through use of either medium or low heat powder, but these are not of major significance). Generally, low or medium heat powders are used for UHT recombined products, as high heat powders had a lower acceptance because they tend to impart more cooked flavour to the product.

Two major factors must be considered: stability to UHT processing, and the development of age gelation in the stored product.

Stability to UHT processing

The major concern is the stability of the reconstituted UHT milk to UHT processing itself. If milk of pH below about 6.65 is subjected to UHT processing, considerable sedimentation will develop in the product (refer to FAQ 12.2.3.3). However, the pH at which instability occurs is a little lower for recombined products than for fresh milk. The reason for the higher stability of milk powder based products is thought to be due to the lower ionic calcium present in recombined products. Thus, plants based on recombining operations may have less difficulty with sedimentation than those using fresh milk. Further, the use of medium or high heat powders will result in an even greater increase in stability compared to low heat powder products.

Control of age gelation

The control of age gelation is much more of a problem in UHT products based on milk powders. For a detailed discussion of the causes of age gelation refer to FAQ 12.2.3.2. As discussed in that FAQ, the source of the enzyme is generally agreed to be psychrotrophic organisms present in the raw milk. These organisms are destroyed by the UHT treatment, but sufficient of the enzyme activity survives to cause gelation in the stored product.

Milk powder to be used in the manufacture of UHT milk must be prepared with the above in mind. In particular, steps should be taken to ensure that the opportunity for the growth of psychrotrophic organisms is restricted during manufacture.

Milk fat

Butteroil which meets usual manufacturing specification is adequate for use in recombined UHT milk. Normal care regarding prevention of oxidation is required to ensure that flavour defects are not introduced into the product. Provided that the fat is made from good quality milk, that care is exercised during manufacture and nitrogen flushing of containers is completed efficiently, the product will store well at ambient temperature. High storage temperatures accelerate the development of off flavours. It is also essential that a system for strict control of stock be introduced, to ensure that turnover is rapid. Once the fat has been melted, or if it is stored in opened drums, it should be used as rapidly as possible. It should be noted that peroxide values and acidity values are not always good indicators of the stability of fat towards oxidative deterioration.

UHT filled milks are also commonly manufactured in many countries. In these products, the source of fat is generally a cheaper vegetable fat such as palm kernel or coconut oil. However in many cases, these fats are more unsaturated than milk fat, and can undergo much more rapid oxidative deterioration. In such cases, particular care must be taken not only during manufacture, but also in the packaging employed. Contact with oxygen must be kept to a minimum. Head spaces in the package can result in introduction of additional oxygen into the system and accelerate development of oxidative defects.

Water

Water is the single biggest component of UHT recombined products, but it is often the most overlooked. Colour flavour and odour may all affect the quality of the end product. Hard water can affect protein stability on heating. A system to ensure potable water quality is therefore an essential part of any UHT recombining operations.

Emulsifiers and stabilisers

In general, stabilisers from specialist companies are preferred by most manufacturers. These components are added to the milk to ensure that the milk fat emulsion formed during the homogenisation process remains stable during processing and storage, as well as to improve the mouth feel of the product. A wide range of systems have been suggested over the years, but most plants now use proprietary mixtures provided by specialist companies. Generally a single product, comprising a mixture of stabiliser and emulsifier is provided to the UHT recombining manufacturer. These products are designed to increase the heat stability of the product, to improve fat dispersion and stability during processing and storage, and to improve the organoleptic qualities of the product, through development of a more desirable viscosity and a richer mouth feel. Some stabilisers also assist in the prevention of froth during mixing operations.

Emulsifiers commonly used in UHT recombining operations include mono- and di-glycerides, and soya lecithin. Emulsifiers reduce fat separation by formation of a membrane at the fat/water interface. Hydrocolloids are often used as stabilisers in UHT products. These act by increasing the viscosity of the aqueous phase, increasing the viscosity of the product and improving mouth feel and reducing the rate of fat separation. Hydrocolloids commonly employed include carrageenans and alginates.

Flavour and sweeteners

As indicated earlier, sweetened products are very popular in much of the UHT market. It is common to introduce a low level of vanilla into such products for a further improvement in palatability. The vanilla used must be stable to UHT processing, and if steam injection with a vacuum flashdown is employed, the vanilla must be comparatively non-volatile.

Sucrose is the most commonly used sweetener in UHT recombined products, but other sweeteners may be employed, from saccharides such as glucose, fructose and glucose syrups, through to artificial sweeteners. In the case of saccharides, considerable care must be taken, as the higher level of reducing residues present in many of these products leads to increased browning of the product during processing and storage, because of increased Maillard reactions.

Any artificial sweeteners must of course be stable to UHT processing, and to extended storage.

Formulation of UHT Recombined Milks

The use of reconstitution is comparatively inflexible in terms of the ease of changing SNF/fat ratios. For this reason, recombining is often the preferred methodology employed in UHT operations.
The use of recombining for the manufacture of UHT milk allows for wide variations in the composition of the final product. The major factors are of course the level of solids-not-fat, and the level of fat

present. A number of factors will influence the levels selected, the major ones being the economic factors (the relative cost of fat, and SNF) and those related to the acceptability of the product.

A further key factor in many markets is the level of added sugar. A considerable portion of the milk drunk as a consumer product in many South East Asian countries is sweetened by the addition of between 1 and 4 % sugar. Thus UHT products destined for these markets should consider the level of sweetener.

As well as milk fat, skim milk powder and sugar, most UHT products also include an emulsifier and stabiliser.

Typical formulations might be:

Unsweetened product	
Anhydrous milk fat	3.6
SNF	9.3
Stabiliser and emulsifier	0.2
Water	86.9

Sweetened product	
Anhydrous milk fat	3.6
SNF	8.5
Sugar	3.5
Vanilla	0.1
Stabilizer and emulsifier	0.2
Water	84.1

As indicated above, the formations can vary very widely - SNF and butterfat contents and ratios can be selected to meet specific cost and product specifications.

Manufacture of Recombined UHT Milk

The following outlines typical methodology for the manufacture of UHT recombined products:

- The required quantity of skim milk power is blended into the water at 40-45ºC.
- Other ingredients are added whilst agitating the mix. The butterfat must be added last, after liquefaction by preheating to 40-45ºC prior to use.
- The butteroil should then be dispersed in the mix. This may be carried out by agitation, or by moderate homogenisation. Conditions will depend on the homogeniser, but might for example involve two stages of homogenisation (say 1500 plus 500 psi, (10 MPa plus 3 MPa) at 65ºC). In many plants, agitation is sufficient, as the recombined product is subjected to UHT processing and homogenisation with minimal storage. It is also generally wise to pasteurise the product (HTST, 73ºC for 35s) at this stage, if the product is to be stored for any period prior to UHT processing. The product should be cooled to 4ºC and UHT processed as soon as possible.
- The mix is UHT processed for example at 138ºC for 3 sec, with homogenisation at say 3000 + 500 psi (20 Mpa + 3.5 Mpa).

One key aspect of the process is to ensure that the product is not stored for an excessive period after recombining, prior to UHT processing. Excessive storage can result in further growth of psychrotrophic organisms, leading to problems with age gelation storage of the UHT product.

Downstream homogenisation (after sterilisation) is often considered preferable to upstream homogenisation (before sterilisation) for recombined products. For whole milk, the benefits of downstream homogenisation, whilst believed to be real, are generally minor for indirect processes. For recombined products however, there are likely gains in terms of reduction of sediment formation in the product by use of downstream homogenisation. For this reason, in spite of the additional cost and complexity, a number of UHT plants processing recombined products utilise downstream homogenisation.

Glossary

Age gelation

Age gelation is a common defect of UHT milk which limits the acceptable life of UHT milk by conversion of the product to a junket-like gel. It is not due to bacterial action, but rather to the action of proteolytic enzymes which survive UHT processing.

Alcohol stability test

The alcohol stability test is widely used in the dairy industry for selection of milks. It involves adding various amounts of alcohol to milk, and noting when coagulation occurs.

Aseptic holding tank

Most UHT plants have been installed with aseptic holding tanks as an integral part the operation. The aseptic holding tank permits ready balancing of flow rates between the UHT processor and the packaging section.

Aseptic packaging

Aseptic packaging systems are designed to fill sterilised fluids into aseptically prepared packages without contamination of the product.

Browning

Browning of milk is generally the result of interactions between lactose and protein. Browning will occur quite rapidly under very high processing conditions, but can also occur during longer term storage of dairy products.

Direct processing

Direct processing is a form of UHT sterilisation which relies on direct contact of the product with steam. After sterilization the product is passed into a vacuum chamber which removes the condensed steam, and also results in a very rapid cooling of the product from sterilization temperature to a temperature of about 75 to 80ºC.

Emulsifiers and stabilisers

Emulsifiers and stabilisers are used by the dairy industry to assist in formation of stable emulsions and to aid in dairy processing.

Fat separation

Fat separation can be a major defect in stored UHT products. Generally it involves excess visible fat on the surface of the product, and in severe cases, a hard crust on the surface of the product.

Free fat

Free fat in milk is caused by either coalescence of smaller particles in the product, or through inadequate recombination techniques leading to fat globule instability.

Heat stability test

The "heat stability" test is commonly used for the evaluation of milks to be used for the manufacture of milk powders with particular functional properties. The test is also used by some UHT plants for selection of milks for UHT processing.

Homogenisation

Homogenisation is widely used by the dairy industry to reduce the size of fat globules in dairy products, and therefore to reduce fat separation during storage. Homogenisation is essential during the manufacture of UHT products.

Indirect processing

Indirect processing is a form of UHT sterilisation which relies on obtaining sterilization temperatures by heat transfer by means of a stainless steel interface, generally part of a tubular or plate heat exchanger.

Lactose hydrolysis

Lactose hydrolysis involves cleaving the di-saccharide of milk, lactose, into its two component mono-saccharides, glucose and galactose. Lactose hydrolysis in the dairy industry is commonly performed by the use of enzymes.

Lipases

Lipases are enzymes which cleave fats. In milk, they can lead to very bad off flavours in the product.

Maillard browning reactions

Maillard browning occurs when reducing sugars such as lactose interact with the amino groups of amino acids during cooking or processing of food. Maillard reactions can affect many factors, including nutritional value (essential amino-acids loss, such as lysine), colour changes (brown pigments formation) and flavour.

Plasmin or native milk enzyme

Native milk enzyme is a protease that is present in raw milk. It can survive UHT processing and can lead to age gelation in the product.

Proteases

Proteases are enzymes which split proteins. In UHT milk the action of proteases can destabilise the colloidal suspension of the milk and lead to gelation.

Protein denaturation

Protein denaturation is often caused by the application of heat. It leads to the unfolding of the molecular structure of the protein and a loss of functionality. A good example is the change that occurs in the properties of egg white on heating.

Proteolytic psychrotrophic organisms
These organisms, which are present in raw milk, can continue to grow under refrigeration conditions, and produce proteases which may survive UHT processing.

Reflectance
For most purposes, reflectance of milk can be considered akin to its colour.

Sediment
Sediment formation in UHT milk can be a major problem. It can occur either immediately after processing or after extended storage.

Steam infusion
One option in the UHT "direct" process, which relies on direct contact of the product with steam, is to inject the product into a steam chamber. This process is known as steam infusion.

Steam injection
One option in the UHT "direct" process, which relies on direct contact of the product with steam, is to inject of steam directly into the product. This process is known as steam injection.

Referrences

APV Aseptic technology in the dairy industry. APV marketing Bulletin, 28 pages

APV (1999) Long-life Dairy, Food and Beverage Products: Technology Update. APV Nordic, Unit Systems, Denmark.

Burton, H. (1988). Ultra-high-temperature processing of milk and milk products. London, Elservier Applied Science.

Datta, N and Deeth, H.C. (2001) Age gelation of UHT milk - a review. Transactions of the Institute of Chemical Engineers C. Food and Bioproducts Processing 79, 197-210.

Datta, N and Deeth, H.C. (2003) Diagnosing the cause of proteolysis in UHT milk. Lebensmittel-Wissenschaft und Technology 36(2), 173-182.

Datta, N., Elliott, A.J., Perkins, M.L. and Deeth, H.C. (2002) Ultra-high-temperature (UHT) treatment of milk: comparison of direct and indirect modes of heating. Aust J. Dairy Technol., 57, 211-227.

David, J.R.D., Graves, R.H. and Carlson, V.R. (1996). Aseptic Processing and Packaging of Food. A Food Industry Perspective. CRC Press, USA.

Deeth, H.C. and Datta, N (2002) Ultra-High Temperature treatment (UHT): Heating systems. Encyclopedia of Dairy Sciences (Eds) Academic Press, London, 2642-2652.

Hawran, L. J., Jones, V. A., and Swartzel, K. R. (1985) Sediment formation in aseptically processed and packaged milk. Journal of Food Processing and Preservation 9, 189-207.

Hsu, D.S. (1970) Dairy and Food Technology Handbook: UHT Processing and Aseptic Packaging of Dairy Products. Damana Tech. Inc., New York.

International Dairy Federation (1981) New Monograph on UHT Milk. IDF, Document No. 133. Brussels: IDF.

International Dairy Federation (1972) IDF monograph on UHT milk. IDF Document 68, 174 pages

International Dairy Federation (1981) Factor affecting the keeping qualities of heat-treated milk. IDF Document 130, 80 pages

International Dairy Federation (1995) Heat-induced changes in milk. 2nd Edition, (Ed. P.F. Fox), 455 pages

International Dairy Federation (1996) UHT cream. IDF Bulletin 315, pp 3-34

International Dairy Federation (1996) Heat-treatments and alternative technologies. IDF Document 9602, 464 pages

Jelen, P. (1982) Experience with direct and indirect UHT processing of milk – a Canadian viewpoint. J. Food Prot., 45, 878-883.

Jelen, P. (1983) Review of basic technical principles and current research in UHT processing of foods. Can. Inst. Food Sci. Technol., 16, 159-166.

Kocak, H. R. and Zadow, J. G. (1985) Age gelation of UHT whole milk as influenced by storage temperature. Aust. J. Dairy Technol. 40, 14-21

Lewis, M. and Heppell, N. (2000) Continuous thermal processing of foods. Pasteurisation and UHT sterilisation. Aspen publishers, Inc., Gaithersburg, Maryland, pp1-447.

McKenna, A. B., and Singh, H. (1991) Age gelation in UHT-processed reconstituted concentrated skim milk. International Journal of Food Science & Technology 26, 27-38.

Robertson. G. L. (1993) Aseptic packaging of food. In Food Packaging Principles and Practice (G. L. Robertson). Marcel Dekker, Inc., New York pp381-408

Tetra Pak (1995) Dairy Handbook. Tetra Pak, Lund, Sweden

Seminar on UHT Processing (1981) Aust. Soc. Dairy Technol. Tech Pub 26, pp1-104

Von Boekelman, B. and Von Boekelman, I.A. (1998) Long life products: Heat-treated, Aseptically Packed: A Guide to Quality Tetrapak Publication 246 pages.

Zadow, J. G. and Birtwistle, R. (1973) the effect of dissolved oxygen on the changes occurring in the flavour of ultra-high-temperature milk during storage. J. Dairy Res. 40, 169-177

DAIRY AUSTRALIA
Delivering for the dairy industry

13

Using Australian Dairy Ingredients in Yogurt

Content

322 13.1 Principles of Yoghurt Processing

326 13.2 FAQ

341 Conclusion

341 Glossary

13.1 Principles of Yoghurt Processing

13.1.1 Introduction

The yoghurt manufacturing process, although a relatively simple series of steps, can be difficult to master to produce consistent high quality yoghurt with a minimum of defects. Furthermore there is a need to keep ingredient and manufacturing costs to a minimum.

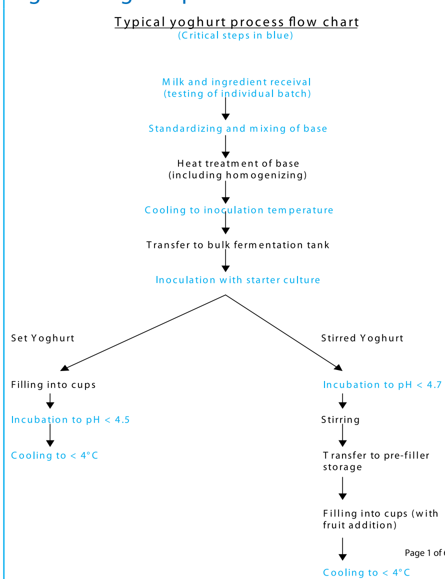
Defects such as whey separation, graininess and nodule formation are in fact symptoms of a lack of understanding and control of either raw materials or the process. A good understanding of the chemistry and mechanism of yoghurt making theory is essential in being able to produce top quality yoghurt. Raw materials are often selected on the basis of minimizing ingredient cost rather than the resultant effect on the yoghurt. Mixing processes are not controlled as well as the rest of the process and temperatures are often allowed to vary. All these factors contribute significantly to defects and the variation seen in viscosity, flavour, appearance and mouth feel of the final product.

As with many other processes good yoghurt manufacture relies on selection of high quality ingredients and then strict control of the manufacturing process. The objective must be to minimize the variation in the ingredients, process, equipment and materials in order to minimize the variation in the product.

13.1.2 The Role of Milk Proteins

The respective level of milk proteins in the base for yoghurt manufacture is arguably the most important factor in producing good quality yoghurt. The ratio of α-lactalbumin and β-lactoglobulin to casein as well as the total protein content as a proportion of the total solids are the main factors that contribute to the final yoghurt matrix. Incorrect ratios of these proteins can lead to runny or soft yoghurt, nodulation or graininess and whey separation. Many plants will standardize to the level of total solids or protein in the base mix but may not standardize down to casein to whey protein ratio level. The variation in these components in raw materials is significant and may vary from batch to batch. This leads to considerable variation being observed in the yoghurt produced even where the raw materials may come from the same source.

Figure 1 Yoghurt process flow chart



The yoghurt structure is formed through a combination of denaturation of the proteins under controlled conditions and fermentation to produce attraction forces from an acidic environment. If this is done correctly under controlled conditions the result is a firm matrix that may withstand reasonable mechanical action. If the conditions are not controlled, the result is often a range of defects that make the yoghurt unacceptable to consumers.

Any reduction or addition of the milk protein components especially β-lactoglobulin and α-lactalbumin will result in dramatic changes in the viscosity of the resulting yoghurt. If there is not enough of either protein available to bind with casein then the matrix cannot bind as strongly and tends to be loose, resulting in soft or runny yoghurt. Too much of these components does nothing to help the protein matrix and is an added expense while at the same time increases the risk of syneresis in the resulting yoghurt.

It is common practice to adjust the total protein level by the addition of high whey protein products such as Whey Protein Concentrates, Whey powders and Ultra Filtered UF concentrates in an attempt to increase the ratio of casein to total whey proteins. Rather than simply add a percentage quantity of whey protein it is essential to standardize each batch individually and accurately to determine the amount of protein adjustment that is required. At the very least, a plant with liquid milk intake should adopt a process of tracking trends for protein components throughout the year and adjust the recipe accordingly to produce the same base mix. Research suggests that this ratio of casein to non-casein protein should be approximately 3.3:1 for good quality yoghurt, although this will vary in each case.

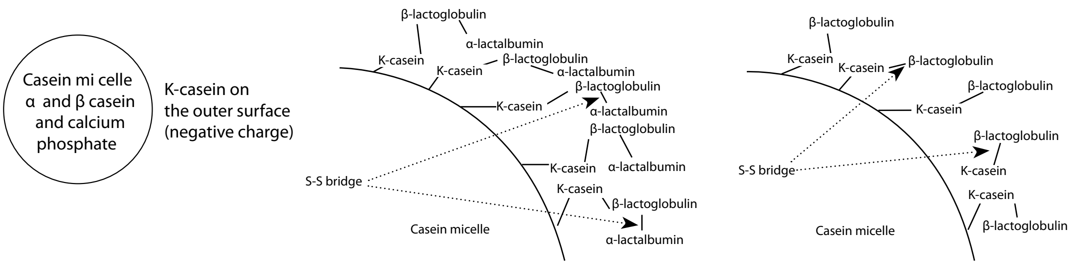
In the same way that heat treatment may denature protein, so too will enzyme action from bacteria, acid production from acid producing bacteria and mechanical action such as pumping. If protein has been denatured prior to the controlled heat treatment process it will result in major defects in the yoghurt. Denatured protein will be readily available to bond with a variety of other compounds depending on what is available. The result of this is that milk that may not be of good quality has opportunity well in advance of the heat treatment process to form complex molecules. The result of this is the formation of large complexes of protein that attract much more strongly than normal and form many small soft nodules. In extreme cases this may be in the form of graininess where the protein has compacted to form hard particles, this is often referred to as compacted protein and is visible and can be easily detected when eaten.

Where protein has been allowed to deteriorate to such an extent that the casein is denatured, usually through acid development from bacteria prior to heat treatment due to poor storage or old milk, the casein will also be readily available to bond. As soon as this casein comes into contact with the hot surface of a heat treatment plant it will bind to form a complex. The result is that casein sticks to the heat treatment surface immediately and can cause blockages; this deposit looks like a white oily or fatty substance similar to soft rubber and can be difficult to remove in extreme cases.

In the same manner that denatured protein forms complex compounds so too can any foreign material or undissolved particles. Where powders are used to produce the base mix any undissolved particles also act as points of attraction forces to protein so that graininess and nodules may also be the result. Again where this is extreme it can result in very grainy yoghurt and can even be sandy in texture.

The whey proteins must be in their natural state at the time of heat treatment; if they have been denatured previously this can lead to major defects. The selection of ingredients then is one of the most critical aspects of consistently good yoghurt manufacture. No matter if the ingredients are powders, concentrates or raw milk straight from the farm they must be handled and treated in such a way as to minimise the impact on the proteins prior to heat treatment and must be standardized, heat treated and fermented in such a way as to maximise the opportunity for these proteins to form a uniform controlled matrix.

Figure 2 Changes in the structure of casein during fermentation



Milk pH 6.6 – 5.9; no change in structure of casein micelle Net negative charge on the external surface of the casein micelle in fresh milk of pH 6.8 becomes slightly less negative with addition of hydrogen ions

Milk pH 5.5-5.2,α-lactalbumin bonds with β-lactoglobulin to form a smooth structure on the surface of the micelle. Calcium continues to dissolve from the calcium phosphate in the casein micelle structure.a

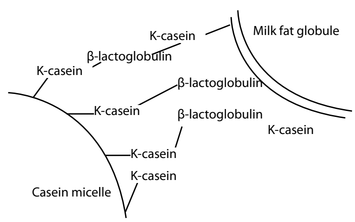
Milk pH5.5-5.2,partial denaturati on of casein micelle, bonding of β-lactogloblulin to K-casein on the surface of the casein micelle to form an irregular shape with spaces between protein strands. Weak bonding occurs across micelles as β-lactoglobulin binds with K-casien across micelles. Calcium begins to dissilce in the main structure of the casein micelle. Charge on the outside of the casein micelle is becoming nore neutral with the addition of hydrogen ions.

13.1.3 Fermentation

The two major culture strains used are *Lactobacillus bulgaricus and Streptococcus thermophilus*. Each of these cultures has its own optimum growth conditions that are required and produce their own unique set of flavour and aroma characteristics. Streptococcus *thermophilus* provides the smooth, buttery flavour while Lactobacillus bulgaricus provides the sharpness. Streptococcus *thermophilus* grows first when added to the yoghurt base as it prefers pH closer to neutral. Once the pH has dropped sufficiently Lactobacillus bulgaricus tends to take over and grow faster while Streptococcus ***thermophilus*** tends to have its growth inhibited by the lower pH.

Culture manufacturers use this and selection of strains with specific traits to develop mixed cultures that grow quickly and result in a predictable pH drop within a specific time frame. The final pH and time taken can normally be predicted reasonably accurately. Factors that influence this pH drop are more associated with conditions imposed by the manufacturing plant. Any change in the growth of either strain of culture will result in changes to the time, pH and flavour and odour characteristics of the yoghurt.

Figure 3 Interaction of casein and fat



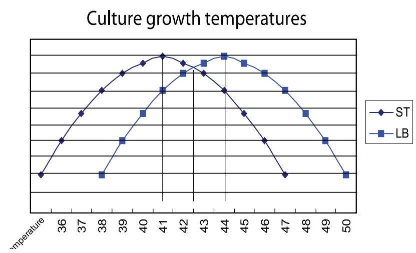
Once denatured β-lactoglobulin has unbond S-H groups that bond to K-casein in the milk fat globule membrane. This allows the casein micelle to become bond to the milk fat globule membrane and hence the milk fat. Approximately 10-20% of the fat present in normal milk can be bound to the casein in this way.

Streptococcus *thermophilus* is susceptible to antibiotics or sanitizers. Even a small quantity of sanitizer remaining in the bottom of the fermentation vat can inhibit the growth of Streptococcus *thermophilus* which in turn slows the pH drop so that lactobacillus bulgaricus also does not grow as readily.

A slight variation in the fermentation temperature may also affect the ability of either culture strain to grow at its optimum. Depending on the particular strain Streptococcus *thermophilus* has an optimum growth temperature of approximately 38 – 42˚C. *Lactobacillus bulgaricus* has a slightly higher optimum growth temperature of approximately 45˚C. This means that the fermentation temperature is normally set as a compromise between these two. If the temperature is lowered or raised by as little as one degree celcius it will mean that one of the culture strains will grow better but the other will be slightly more inhibited. In effect this changes the impact of each culture strain on the final product in terms of pH drop, flavour and odour as well as mouth feel, viscosity and syneresis.

If the temperature is too low *Streptococcus thermophilus* will grow better but Lactobacillus bulgaricus will be inhibited. This can result in a milder, smoother yoghurt but may mean long fermentation times and the resultant pH being hard to reach. If the temperature is too high *Streptococcus thermophilus* will be inhibited slightly and will take longer to reach the point where *Lactobacillus bulgaricus* grows well. At this point lactobacillus bulgaricus grows very rapidly and tends to over produce acid resulting in excess pH drop and consequent syneresis in the final yoghurt.

Figure 4



13.1.4 Cooling and Pre-filler Storage

At the conclusion of fermentation, the pH should be close to the isoelectric point of casein (pH 4.6) to ensure maximum attraction forces are maintained. At this stage the yoghurt base needs to be pumped to pre-filler storage. Any mechanical action on the yoghurt at this stage will start the process of breaking the matrix down and it is the attraction forces that hold the matrix together. If the fermentation is permitted to continue too far past the isoelectric point the balance of charges is tipped in favour of the positive charge and these start to repel each other. As the positive charge increases with the formation of more acid (lower pH) the matrix will start to break apart resulting in syneresis or whey formation in the yoghurt.

Control of this further fermentation is often obtained through a combination of culture selection for fermentation and cooling to a lower temperature where the culture becomes less active. Selection of cultures needs to be considered carefully in balancing the need for short fermentation times with aggressive culture strains with the need to halt the fermentation with cooling.

Selection of culture strains that drop the pH to a specific range just below the isoelectric point helps to stop further fermentation. These same culture strains may also be selected to reduce activity with lower temperature as well as the pH range. A selection of strains of *Lactobacillus bulgaricus* is available from a number of commercial starter culture manufacturers to achieve this. These have been specifically isolated to inhibit their own growth below a predetermined pH.

The pump and cooling system for the yoghurt should be placed as close as possible to the fermentation tanks so that there is very little mechanical action on the yoghurt prior to it being cooled. Cooling itself should be low enough to inhibit culture activity during the storage period, as determined by the culture supplier, while still being high enough to allow effective pumping and filling (see filling).
The temperature for filling is normally around 20˚C for most applications as this allows for storage and

Chap - 13

transport through pipe-work and vats at the same ambient temperature. This temperature also helps filling machines to operate at slightly higher rates than would be desired for a more viscous product. In using this temperature however it is important that the time taken prior to filling is as short as possible, filling would normally be timed to complete within 12 hours of transfer to storage.

13.2 FAQ

Common process defects

Defect	Reason	Cause
Runny yoghurt	Total solids too low	Poor standardizing
	Protein level too low	Poor standardizing
	Casein level too low	Poor standardizing
	Casein to whey protein ratio too high	Poor standardizing
	Excessive mechanical action after fermentation	Shearing at too high pressure Pumping too far to filler Vibration
	pH too low (past isoelectric point)	Delay in filling after fermentation Over active culture
	pH too high (isoelectric point not reached)	Under active culture Protein levels incorrect Sanitizer contamination
Nodule formation	Unmixed dry ingredients	Mix temperature too low Mix time insufficient Mixing equipment inadequate Poor solubility of dry ingredients
	Protein denatured prior to heat treatment	Low heat powders not used. Low heat powders with high level of denatured whey protein. Milk stored at too high temperature Excessive pumping of milk
	Excessive heat treatment	Recirculation through pasteurizer Time /temperature incorrect
Graininess	Extreme heat treatment	Recirculation through pasteurizer Time/temperature incorrect
	Unmixed dry ingredients	Very poor solubility of ingredients
	Protein denatured prior to heat treatment	Very poor quality milk protein
Whey separation	Over acidification	Over active culture pH allowed to drop too far past the isoelectric point Culture still active after packaging and cooling Yoghurt temperature allowed to increase during cooling or storage
	Casein to whey protein ratio incorrect	Poor standardizing

13.2.1 Raw Materials

1. *How does selection of low, medium and high heat powders impact on yoghurt manufacture?*

   To manufacture the best quality yoghurt it is necessary to select milk powder that closest resembles raw milk. It is the level of denatured whey protein rather than undenatured whey protein, measured by Whey Protein Nitrogen Index (WPNI) that is critical to this.

   The level of undenatured whey protein as measured by WPNI changes significantly with season, region, cattle breed and the treatment of the milk. Some regions have great difficulty in producing Low Heat powder at different times of the year even though the milk is handled carefully and the quality may be exceptionally good. This is simply because there is a natural tendency for low levels of total whey proteins at that time of year or in that region. The result is that a low level of total whey protein in the raw milk must give a low level of total whey protein in the powder so the undenatured component of this must also be low. This gives a false or misleading result that the resulting milk powder is medium or even high heat and is not as suitable for yoghurt manufacture, when in reality the level of denatured whey protein is very low.

The opposite effect can also apply in regions where there is a naturally high level of whey protein in the raw milk. A high level of total whey protein in raw milk will result in a high level of total whey protein in the powder and the amount of undenatured whey protein may also be high even though medium heat temperatures were used. This gives a false or misleading result that the milk powder is low heat and is suitable for yoghurt manufacture when in fact it will also have a high level of denatured whey protein as well. For example, milk powder produced using medium heat time and temperatures of 80 - 90˚C for a few minutes may still record a WPNI > 6.0 mg/g if there was a high level of undenatured whey protein present initially.

Many yoghurt plants that use milk powders still notice significant variation in yoghurt quality especially in the areas of syneresis, graininess and nodule formation even though they are using Low Heat powder consistently, in the majority of cases this may be due to the milk not being handled correctly prior to evaporation and drying from milk with a naturally high total whey protein level.

In order to reduce variation in the ability of the milk powders used to manufacture consistent quality yoghurt it becomes necessary to take total whey protein as well as undenatured whey protein into account. An analysis of milk powders for undenatured whey protein and total whey protein gives an indication of the level of denatured whey protein level in the milk powder.

2. *Which is better to be employed for increasing viscosity and sensory quality -WPC or SMP?*
The use of Skim Milk Powder (SMP) will only increase the total solids in the mix unless it has been specifically produced for yoghurt manufacture. The result of this is that there may only be a marginal increase in viscosity but along with this may be an increase in powder flavour.

Whey Protein Concentrate (WPC) will help to increase viscosity if used in the correct proportion of casein to whey protein. The WPC must be handled and produced in such a way that the level of undenatured whey protein is retained while the level of denatured whey protein is minimized. WPC is often not handled in this manner and care must be taken in selecting a supplier and ensuring the quality parameters are strictly adhered to.

3. *How do you minimize ingredient costs in yoghurt?*
The most effective way of minimizing ingredient costs is to use very good quality ingredients that have been selected specifically for yoghurt manufacture. Any compromise in quality usually results in down grade or poor quality yoghurt that is unsuitable for sale or results in lost sales due to customer complaints.
A number of manufacturers that use poorer quality ingredients compensate for this by increased use of stabilizers and emulsifiers. It is debatable as to whether this is less expensive

and it certainly results in flavour and consistency changes.

A number of alternatives are available in milk powders for yoghurt manufacture where the level of whey protein has been standardized prior to spray drying. Where the milk and WPC has been selected and standardized carefully and spray dried as low heat milk powder this gives a pre-standardized powder that is much easier to use. Savings in purchase, transport, storage and mixing of a range of ingredients can offset the slightly higher cost of the milk powder blend.

4. *How to decrease the powder-flavour in yoghurt when milk powders are used?*

Powder flavour in yoghurt is due almost exclusively to the selection of ingredients that are not suited to the yoghurt making process. Use of high and medium heat powders or even powders classed as low heat that have elevated levels of denatured protein contribute to powder flavours following through to the yoghurt. Powders must be selected for minimum protein denaturation so that they approach the quality of raw milk as near as is practically possible.

5. *What's the proper combination of temperature and hydration time for milk powders and whey products?*

The type of powder selected often determines the need for longer mixing times, higher temperatures and better blending equipment that reduces air incorporation. To cover most applications at least 15 min blending at 40ºC is recommended, this must be done prior to any heat treatment. A common mistake is to assume that the heating of the mix in the heat treatment unit assists in dissolving any undissolved powder particles. In fact undissolved particles act as seed points for protein denaturation and result in sandy or grainy texture or nodules.

Powder blending high-speed mixer

It is possible to mix powders at low temperatures given the correct quality of powder in combination with the correct mixing systems. Blending systems that reduce the incorporation of air while providing effective mixing are available and capable of mixing powders below 4 in a relatively short time. A number of plants rely simply on recirculation using centrifugal type pumps at high volumes to do the blending. These systems are rarely effective and usually lead to high instances of graininess or whey separation. Better systems are those purpose built for the operation such as tri-blenders or colloid mills.

Brookfield viscometer used for accurate viscosity testing.

6. *What are the requirements for powders for yoghurt manufacture?*

A number of tests may be carried out and the powder selected on the basis of these to obtain the best possible results. The following table sets out the minimum standards for powders

Test	Description	Standard
Moisture		3 – 4%
Fat	As required for final yoghurt fat content	
WPNI	Whey Protein Nitrogen Index	Low heat > 6.0 mg/g
Solubility index	This is a direct measure of the undissolved powder remaining after reconstitution at 20°C and centrifuging	<0.1ml. from 10g.
Sludge	This is a measure of the degree of sludge build up after reconstitution and allowing the sample to stand for a period of time.	Nil
Scorched particles	This is a measure of any scorched, burnt or discoloured particles in the powder that do not dissolve.	Nil (A disc)
Dispersibility	– This is a measure of the ability of the powder to disperse in water in a given time frame.	>90%
Wettability	– This is a measure of the ability of the powder to come completely in contact with water over a period of time.	<5 sec.
Sinkability	– This is a measure of the ability of the powder to become completely immersed in standing water over a period of time.	<10 sec.
Gelation test	– This is simply a measure of the ability of the powder to coagulate following heat treatment at 100°C and 120°C and incubation over time.	Gelled in 24 hrs
Alcohol test	– This is a variant of the gelation test where alcohol is used at a 1:1 ratio of the reconstituted milk to test the tendency to gel.	gelled

for yoghurt manufacture.

7. *In China most people prefer a highly viscous yoghurt, how to meet this requirement by selecting ingredients?*

By standardising the proteins present as well as the total solids it is possible to make consistently high viscosity yoghurt. Part of this is the selection of good quality ingredients that remain as near as possible to raw milk in quality. Protein levels must be increased by careful selection of high protein supplements. The most common sources of this protein are from whey powder or whey protein concentrate. High Protein Whey Protein Concentrate (HPWPC) is usually the source that gives the greatest impact on yoghurt viscosity. Commercially available High Protein Whey Protein Concentrate may range in concentration of protein from 80 - 90%, the normal range of Whey Protein Concentrate is from 35% - 80% Protein. High Protein Whey Protein Concentrate that has been concentrated by ultra-filtration has had the mineral salts removed that are normally associated with slower fermentation times. Provided the High Protein Whey Protein Concentrate has been handled carefully there should be high levels of undenatured whey proteins and very low levels of denatured whey proteins. Both these levels should be determined and standardised on the basis of undenatured whey protein. Denatured whey protein must be kept low to reduce the incidence of graininess or whey separation. High Protein Whey Protein Concentrate is more economical than lower protein level WPC as the quantity required to standardise to the same level is far lower. The addition

Bostwick consistometer used for rapid estimates of viscosity rate will be around 2% but will vary according to each batch and recipe requirements. The temptation to simply add High Protein Whey Protein Concentrate, or any other supplement, at a standard rate must be avoided, all this does is increase the total protein level without reducing the variation in the proteins. It is this variation in the protein type levels that has the greatest impact on resultant yoghurt viscosity.

A Brookfield viscometer is commonly used to obtain accurate measures of viscosity but does not lend itself to rapid testing in the plant.

Using a Bostwick consistometer the viscosity of yoghurt can easily be estimated by measuring the distance the yoghurt moves over 1 minute. This should be between 6 and 11 cm per minute at the point of packaging, 4 to 6 cm after cooling and less than 4 cm at the point of sale.

8. *What is the difference between the final yoghurts made by reconstituted milk and by fresh milk?*

The main difference between fresh milk and reconstituted milk is in the impact that the evaporation process, particularly the pre-heat treatment has had on the whey protein component. Whey proteins are denatured by heat with α-lactalbumin and β-lactoglobulin being the main whey proteins affected. If the level of protein denaturation can be minimised through the use of low heat powder this helps to minimise the impact on the final yoghurt. Denatured protein has little effect in the matrix formed and so contributes to graininess and whey separation. It is then theoretically ideal to make yoghurt from fresh milk of good quality and standardise this through the addition of Whey Protein Concentrates. Practically however fresh milk supply has a great deal of variation and factories may not be set up to standardise the whey protein levels effectively. There are also conflicting demands on the milk supply in many larger plants so that the yoghurt process must utilise milk that may not be ideally suited for yoghurt manufacture. Yoghurt from fresh milk exhibits a wide range of consistency for this reason especially in relation to viscosity and whey separation from varying levels of whey protein. Yoghurt from reconstituted milk has the advantage of being much more consistent if selected properly but may have the disadvantage of having higher levels of previously denatured whey proteins which may lead to graininess or whey separation. Even low heat powders may have high levels of denatured whey protein as the WPNI is a measure of undenatured whey proteins only. Powders selected on the basis of both are able to produce more consistent yoghurt with fewer defects. The powders again can be standardised with High Protein Whey Protein Concentrate to produce the correct level of proteins within the yoghurt. If powders are selected carefully they are able to produce yoghurt of quality similar to that from fresh milk. It is also possible to commission the production of milk powders that have been pre-standardised to the desired casein to whey protein ratio while at the same time being low heat powder with low levels of undenatured whey protein.

9. *Can UHT be employed to produce yoghurt and what is the influence on final product?*

The purpose of UHT is to destroy bacteria and spores while at the same time having minimal impact on the milk components. This is achieved by heating milk to very high temperature very short time for example 140˚C for 2 – 5 seconds. The majority of milk components such as casein, lactose and milk fat are relatively heat stable and are not affected greatly by the time and temperature combination. The whey proteins are more susceptible to heat and may be denatured to some extent. If a very short time is used the impact on these whey proteins can be minimised. This depends largely on the ability of the process to raise the temperature of the milk from 4°C to UHT temperatures and then cool it again. Modern plants are far more efficient in this regard than have been in the past and exercise better control and improved temperature profiles.

There are a number of volatile flavour compounds that may be released due to the high heat treatment and this can have an impact on the flavour profile of the milk and then any yoghurt that is manufactured from it. The high temperature used results in some flavour changes in the milk, especially related to whey protein denaturation and this needs to be taken into account before using UHT milk for yoghurt manufacture.

13.2.2 Processing

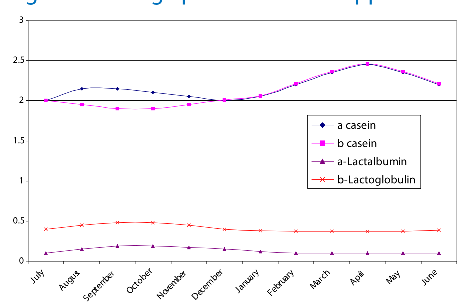
1. *What is the best method of addition of whey protein?*

The base mix for yoghurt manufacture will require an increase in the total solids content to obtain the best quality yoghurt. It is not simply a matter of addition of skim milk powder or skim milk concentrate to increase the solids content and hope that this has a positive impact. A range of products exist that can help to achieve the correct ratio of casein to whey proteins while increasing the total solids. Whey protein products have been used in the past to reduce costs by replacing casein with whey proteins. The reason for addition of whey protein must be to improve flavour and functionality of yoghurt by balancing the correct components for the particular yoghurt required. The relative cost reduction should be seen as a bonus from this rather than the sole reason, in this way manufacturers are not tempted to increase the use of whey products beyond what is the optimum and risk defects from overuse. As well as this the temptation to compromise on product quality or select cheaper inferior grade products is also avoided in a misguided attempt to reduce costs. In most cases the cheaper ingredients create many more problems with yoghurt defects and lead to loss of sales or over use of stabilizers to compensate.

Skim milk powders – May be used as a base but should not be relied on to increase the total solids content of raw milk alone. Addition does not standardize the ratio of casein to whey proteins, whey proteins should be added as well. Powders must be low heat to ensure very low levels of undenatured whey protein. It should be noted that powders manufactured as Low Heat may in reality have elevated levels of denatured whey proteins. WPNI is used as an indicator but is a measure of undenatured whey protein not denatured whey protein, both these should be taken into account when standardizing.

Skim concentrates – As with milk powders skim milk concentrate should be used as a

Figure 3 Average protein levels - Gippsland



Variation in protein components due to seasonality base but not as the sole method of increasing total solids. It should be used in combination with whey protein addition to standardize the casein to whey protein ratio as well as the total solids content.

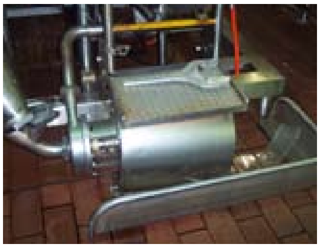
Whey powders – These have been used as a relatively cheap source of extra solids for yoghurt manufacture. While introducing whey protein to yoghurt base they may also introduce higher levels of salts and minerals that have a significant impact on the flavour characteristics of the final yoghurt as well as reducing the fermentation time, these mineral salts inhibit the fermentation process.

Demineralised whey powders can alleviate these problems as the mineral salts have been removed and the whey powder is then quite effective in producing good flavour characteristics as well as viscosity provided it is added in the correct ratio.

WPC – Whey Protein Concentrates are probably the most effective way of balancing flavour and functional characteristics. WPC from Ultra-filtration has in the process also removed the mineral salts associated with poor flavour and inhibited fermentation. A number of WPC products are available with varying levels of protein (35%, 50% and 80%) but the level of whey protein addition must be balanced with both the casein and whey protein in the base milk for the best results.

2. *What advantages and disadvantages are there in the use of stabilizers in yoghurt manufacture?*

The use of stabilizers is relatively common in yoghurt manufacture. The most effective being simple starch based or gelatine or a combination of both. These are used to thicken the yoghurt both as a response to customer requirements and to mask any defects that may be present such as runny yoghurt or whey separation. Although useful in doing this it is also a relatively expensive addition as it is necessary to add to all the yoghurt in order to comply with labelling requirements. It must be stated on the ingredient list if it has been added. Well-made yoghurt from good quality ingredients does not require the addition of thickening agents. If stabilizers are added it may be a sign that the process is not controlled as effectively as it should be. If circumstances are such that it is not possible to access the best quality ingredients, for example when the demand for milk powders drives the price up excessively, the only option available may be to use alternate ingredients and stabilizers to mask the effect. The use of stabilizers where the process is subject to variation may lead to yoghurt becoming excessively thick when conditions are correct. This can mean that very thick yoghurt is hard to pump through to the filling process after fermentation.


Old style powder mixing system

3. *How do you improve the functionality of yoghurt by addition of ingredients?*

Probiotics - Addition of a range of probiotic cultures is common practice in marketing the healthy properties of yoghurts. The range of probiotic cultures available for use is based on the natural flora of the gut and includes single strains as well as mixtures. The most common probiotic cultures used are

- Lactobacillus casei
- Bifidobacteria
- Lactobacillus acidophilus

These are normally used in conjunction with Streptococcus **thermophilus** to produce the pH drop required and to provide the smoothness and flavour associated with diacetyl.

The main problem with these cultures is the need to keep them viable in the yoghurt where the pH is below 4.5, an environment that does not necessarily favour their growth. Strains of probiotic cultures have been developed which are able to survive and grow in the yoghurt. Along side this is the manner in which they may or may not be utilized in the gut once eaten. In many cases the probiotic bacteria are subject to stomach acid that reduce their effectiveness or destroy them so the health benefits become a perception rather than a reality. Addition of Whey Protein increases the buffering effect of yoghurt which in turn can act to protect the probiotic bacteria. It is also thought to increase the level of lactase enzyme activity in the intestines.

The bioactive properties of components of whey products especially proteins has not been utilised as well in marketing. A number of whey proteins have been linked to lowering of cholesterol, enhancement of the immune system and reduction in the incidence of a number of cancers especially colon cancer. While research is not yet definitive it is well worth investigating the various benefits of addition of components that have been extracted from whey. Technology is now available to isolate and purify specific components of milk and milk proteins for use as functional ingredients.

4. *How do you minimize whey separation in yoghurt?*

Whey separation will usually be due to a loss of control of the process and can be narrowed down to one of a few main causes. The main possibility is due to poor selection of ingredients and is commonly related to a lack of standardizing accuracy. The base mix is standardized on the basis of total solids or protein and doesn't take into account the ratio of casein to whey protein in the final mix along with the desired total solids and protein level. This means that there is not enough whey protein (α-lactalbumin and β-lactoglobulin) available to form the bridge between casein micelles and leads to soft or runny yoghurt.

It is also common for the protein, particularly whey proteins to be denatured prior to heat treatment due to poor storage, holding too long or poor selection of ingredients. The use of powders or other ingredients that have elevated levels of denatured protein and low levels of undenatured protein has essentially the same effect. There is also not enough protein available to form a stable matrix.

The next possibility is lack of control of the heat treatment process where the whey proteins are not denatured sufficiently and effectively don't contribute to the formation of the protein matrix. This is less common as most processes ensure their heat treatment is effective, usually around 90ºC – 95ºC for 5 to 6 minutes.

During fermentation it is possible that small variations in temperature lead to considerably different growth rates for the cultures used. Mixed strain cultures are most commonly used but elevated or lowered temperatures mean the growth of each strain will either be depressed or enhanced. This can lead to flavour and texture changes and depending on the strain that grows more rapidly can lead to over or under acidification. Fermentation times become longer and the desired pH much harder to attain so the yoghurt becomes soft and runny.

Highly active cultures also act to over produce acid, particularly strains of lactobacillus bulgaricus. This starts to change the net charge on the casein to positive rather than neutral as it pushes the pH past the isoelectric point. As the charge increases, the protein matrix starts to break apart this leads to sharp acid flavours as well as whey separation.

Nodules formed in yoghurt

Mechanical action

All these factors lead to a coagulum that is loose and easy to break apart; any vibration, movement or temperature change after packaging assists in breaking down the matrix and allowing the entrapped water to be released (whey separation). This may be noticeable at the time of packing or in more extreme cases during fermentation but is more commonly noticed by the consumer in the tub when the yoghurt is approaching its shelf life limit.

Larger nodules are visible in the yoghurt but many small nodules can be seen under extreme close up. Shearing the yoghurt after fermentation will reduce the large nodules but the many small nodules remain and although not seen with the naked eye in the yoghurt may be felt on the tongue if they are hard enough. The yoghurt is also much more likely to exhibit whey separation as the matrix has not been formed properly, the protein forms into localized nodules instead of a smooth matrix.

5. *Why does yoghurt become sandy or form nodules sometimes?*
Sandy or grainy texture or nodules in yoghurt is usually the result of poor selection or mixing of ingredients. In particular, any protein denatured prior to the heat treatment process is particularly likely to attract other protein molecules during the fermentation process. Protein that has been denatured previously will tend to bond with other compounds for a large complex molecule or particle. During heat treatment, it denatures and bonds more and then on the introduction of an acid environment as the pH approaches the isoelectric point, the attraction forces from the balancing of charges attracts more and more protein. The effect of this is the formation of tightly packed protein particles or compacted protein that is then readily detectable during consumption. The obvious solution to this is to only use ingredients that have been treated carefully prior to yoghurt manufacture so that there is no opportunity to denature protein.

6. *Where dry ingredients are used the same applies for their*

treatment prior to yoghurt manufacture, this is more compex when dealing with low, medium or high heat powders (see section on milk powder).
The other main source of grainy yoghurt or nodules comes from the addition and re-hydration of dry ingredients such as milk and whey powders. If the powders have not been reconstituted properly it has essentially the same effect as those of previously denatured protein except the particles tend to be even harder in the final yoghurt. Again the undissolved particle attracts protein to it during and after heat treatment and then in the fermentation. Attempts have been made to overcome this defect by a number of methods. Filtering after the mixing step and prior to heat treatment to reduce the number of undissolved particles that remain in the milk and act as an attraction point. Filtration is often only partly effective as it doesn't filter out particles to a small enough level. Clarifying the mix prior to heat treatment for the same reason, this method being much more effective but also more expensive to achieve. Adding an homogenizing process after the heat treatment to break up any small particles. This may also be partly achieved by increasing the homogenizing pressure to break up any larger particles. The most effective method is to design the powder mixing process so that re-hydration is maximized and ingredients that are of exceptional quality and re-hydrate well are selected. The re-hydration process must be designed so that blending is quick, efficient and complete, this may necessitate the re-engineering of blending and pumping equipment and adjusting of the temperature to assist. The blending temperature should not be less than 20°C and ideally is just over the temperature that the fat component is in liquid form approximately 40°C.

7. How to balance the aroma formation and fermentation time during yoghurt fermentation?
The selection of the correct mix of starter cultures has arguably the greatest impact on flavour and aroma characteristics of yoghurt. The desired flavour requirements of the target market will determine the requirement to use specific cultures. A target market that requires a very sharp and clean yoghurt flavour will necessitate a higher level of *Lactobacillus bulgaricus* cultures as these produce the majority of lactic acid in yoghurt and that produce acetaldehyde that contributes greatly to this type of flavour. A target market the prefers a smoother and creamier yoghurt will require a higher level of *Streptococcus thermophilus* cultures that produce less lactic acid but develop more diacetyl which contributes to the smooth buttery flavour.

Having established the market requirement and achieved the correct mix of cultures and the correct recipe, accurate control must be exercised over the fermentation process in order to achieve the desired result. A slight variation in temperature for fermentation, even by as little as one degree will allow one strain to dominate and the other to be inhibited. This means that the resultant flavour of the yoghurt will change as higher levels of a particular culture dominate the fermentation. This can result in longer or shorter culture times, more or less acid production and variation in acetaldehyde and diacetyl production. Mixed strain cultures can be a mix of 5 or more strains, some for rapid acid production that may not contribute to flavour greatly, some with low acid production that may contribute significantly to flavour. Selection of the correct strains of culture is important but in order to produce the same flavour profile in the shortest possible time, great control must be exercised over the fermentation process especially ingredient selection, mixing and temperature.

It is possible to determine, by grading the yoghurt base after fermentation, the most likely source of flavour and aroma defects. Human taste can detect even small variations in flavour and aroma and this should be used to establish the cause of any loss of control of the process. A simple grading sheet may be used to record any notable flavour or odour characteristics of the yoghurt base after fermentation and cooling to 20°C. If a stronger than normal smooth diacetyl flavour is noted it can indicate that Streptococcus thermophilus has been dominant. This may mean that the fermentation temperature was a little low and may also be a factor if the fermentation time was longer than expected. If a sharper than normal flavour was noted it can indicate that Lactobacillus bulgaricus has been dominant. This may be due to the fermentation temperature being slightly higher than normal especially if the fermentation time was longer than expected. If there is a noticeable reduction in both sharpness and creaminess it may indicate that only rapid lactic acid producing strains have been dominant that may have reduced the fermentation time but have contributed very little to the flavour of the yoghurt.

Longer fermentation times may also be due to antibiotic or sanitizer residues inhibiting starter cultures, especially Streptococcus thermophilus. Lactobacillus bulgaricus does not grow well until the pH has dropped. Streptococcus thermophilus produces the initial pH drop that allows Lactobacillus bulgaricus to grow well. If Streptococus thermophilus is inhibited then slow growth of it leads to a delay in the growth of lactobacillus bulgaricus which extends the fermentation time.

Longer or shorter than expected fermentation times can be an indication of loss of control and can lead to flavour and consistency defects. The length of fermentation time needs to be balanced with flavour production expected in the market for the process to be strictly controlled.

8. *What are the economical benefits of using good and consistent quality ingredients?*

To make top quality yoghurt becomes a matter of selection of top quality ingredients. Selection of these ingredients can virtually eliminate the need for any additional expensive ingredients such as stabilisers and emulsifiers. Standardising of protein and total solids levels in the mix is critical and control over this is a major factor in design of plant and equipment. A number of other factors help to improve the marketability of yoghurt made from good quality ingredients, low incidence of antibiotics, gentle handling and cooling of milk from farm to processing, ability to standardise and produce specialty products for yoghurt manufacture such as High Protein Whey Protein Concentrates and yoghurt milk powder bases already standardised for casein to whey protein ratios. Use of these ingredients selected for the target market reduce the incidence of defects such as whey separation and graininess and as a result lower levels of customer complaints and higher repeat buying.

9. *How to get ideal stability of drinking yoghurt when stabilizers are absent?*

Drinking yoghurt must remain in liquid form without becoming too viscous and for this reason much lower levels of protein must be present. At the same time there must be sufficient nutrients to allow cultures to grow and sufficient lactose to allow conversion by the cultures to lactic acid.

The protein in the drinking yoghurt will tend to separate from the water phase upon storage as a matrix is not formed and for this reason stabilizers are normally used to assist to keep the components in solution.

As stabilizers are relatively expensive, it is desirable to reduce this level of addition to help reduce the cost of production. Factors that may help in minimizing cost of production include.

Accurate standardizing of the protein component so that it meets the level required in legislation without any additional protein and changing the ratio of casein to whey proteins can help to reduce the tendency to form a matrix. In the same manner that this ratio helps to produce a matrix in natural yoghurt, so too it may help to reduce the matrix by altering the ratio through addition of whey protein and reducing the casein component. The lowering of pH to below 4.5 assists in setting up the matrix by forming a balance of charges. The bonding between the whey proteins and casein is less likely to reform after mechanical action and so a reduction in the level of charges and an increase in the sulfhydryl and sulphide bonds combined with mechanical action after fermentation is more likely to ensure that the product stays in a stable and homogeneous form.

Vigorous mechanical action after fermentation can include homogenization which acts to break particles down to a size that ensures that their mass is small enough to enable them to stay in stable and homogeneous form.

As with all yoghurt manufacture an essential part of the process is the initial mixing of ingredients. Ingredients that have been mixed and distributed evenly will have a far greater tendency to stay in that form.

Use of cultures that produce EPS (exopolysaccharides) may also be of help in keeping the protein in evenly distributed. Some strains of cultures are able to produce sugars as a by-product and surround themselves in protective coatings of them. These sugars act in the same manner as stabilizers and may be used as a replacement for them. Balancing the production of EPS with flavour, sweetness and acid production must be taken into account when doing this.

13.2.3 Cooling and Packaging

1. *The coagulum formed during fermentation is sensitive to mechanical treatment, what should be considered during plant design especially at cooling stage to reduce the breakdown of the coagulum?*

   The design of plant must enable the yoghurt to be cooled to approximately 20°C and filling to take place as quickly as possible to inhibit culture activity while at the same time being gentle on the product to minimise mechanical treatment. The fermentation tanks should be located as close as possible to the final filling point. Stirred yoghurt is very gently agitated in the fermentation tank, this process is not one of agitation but must be of 'folding' and blending the yoghurt gently until a smooth base is obtained.

   Cooling of the product must be rapid but gentle, for this reason it is advisable to use large diameter pumps and pipe-work with single flow through design. These pumps are normally positive displacement screw type impeller pumps designed specifically for aseptic and gentle transfer of high viscosity products. They are designed to clean easily by allowing high flow during cleaning with bypass at only the screw impeller section.

The outlet should feed closely into the pump and then directly into the cooling heat exchange. This must also be designed to allow gentle heat transfer and are normally shell and tube heat exchangers. The main aspect of the cooling is that it is located close to the pump and fermentation tank. The yoghurt is normally cooled to approximately 20°C and stored in vats prior to filling. It is also important that these vats are located close to the filling point so minimal movement of the yoghurt is required.

Design of plant usually incorporates some mechanism for reducing any lumps, nodules or grains that may be present after fermentation. This is usually in the form of a backpressure or shear valve, coarse filter or strainer prior to cooling. Although effective in reducing these defects after they are formed, they may also contribute to the mechanical breakdown of the yoghurt and may manifest itself as whey separation particularly towards the end of its shelf life.

One of the main factors that can start to break down the yoghurt matrix is vibration, for this reason it is important that all agitators/stirrers and pumps are not subject to any vibration. This vibration can occur due to this equipment being out of balance, working too hard or due to poor design or sizing of plant.

Vibration may also occur during or after the filling operation especially during transport of filled tubs and cartons to cool rooms for cooling and storage. Any vibration or movement during cooling will tend to disrupt the matrix of the yoghurt. Vibration due to transfer by road or rail from manufacture to point of sale will also have an impact on this.

Having taken all these factors into account during plant design, if yoghurt has been produced to the fermentation stage with accurate control from high quality ingredients, the yoghurt itself is largely forgiving in its ability to withstand a reasonable amount of mechanical agitation even without the addition of artificial stabilizers. The accurate achievement of final pH at or near the isoelectric point and the formation of the casein/whey protein and fat matrix all help to keep the yoghurt together and give it thixotropic qualities where it can recover quite well from some mechanical disruption.

2. *Yoghurt has thixotropic flow behaviour, how is the viscosity recovered and how much is the extent of this recovery after filling?*

The ability of yoghurt viscosity to recover or thicken after filling is largely dependant on the final pH of the yoghurt. Yoghurt with a pH close to the isoelectric point is far more likely to recover after any mechanical agitation including filling. The initial standardizing of proteins assists in forming a strong matrix by ensuring correct levels are present to develop maximum numbers of sulfhydryl and sulphide bonds between casein complexes and whey proteins. These bonds however can be broken down by mechanical action and pH change and may not reform as readily, thus contributing to whey formation and runny yoghurt. It is mainly the balance of positive and negative charges that creates the attraction forces that ensure the yoghurt is able to recover provided the mechanical action is not too severe.

These forces are the reason that yoghurt is initially cooled to approximately 20°C for pre-filler storage, transport and filling. As long as the pH does not change from the final pH these attraction forces keep the yoghurt matrix together.

Upon cooling below 20°C there is also a resultant formation of crystals or solidifying of the fat component in the yoghurt. As the fat component has been distributed evenly throughout the yoghurt and is often bound into the protein matrix this phase change helps to improve the viscosity. Other components such as whey proteins exhibit some gel properties on the aqueous phase of the yoghurt.

The pH of the final yoghurt then is the main factor in recovering viscosity after filling. Provided control is maintained over acid production after fermentation, there is maximum ability of the yoghurt to maintain and recover viscosity. Any loss of control after fermentation means that positive and negative charges will become out of balance and there will be a greater tendency for the like charges to repel resulting in runny yoghurt or even whey separation in more extreme cases.

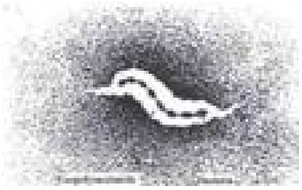
The extent of the recovery of viscosity can be quite significant once the yoghurt has been cooled to below 4°C. Even yoghurt that appears runny can significantly improve once filling is complete and storage temperature is attained. The reason for the yoghurt being initially runny must be investigated and action taken to prevent this from happening again as other defects may become apparent. If the reason for the yoghurt being initially runny was due to excessive mechanical action this needs to be investigated and the process design modified to correct the process.

It should be possible to produce consistently viscous yoghurt without the need for the addition of stabilizers if good control is maintained over the process. In many cases control is not maintained this accurately and a degree of variation is inherent. This means that stabilizers are often used to mask or cover this variation so that the process is easier to maintain.

The use of EPS (exopolysaccharide) producing bacteria in cultures is another method of recovering viscosity without the use of stabilizers. EPS cultures surround themselves with a protective layer of sugar and are commonly known as slime producers. In effect this acts as a stabilizer that is produced naturally by the culture bacteria, and reduces the need for the expense of adding artificial stabilizers.

3. How to control the after-acidification of final products?

Post acidification is due mainly to activity by the culture after fermentation. Selection of correct strains of cultures can assist in reducing the likelihood of further pH drop after the end of fermentation. Starter bacteria strains are selected that produce quantities of lactic acid rapidly, particularly strains of *Lactobacillus bulgaricus*. These strains may be selected to drop pH to a predetermined level, under normal conditions, and then to plateau out at that level. They do this by producing enough lactic acid to inhibit their own growth or by becoming less active below 20°C. or even dormant below 4°C.



Culture activity is then controlled by filling and cooling as quickly as possible.

In well made yoghurt post acidification is largely due to poor handling after fermentation. Commonly the poor handling is a result of production problems where there is a delay in filling and the yoghurt must be stored for extended periods of time. The result of this is a slight pH drop prior to filling. It must be remembered that the pH scale is logarithmic and that a slight drop in pH from around 4.5 to 4.0 is the result of a significant amount of acid production. Slight drops in measurable pH will have a large impact in the flavour characteristics of the yoghurt as human taste is easily able to detect these small variations.

If the post acidification is significant enough, it will result in whey separation; however slight the product's post acidification can result in whey separation towards the end of its shelf life.

Another common source of post acidification is where there is a delay between filling and cooling, usually because of production delays in filling pallets or due to breakdowns. A pallet of yoghurt may be filled and packed properly but then may be left at room temperature for a period of time due to delays unless contingency plans are put into place. This allows the culture in individual tubs to continue acid production until they are finally cooled to a temperature below which their activity slows.

An extension of this is where tubs are subjected to higher temperatures after cooling, during distribution.

13.2.4 Storage and Distribution

1. *What are the main factors that affect yoghurt stability after packaging?*

It is important to cool the yoghurt as quickly as possible after packaging; this is usually achieved by stacking cartons in an open formation to allow cold air to circulate between cartons. The cartons and tubs will gradually cool to below 4˚C over approximately 8 to 12 hours mainly due to the insulating nature of the cardboard carton. The initial cooling from 20˚C to less than 10˚C occurs rapidly but the remaining cooling takes a considerable length of time. Rapid initial cooling is desirable to both reduce the likelihood of growth of contaminant bacteria that may have entered during filling and to reduce the likelihood of whey separation.

Cooling of full fat or reduced fat yoghurt over a period of 8 to 12 hours should ensure that latent heat released due to fat crystallization is eliminated; otherwise this would normally cause a temperature rise after storage.
In order to retain the shelf life desired of more than a month it is vital that the temperature of yoghurt at all times remains below 4˚C.

Correctly produced yoghurt is able to withstand a reasonable level of mechanical action after it has set properly. Movement due to conveyors, forklifts, trucks and transfer to shop or supermarket shelves should have little impact on the yoghurt provided the integrity of the tub and the temperature remain unchanged. Vibration however will have a major impact on the yoghurt causing whey separation and breakdown of the protein matrix to produce runny yoghurt especially during the first 48 hours after filling. The yoghurt will have increased in viscosity after this time and is much less likely to break down. It is wise to ensure that the method of transport does not result in excessive vibration or movement for a number of days after the yoghurt has been produced. This can be achieved by limiting the speed of trucks, using trucks that ensure smooth ride, taking roads to storage depots that have good access and are smooth and using smooth tyred fork lifts.

Typical yoghurt carton with air holes to view contents and improve cooling

Conclusion

Consistent manufacture of good quality yoghurt is achieved by focusing attention on the areas that reduce the variations in the process. These are almost always in selection of top quality and consistent ingredients and then in controlling the mixing and standardizing processes. Defects in yoghurt manufacture are associated almost exclusively with either poor selection of ingredients or with poor treatment during storage, mixing, heat treatment or fermentation. Many manufacturers spend a great deal of time and resources in analyzing and adjusting processes after fermentation such as storage of base, transport and filling. In reality this is often a poor use of resources as the damage has already been done. Well made yoghurt is able to withstand some mistreatment or abuse, provided it is not excessive, without any lasting effect on the yoghurt matrix. It is far more advisable to concentrate efforts on reducing the variation in the process of making the yoghurt so that filling machines and related equipment does not have to cope with great fluctuations in areas such as viscosity and temperature for which it has not been designed. The quality of packing materials should also become an increased focus of attention rather than attempting to modify a filling machine to try and cope with the variation.

Glossary

Acidification

The formation of acid, or a more acid environment.

Alcohol test

A variant of the gelation test where alcohol is used at a 1:1 ratio of the reconstituted milk to test the tendency to gel. It is sometimes used as a rough quality test on raw milk looking for immediate coagulation but can also incorporate incubation over time as a quality test. It is more likely to test denaturation of protein due to acid development through poor handling.

PH

A measure of the acidity or alkalinity of a substance on a scale of 0 to 14 with 7 being neutral. It is a measure of the concentration of hydrogen ions on a logarithmic scale equal to log10 (1/[H+]).

Culture

Bacteria selected and purified to perform a specific task, in the case of yoghurt the conversion of lactose into lactic acid.

Detergent

A cleaning agent used to remove soil deposits or loading.

Dispersibility

A measure of the ability of the powder to disperse in water in a given time frame. It is measured by dissolving the powder under controlled conditions, allowing standing for a short time then pouring a quantity off and calculating the total solids in the dissolved milk as a proportion of the original powder.

EPS

Exopolysaccharide, a type of organism that surrounds itself with a capsule of sugar.

Fermentation

Acid formation from culture bacteria that convert sugar.

Gelation test

A measure of the ability of the powder to coagulate following heat treatment at 100˚C and 120˚C and incubation over time. This test can be useful in the selection of milk powders for yoghurt manufacture by directly testing its ability to form a matrix as it is an indirect measure of the level of undenatured whey protein. This test can also be used on liquid ingredients.

Graininess

The formation of small hard grains in yoghurt normally associated with excessive heat treatment or very poor quality ingredients.

HIPS

High Impact Polystyrene.

Homogenisation

Exposing milk to high pressure differentials to shatter the components into smaller pieces and distribute them evenly throughout the mix. In yoghurt to create a uniform blend of protein.

HPWPC

High Protein Whey protein Concentrate.

Isoelectric point

The balance point of charges on the casein micelle complex where positive and negative forces are equal and provide maximum attraction.

Nodulation
The formation of soft balls in yoghurt usually consisting of denatured protein, sometimes referred to as fish eyes.

Pasteurisation
Heat treatment for a defined temperature and time (equivalent to 72°C for 15 seconds or higher) to destroy pathogenic organisms. In yoghurt manufacture the heat treatment is nominally called pasterurisation but in reality is much more extreme in order to denature protein.

Sanitiser
A chemical or similar agent used to lower the bacterial load to an acceptable level, usually commercially acceptable.

Scorched particles test
A measure of any scorched, burnt or discoloured particles in the powder that do not dissolve. It is a simple filtration test where reconstituted milk powder is filtered through a cloth disc and analysed for any remaining particles. A set of standard photos are used to compare the disc to.

Sinkability
A measure of the ability of the powder to become completely immersed in standing water over a period of time.

Solubility
A direct measure of the undissolved powder remaining after reconstitution at 20˚C and centrifuging.

Standardisation
The controlled mixing or blending of different components to produce a desired ratio of these components in the final mix.

Syneresis / Whey
formation The separation of the water component from the yoghurt matrix to give an undesireble appearance to consumers.

UF
Ultra Filtration.

Viscosity
A measure of the thickness of a substance similar to flow characteristics.

Wettability
A measure of the ability of the powder to come completely in contact with water over a period of time.

WPC
Whey Protein Concentrate, a concentrated form of whey in which the protein has been increased, used as an ingredient in many manufacturing processes.

WPNI
Whey Protein Nitrogen Index.

Yoghurt
A fermented food product manufactured by the controlled addition and fermentation of lactic acid producing bacteria in milk.

DAIRY AUSTRALIA
Delivering for the dairy industry

14

Applications of Australian Dairy Ingredients in Ice Cream

Content

346 14.1 Introduction to Ice Crema Manufacturing

357 14. 2 FAQ

368 References

14.1 Introduction to Ice Crema Manufacturing

14.1.1 Classifications of Ice Cream

Ice cream is a frozen product containing water, milk products, sweeteners, stabilizers, emulsifiers and flavourings. Ice cream may also contain colourings, egg products, starch derivatives, syrups, fruit and confectionary.

Although each country has its own legal definition of ice cream, typically ice cream is classified as either standard ice cream (containing 10 % milkfat), low or reduced fat ice cream (containing <4 % or < 6.5% milkfat respectively) and premium ice cream (containing >12 % milkfat).

Legal requirements in Australia

The Food Standards Code contains the legal requirements for the composition, labelling and processing of ice cream in Australia (see Table below).

Food Standards Regulation for Ice Cream and Related Products				
	Milk fat %	Minimum food solids g/L	Standard plate count per g	Coliforms per g
Ice cream	10 % Minimum	168	<50,000	<100
*Reduced fat ice cream	Typically 7 % Maximum		<50,000	<100
*Low fat ice cream	Typically 3 % Maximum		<50,000	<100

*The definitions for "reduced fat" and "low fat" are contained in the "Code of Practice on Nutrient Claims in food labels and in advertisements (January 1995)"

The Australian New Zealand Food Standards Code provides definitions for "ice cream" "reduced fat ice cream" and "low fat ice cream".

Ice Cream means a sweet frozen food made from cream or milk products or both, and other foods, and is generally aerated.

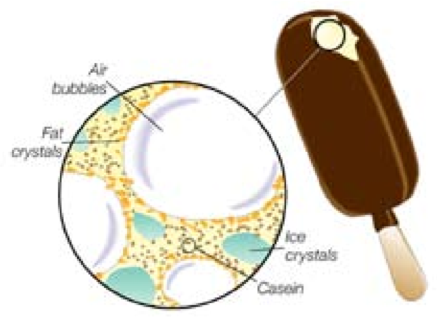
The Food Standards Code developed by Food Standards Australia New Zealand (FSANZ) requires that where animal fats other than milkfat are used in ice cream the source must be declared. Where vegetable fats are used the product cannot be called ice cream.

14.1.2 Application of Key Ingredients in Ice-cream Making

The basic ingredients in any ice cream mix are fat, milk solids non fat, (MSNF) sugar, flavours, colours, stabilisers, emulsifiers, air and water. The interaction of these ingredients as well as the relative proportion of each component is important. The quality of the ice cream produced will depend on the requirements of the consumer and is a balance between flavour, body, texture and colour. Ice cream body and texture are largely determined by the principal ingredients and the stabiliser / emulsifier system but will also be affected by the amount of air incorporated during freezing/churning. This incorporated air is called the overrun and will vary depending on the formulations of the mix and the type of freezer used.

Ice cream is basically a foam in which the air is dispersed as small air cells within the partly frozen continuous phase of an oil in water emulsion. This phase also contains dissolved solids such as sugars, salts and colloidal substances such as proteins and stabilisers. A colloid is a dispersed system of at least two different ingredients, e.g. emulsion - liquids in liquids, foam - gases in liquids or solids. The figure below shows the microstructure of ice cream consisting of air bubbles, ice crystals, fat, MSNF and stabilisers.

Microstructure of ice cream (Dairy processing handbook, 2003)



There are many ingredients which can be used to manufacture ice cream such as cream, unsalted butter, anhydrous milk fat (AMF), condensed skim milk, skim milk powder, whole milk powder, butter milk powder dry sugar, glucose syrup and dextrose.

Some major considerations in the selection of the type and quantity of ingredients include legal requirements, cost, availability and consumer preference.

The table below from Marshall and Arbuckle (1996) show some typical ice cream formulations.

Table 4.1 Approximate composition (%) of commercial ice cream and related frozen desserts

Product	Milkfat	NMS	Sweeteners[a]	Stabilizers[b] and emulsi-fiers	Approximate TS
Nonfat ice cream(hard)[c]	<0.8	12-14	18-22	1.0	35-37
Lowfat ice cream(hard)[c]	2-4	12-14	18-21	0.8	35-38
Light ice cream(hard)[c]	5-6	11-12	18-20	0.5	35-38
Reduced fat ice cream(hard)[c]	7-9	10-11	18-19	0.4	36-39
Soft-serve ice cream	3-4	12-14	13-16	0.4	29-31
Economy ice cream	10.0	10.0-11.0	15.0	0.30	35.0-37.0
	12.0	9.0-10.0	13.0-16.0	0.20-0.40	
Trade brand ice cream	12.0	11.0	15.0	0.30	37.5-39.0
	14.0	8.0-9.0	13.0-16.0	0.20-0.40	
Deluxe ice cream(premium-super premium)	16.0	7.0-8.0	13.0-16.0	0.20-0.40	40.0-41.0
	18.0-20.0	6.0-7.5	16.0-17.0	0.0-0.20	42.0-45.0
	20.0	5.0-6.0	14.0-17.0	0.25	46.0
	6.0-10.0	2.7 (Protein)	14.0-17.0	0.40	36.0-38.0
Mellorine Frozen yogurt	3.25-6.0	8.25-13.0	15.0-17.0	0.50	30.0-33.0
	0.5-2.0	8.25-13.0	15.0-17.0	0.60	29.0-32.0
	<0.5	8.25-14.0	15.0-17.0	0.60	28.0-31.0
Sherbert	1.0-3.0	1.0-3.0	26.0-35.0	0.40-0.50	28.0-36.0
Ice	—	—	26.0-35.0	0.40-0.50	26.0-35.0

[a] Includes sucrose, glucose, fructose,corn syrup solids, maltodextrins, polydextrose, and other bulking agents, some of which contribute little or no sweetness.
[b] Includes cellulose gum and cellulose gel.
[c] Terms for specific fat content claims are defined in 21 CFR 101.62.

MilkFat

Fat accounts for most of the rich, creamy taste of the ice cream and only a limited amount of substitution with other ingredients can be made without changing this characteristic. Fat gives body to the product and provides a smooth texture. The higher the fat content, the smoother is the mouth feel of the finished product due to the lubricating effect of fat. Butter fat melts below body temperature and so it melts on the tongue, adding to the smooth mouthfeel. Legal requirements in many countries mean that ice cream must contain a minimum of 10% milk fat. Cream is the preferred source of milk fat but there may be difficulty in ready supply and storage of cream. The ice cream industry often use anhydrous milk fat (AMF) as an inexpensive source of milkfat. AMF is prone to oxidative off flavours if not stored correctly.

Milk solids not fat (MSNF)

Milk solids not fat (MSNF) consist of milk proteins, lactose and minerals which contribute a pleasant milky flavour to ice cream but are more important to body and texture properties. The milk proteins include casein which has important whipping properties. Lactose is a type of disaccharide which has low levels of sweetness. As the fat content is increased, the MSNF is decreased to maintain a proper balance of total solids. The proteins bind some water, have an emulsifying effect on the fat and give viscosity and chewiness characteristics to the body. The milk solids also contain the milk salts and lactose. MSNF normally make up 7-12% of the mix. If used in excessive amounts, the milk solids can cause a condensed milk or milk protein flavour.

For many years the fear of lactose crystallisation which gives a coarse, sandy texture, has forced manufacturers to limit the MSNF in ice cream to 12% or less. Commercial experiences as well as research findings have shown that higher levels of MSNF can now be safely used. Due to technological advances the possibility of sandiness developing is low and this defect is rarely encountered in commercial ice cream. Better temperature control and the use of stabilisers which inhibit lactose crystal nuclei from forming, and therefore lactose crystals, have helped to eliminate this defect.

The use of MSNF tends to reduce the apparent richness of the fat and other delicate flavours. Consequently a balance must be found between the proportion of flavouring agents, the MSNF portion and the sugar content.

Sources of MSNF include liquid skim milk concentrate, liquid skim milk and dried powders such as skim milk powder, buttermilk powder, whey protein concentrates or whey powder. The preferred source of MSNF for ice cream manufacture is fresh liquid skim milk concentrate (25-35%) as this provides the required MSNF without potential off flavours (cooked or stale flavours) which can occur in dried powders. Liquid skim milk, skim milk concentrates and skim milk powder are costly sources of MSNF, so some bulk ice cream manufacturers substitute with maltodextrins or use cheaper sources of MSNF such as whey powder or buttermilk powder in order to keep costs down.

With whey products, it may be possible to only partially replace the MSNF proportion as the higher levels of lactose in whey based products may cause problems with a poor textured product.

Whey Products

Whey and whey products have been used in ice cream and related products for many years. The most commonly used whey products are sweet whey, modified whey, whey protein concentrates (35-80% protein), whey protein isolates (>90% protein) and demineralized whey. The use of whey products in ice cream can result in improved flavour, body and texture and give better heat shock resistance. As whey products are relatively cheap compared to milk proteins and stabilisers, manufacturers can also make cost savings. Excessive use of whey products (say greater than 3-4 % of the mix) can lead to lactose crystallisation and or off flavours (eg cheesy and salty flavours) in the ice cream.

Commonly used whey products in ice cream include:

- Sweet Whey
- Demineralized Whey (D40, D70)
- Modified Whey
- Whey Protein Concentrate (WPC 35% protein: WPC35)
- Whey Protein Concentrate (WPC 50 protein: WPC50)
- Whey Protein Concentrate (WPC 80% protein: WPC80)
- Whey Protein Isolate (90% protein: WPI)

Sugars

These ingredients play an important role in any ice cream and have the following functions:

- provide sweetness;
- add to the solids content and therefore contribute to the body and texture;
- lower the freezing point of the product so that the product is soft and smooth at low temperatures.

Sugar levels of 14 -16% seem to be the optimal level preferred by consumers. The total solids content is related to the sugar content and too much solids, or too high a sugar content, will affect the body of the finished product.

Sugar syrup is commonly used by ice cream manufacturers because of its ease of storage and handling. Dried sugar is also suitable for use.

In order to improve the handling properties of the finished ice cream and to reduce costs, sugars other than sucrose are sometimes used. These sugars typically include glucose syrup and dextrose. The use of sugars in the correct proportion may produce an ice cream which can be served directly from a deep freezer;

- glucose syrup is less sweet than sucrose and may be used to replace some of the sucrose so as to improve the firmness and mouthfeel of the product as well as to increase the shelf life;
- enzymic conversion of glucose to fructose, and lactose to glucose and galactose, increases the sweetening value of these sugars and opens new avenues for ice cream manufacturers interested in reducing costs.

Lactose (milk sugar) is not intentionally added to ice cream, but is a component of the dairy ingredients such as milk, milk concentrates, and milk and whey powders which are added to the ice cream mix. Some people are lactose intolerant i.e. they do not produce enough lactase enzyme to break down lactose. Instead, undigested lactose sits in the gut causing gas, bloating, stomach cramps, and diarrhoea. In order to overcome the problem of lactose intolerance some ice cream manufacturers add lactase, an enzyme which can hydrolyse lactose to galactose and glucose, to the ice cream mix.

Emulsifiers

Emulsifiers are used in ice cream to produce desirable characteristics, such as:

- improved whipping properties or ease of incorporating air into the mix;
- a smoother texture and consistency;
- resistance to shrinkage;
- "stand up" or slow meltdown of ice cream;
- increased drying of the surface which reduces dripping of the product.

Emulsifiers contain a lipophilic portion which associates with the fat and a hydrophilic portion which associates with the water phase. The emulsifiers also act at the air/water interface and help the formation of small air cells. Factors such as fat content, degree of homogenisation, and MSNF-to-water ratio influence the concentration of emulsifier used. A wide range of emulsifiers are available for use in ice cream; the ones most commonly used are the mono diglycerides of fatty acids.

Stabilisers

Stabilisers are primarily used to absorb free moisture and to stop the formation of very large ice crystals. This makes the frozen product more resistant to heat shock or damage during handling. Like emulsifiers, they have a number of other functions. These are to:

- increase the viscosity of the mix;
- improve the incorporation of air;
- improve body and texture;
- improve melt down properties;
- improve handling properties during storage.

Two types of stabilisers are commonly used, the gelatine type, and those of vegetable origin such as guar gum, locust bean gum, carrageenan, xanthun gum, sodium alginate and sodium carboxymethylcellulose.

The action of stabilisers is generally attributed to two properties. They increase the viscosity of the mix which slows down the movement of water molecules and their orientation for freezing, and they bind water either as water of hydration or by immobilising it within a gel structure.
The concentration of stabiliser used is determined by the same factors that influence the use of emulsifiers, including legal requirements.

Water and air

Water is an important constituent of ice cream although it is often overlooked as it is normally present in the other ingredients. If water is added directly to the mix, it must be clean, have no off-flavours, and be of good microbiological quality.

Water is the continuous phase in ice cream, all other ingredients being dispersed or dissolved in it. Water is present as liquid, solid (ice) or a mixture of the two states. The air is dispersed through the water-fat emulsion which is composed of liquid water, ice crystals and solidified fat globules. The interface between the water and air is stabilised by a thin film of interfrozen material. The interfaces of the fat are covered by a layer of fat emulsifying agent.

The water present should be balanced against the total solids content of the mix. Too much water will increase the chance of large ice crystals forming.

Air is another essential component of ice cream and is used to increase the volume of the final frozen product. This increase is called overrun. The quantity of air incorporated into the product influences the final quality and cost of the product, but must comply with legal requirements.

Colours and flavours

The colour of ice cream should be only intense enough to be easily recognised, and to match the colour normally associated with the flavour. Adults tend to like paler colours; children however are more attracted to bright colours. The permitted colours, both natural and artificial, are set out in the appropriate Food Standards Code.

Different flavours in ice cream are achieved by the use of added flavourings. Flavours are generally available as natural, nature identical, and artificial, and are easily incorporated into the ice cream mix. The level of flavour addition should be intense enough to be easily recognised and delicately pleasing to the palate. Overuse of flavours can introduce an unpleasant, almost "chemical" note. Where fruits are added it is often necessary to add flavour to enhance the overall flavour perception.

A wide variety of flavours, fruits, nuts, confectionery and pastry can be added to frozen products. The most popular flavours are vanilla, chocolate and fruit flavours. Popular fruit flavours include strawberry, raspberry , blackberry, boysenberry, mixed berry, mango, passionfruit and mixed tropical fruit.

Bulking agents

As consumers have become more health conscious interest in reduced kilojoule (calorie) and low kilojoule (calorie) foods has been growing. In order to manufacture such ice creams it is necessary to substitute part of the sweetener or fat with a bulking agent and/or artificial sweeteners.

	Low Fat/Low Calorie Ice Cream Recipe 1	Low Fat/Low Calorie Ice Cream Recipe 2
Milkfat	4%	4%
M.S.N.F.	12%	12%
Aspartame	0.1%	0.1%
Polydextrose	12%	6%
Maltodextrin	0%	6%
Stab/Emuls	1%	1%
Total Solids	29.1%	29.1%

Polydextrose (a polymer of dextrose) is an example of a bulking agent that is a water-soluble polymer of dextrose. This product is only partially metabolised by humans, hence yielding only four kilojoules (one calorie) per gram or one quarter of the amount derived from carbohydrate.

Maltodextrins (D-glucose) may be used to replace milkfat as they can provide solids (bulk) and a suitable "mouth feel".

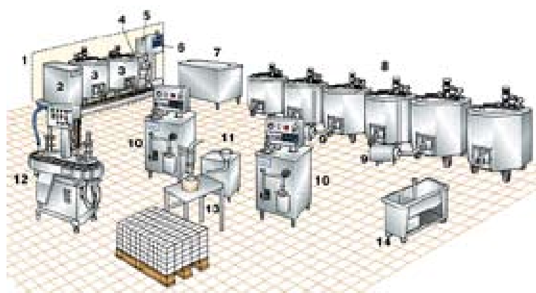
14.1.3 Key Processes and Parameters in Ice-cream Manufacturing.

Ice cream mix preparation is a multi-step process involving the blending and dispersing of a variety of liquid and solid ingredients into a homogeneous fluid product that is pasteurised, homogenised and cooled.

Ice cream processing involves:

- mix formulation / calculation
- raw material selection
- mixing and blending
- standardisation
- homogenisation
- heat treatment
- aging, flavouring
- freezing
- filling/packing
- hardening
- packaging/ storage

1	Ice cream mix	8	Ageing tanks
2	Water heater	9	Discharge pumps
3	Mixing and	10	Continuous freez-
4	Homogeniser	11	Ripple pump
5	Plate heat ex-	12	Roto-filler
6	Control panel	13	Can filler, manual
7	Cooling water unit	14	CIP unit



Ice Cream Production plant
(Dairy processing handbook, 2003)

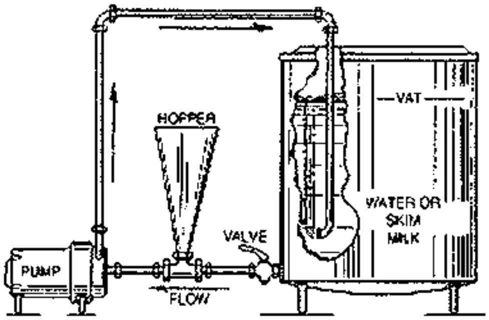
Mixing and blending

Mixing is normally carried out with strong agitation and heating. High speed stirrers (e.g. colloid mills and triblenders) produce a coarse emulsion. This is necessary so that a uniform feed is provided for the homogenizer. Solids are always added to warmed liquids.

Mixing may be manual or automatic, batch or continuous, according to the scale and sophistication of the operation.

The liquid ingredients such as cream, milk, water, liquid sugar are first added to the mixing vat. These are agitated and heated (45°C - 50°C) then the dry ingredients are added.

Dry ingredients such as sugar, milk powder, stabiliser, emulsifier, cocoa should be mixed together first to avoid lumping and ensure even distribution. Often the stabiliser/emulsifier is preblended with the dry sugar prior to addition to the mix. The time and method for adding the stabiliser will depend upon



"Powder funnel" mixing system (Marshall, 1996)

Colloid mill

Triblender

the type of stabiliser used. Most stabilisers are added to relatively cool mix which is then heated so the stabilisers are completely dispersed and hydrated. Adding gums at too high a temperature can lead to lumps of partially hydrated gums (called fisheyes) which are extremely difficult to break up and disperse. Stabiliser dispersion seldom presents a problem when the mix is batch pasteurised. When the mix is processed in HTST equipment, difficulty may be encountered with limited time for dispersion and hydration as the mix is passing through the plate heat exchanger. The short holding period at high temperatures may be insufficient for the stabiliser to disperse and hydrate, so it may be necessary to add more stabiliser to the mix.

DR Tech's Batch Pasteurizer

Once blending is complete the mix is often filtered through a cloth or stainless steel mesh to remove large pieces of undissolved matter.

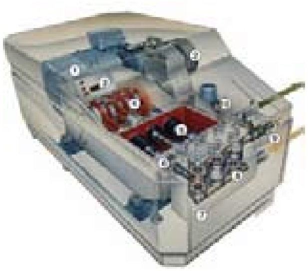
Heat treatment

Ice cream mix is pasteurised to destroy all pathogenic microorganisms, improve keeping quality, dissolve ingredients and improve flavour. Pasteurization also causes an increase in water-holding capacity of the proteins.

HTST pasteuriser (Dairy processing handbook, 2003)

More heat is required to effectively pasteurise an ice cream mix than milk because of its higher total solids content. Higher fat and sugar levels exert a protective effect on some microorganisms. Typical temperature time combinations used for batch pasteurisation may be 65-68°C for 30 minutes. For continuous flow high-temperature short-time (HTST) pasteurising equipment used by most large ice cream plants, the temperature/time combination is 79.5°C for 25 secs.

If continuous HTST pasteurisation is followed by a vacuum deodorisation and a cooling step is used, the mix must be heated to at least 90°C. In all cases, regenerative cooling to below 5°C follows the pasteurisation step. Ice cream may also be Ultra Heat Treated (UHT) at 150°C for 0.2-6 seconds, sometimes used to produce soft serve mixes.



Homogeniser (Dairy processing handbook, 2003)

Homogenisation

The homogenizer reduces the size of the fat globules to less than 2 microns in diameter. It is an essential step where milkfat or vegetable fats are used. Where cream is used, the globules are reduced to approximately one tenth of their original diameter. New membranes around the globules are formed from the emulsifiers and milk proteins present. Two stage homogenizers are often used to prevent clumping. Homogenisation ensures the fat globules will not become destabilised during the freezing process. Unhomogenised mix will partially churn during freezing and small particles of butter will form which give an undesirable texture. The effect of fat distribution and agglomeration affects the consistency, mouth feel, melting properties and flavour release in the frozen product. Homogenisation also improves the whipping properties of the mix during the freezing stage. The small fat globules accumulate around the air cells. The smaller the fat globules, the smaller the air cells can be so the easier it is to incorporate the air into the mix.

Ageing tank (Dairy processing handbook, 2003)

Good ice cream texture depends on correct temperature and pressure of homogenization. The temperature must be high enough to ensure that all fat is liquid. Usually homogenisation is done within the temperature range of 63°- 74°C and at pressures of 10.3-20.7 MPa (1500 to 3,000 psi) on the first stage and 3.4 MPa (500 psi) on the second stage. The typical homogenisation pressures for a 10% milkfat mix would be 2,000 psi in the first stage and 500 psi in the second stage.

Correct homogenisation results in smoother ice cream with increased perception of richness and mouthfeel and increased resistance to melting.

Aging

Immediately after homogenization, the mix is cooled in a plate heat exchanger and held at refrigerated temperatures (2-4°C) for 1-4 hours. Where gelatin is used as a stabilizer, aging takes longer (up to 24 hrs).

The changes taking place during aging are not fully understood. The major changes, however, are:

- Fat crystallization
- Hydration of Milk Proteins and Stabilizer, increasing mix viscosity
- Partial coalescence of fat globules

Freezing

During the freezing process, the liquid mix is converted into a partially frozen semi plastic mass. At the same time, air is incorporated to produce a solid foam. The quantity of air incorporated determines the quality and volume of the final product. The air incorporated into the ice cream mix is referred to as overrun.

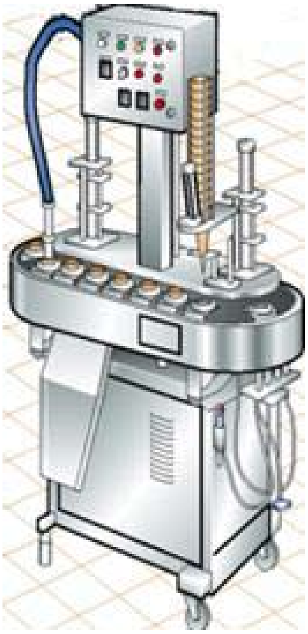
Continuous freezer (Dairy processing handbook, 2003)

Two types of ice cream freezers are used:

- the batch type, which freezes a measured quantity of mix to a specific volume of ice cream. Once frozen the ice cream is removed and the process repeated, one batch at a time;
- the continuous type, which takes in a continuous flow of ice cream mix and discharges a continuous flow of partly frozen ice cream.

Both types of freezers have a freezing cylinder where the cooling is performed by direct expansion of the refrigerant. As heat is removed from the mix by the refrigerant, ice forms on the cylinder wall. A dasher with sharpened, metal blades attached, revolves within the cylinder and scrapes the surface to continually remove the frozen film of ice cream. Many small ice crystals are rapidly formed, scraped off, and mixed with the unfrozen liquid. At the same time, the moving parts of the dasher whip the partially frozen mass to distribute the air as minute bubbles, and so produce the desired overrun.

Batch freezers are not commonly used in the large scale commercial situation due to their limited capacity and their high labour requirement. The ice cream cannot be frozen to less than –5 to –6°C because it must be sufficiently fluid to flow from the freezer to empty it.



Cup and cone packaging machine (Dairy processing

Continuous ice cream freezers range in capacity from 100 to 10,000 litres per hour. This type of machine is used almost exclusively in commercial ice cream plants. Where large capacities are required, multiple units are installed with the ice cream discharge from several machines connected together to supply the requirements of automatic or semi automatic packaging or filling machines.

Continuous freezers can be used for nearly every flavour of ice cream, for ice milk, sorbets, sherbets, ices or other frozen desserts. When the flavouring consists of particulate matter, such as nuts, whole fruit or candy pellets, the mix is run through the continuous freezer and then the ice cream is passed through a fruit feeder, which automatically feeds and mixes the flavour particles into the ice cream.

Ice cream is usually discharged from continuous freezers at about –5 to –6°C but this can be changed to alter the consistency of the partially frozen ice cream to meet the needs for packaging. The lower the discharge temperature, the stiffer the ice cream and the smoother the texture. However, lowering the discharge temperature reduces the capacity of the freezer because the product must be held longer in the freezer to lower the temperature.

Packaging

Unless fruit or nuts are to be added to the semi frozen ice cream, the next step in the ice cream manufacturing process is the packaging of the product. The ice cream from the freezer is a semi solid mass with 50 % of the water being frozen, which can be packaged into various containers (eg tubs, cups, cones, moulds) to give it the required shape, size and appearance. This can be done manually by an operator or automatically by machine. In the latter case, the machine dispenses the tub and ice cream, adds the lid and mechanically seals the container. The filled tub may then be accumulated with other tubs before being put in an outer container or shrink wrapped with plastic to help subsequent handling. After this step, the product is moved to the hardening room sometimes via a hardening tunnel or blast freezer.

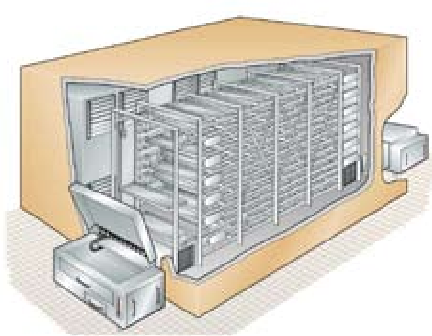
Fruit feeders and variegating devices

A fruit feeder is a device for incorporating solid foods, e.g. fruit, nuts, into the extruded ice cream. The semi frozen ice cream is piped to the fruit feeder and a mechanical device, e.g. an auger, adds a known amount of the food to the ice cream stream. Variegating devices are ripplers or swirlers that incorporate syrup and other liquids into the extruded ice cream.

Hardening

When the ice cream leaves the freezer, it is in a semi solid state and must be further frozen to become solid enough for storage and distribution. During freezing approximately 50% of the water is frozen when the ice cream comes from the freezer at –6°C. To produce and retain a smooth texture in hardened ice cream, it is necessary to rapidly freeze about 80% of the remaining water so that the ice crystals formed will be small. Therefore most hardening rooms are maintained at temperatures of –29°C to –35°C.

Some larger plants use hardening tunnels which discharge the ice cream into a low temperature storage room. Because of the various sized packages which need to be hardened, most tunnels are of the air blast type, operating at temperatures of 35° to 40°C. One or two litre tubs are usually hardened in these blast tunnels in about one hour.



Hardening tunnel (Dairy processing handbook, 2003)

Some plants use contact plate hardening machines. A number of vertical freezing plates are arranged side by side and spaced to the thickness of the ice cream packages. The plates are separated and the packages lowered in between the plates. The contact allows for rapid removal of the heat from the package to produce a smooth textured ice cream.

After hardening, ice cream must be kept at low constant temperatures to maintain its smooth texture. Any increase in temperature may allow the partial thawing of the product. Upon refreezing, ice crystals are likely to become bigger and cause problems with the mouthfeel of the product.

14.1.4 Advanced Technology and Machines Used in Ice-cream Production

Erich Windhab, a food engineering professor at the Federal Institute of Technology in Zurich, has developed a new process which churns and pumps the ice cream out of an extruder at lower temperatures and with smaller ice crystals and smaller air cells than the traditional process allows. After conventional freezing (to –7 °C) and whipping, the ice cream passes through a low temperature twin-screw extruder from which it exits at around –15°C. The ice cream can then be moulded and packaged. There is no need for traditional hardening. Finished products have smaller ice crystals and smaller air cells, retain more of their shape upon melting, and have "creaminess" similar to ice creams with higher fat levels.

" High pressure homogenization technologies are now being utilized in the ice cream industry," says Bruce Tharp, Ph.D., owner of Tharp's Food Technology, Wayne, PA. "Homogenization at four to five times the normal pressure (12,000 rather than the usual 2,500 PSI) can decrease the size, and increase the number of fat globules in the ice cream product, providing better distribution of the available milkfat in a fat-reduced product. " Klahorst, S (1997)

"A process innovation in ice cream aeration is an added step, called 'preaeration,' in which air cells are incorporated into the mix before the freezing step, rather than the conventional method of aerating and freezing simultaneously. By separating the processes into a sequence, a smaller, more stable air-cell structure can be achieved." Klahorst, S (1997)

14. 2 FAQ

14.2.1 Ice Cream Ingredients

1. How does the chemical composition of ice cream affect the quality of final product?

Typical Chemical Composition	Standard Ice Cream	Premium Ice Cream	Super Premium Ice Cream
Milkfat	10 - 11%	12 - 14%	15 - 20%
M.S.N.F.	10 - 11%	7 - 8%	6 - 8%
Sweeteners	14 - 17%	13 - 17%	16 - 17%
Stab/Emuls	0.3%	0.3%	0.2%
Total Solids	35-37%	40-41%	42-44%

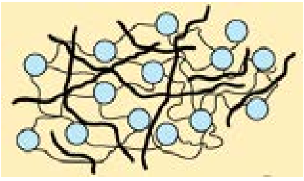
Milkfat provides ice cream with a rich creamy flavour and gives the final product a smooth texture. As the milkfat melts in the mouth, it has a lubricating effect which gives ice cream the smooth mouthfeel. Too little milkfat can result in a final product which lacks a creamy flavour and has a weak body and texture. In low fat products bulking agents and additional stabilisers are used to overcome the lack of milkfat. Too much milkfat in a mix can result in a final product which has a greasy mouthfeel. In high milkfat products, additional sweeteners are added to balance the higher fat content.

Milk solids non fat (MSNF) provide ice cream with a "milky" flavour and give the final product a desirable body and texture. Too little MSNF can result in a final product with a weak, watery texture. Too much MSNF can result in a final product with a condensed milk flavour and a heavy soggy body. Using high levels of MSNF can also result in lactose crystallising giving ice cream an unpleasant gritty, sandy texture.

Sweeteners (such as sucrose, glucose syrup, dextrose, lactose, etc) have the following roles in ice cream:

- provide sweetness, help to balance the fat
- improve body and texture by adding bulk/total solids
- act as flavour enhancers
- control freezing point depression and scoopability

Too little sweetener can result in an unbalanced final product (possibly too greasy) with an incorrect flavour level and a weak, watery texture. Too much sweeteners e.g. glucose syrup with high Dextrose Equivances (DE) can result in a final product with excessive freezing point depression resulting in a soft, sticky ice cream. Too much glucose syrup with a low DE can result in a final product with off flavours (e.g. metallic-like, off flavours). (see section 14.2.1-5)



Hydrocolloids binding up free water

Stabilisers (hydrocolloids) bind up free water, preventing ice crystal growth which results in a smoother ice cream. The water binding effect of stabilisers can affect the ice cream's mix viscosity, texture/body, mouthfeel, melting resistance, tolerance to heat shock and flavour release. Stabilisers are typically added at a rate of 0.2-0.5 % (this rate may vary depending on the product type and equipment used). Too little stabiliser can result in a final product with low tolerance to heat shock, resulting in a coarse icy product. Too much stabiliser can result in a final product with excessive viscosity, giving it an excessively chewing, gummy mouthfeel.

Emulsifiers are used in ice cream to produce desirable characteristics, such as:

- improved whipping properties or ease of incorporating air into the mix;
- a smoother texture and consistency;
- resistance to shrinkage;
- "stand up" or slow meltdown of ice cream;
- increased drying of the surface which reduces dripping of the product.

Emulsifiers are typically added at a rate of 0.1-0.2 % (this rate may vary depending on the product type and equipment used). Too little emulsifier can result in a final product with large air cells, resulting in a fluffy or crumbly product, which melts rapidly. Too much emulsifier can result in a final product with slow meltdown and excessive dryness, giving it a dry non refreshing mouthfeel.

2. *What's the advantage in employing WPC as an ingredient?*

The use of small amounts of whey protein concentrate (WPC) can result in improved ice cream flavour, body, texture, and give better heat shock resistance. As WPC is relatively cheap compared to milk proteins and stabilisers, manufacturers can also make cost savings.

According to Dr. Steven Young, (1999), other advantages of WPC include:

- Increased emulsification and whipability, improving fat distribution and air incorporation, resulting in a well structured ice cream.
- Increased viscosity and water binding, resulting in reduced free water and smaller ice crystals, giving a smoother ice cream.
- Can be used as a bulking agent e.g. replacing milkfat

Excessive WPC can result in lactose crystallisation and or off flavours.

3. *What should be taken into consideration if dried milk is used as an ingredient?*

Dried milk powders are often used in the manufacture of ice cream as they provide a relatively cheap source of milk solids required to give ice cream a milky flavour and the correct body and texture.

Whole milk powders, skim milk powders, buttermilk powders and whey powders can be used in the manufacture of ice cream. Care needs to be taken with whole milk powders as they are relatively high in fat and can easily undergo oxidation during storage giving the final ice cream a stale flat flavour.

Low, medium and high heat skim milk powders can be used in the manufacture of ice cream. A potential advantage of high heat skim milk powders is that the high pre-heat temperatures cause denaturation of whey proteins which tend to absorb more water, resulting in ice cream with better body and texture. A potential disadvantage of high heat skim milk powders is that the ice cream can have cooked flavours. Care needs to be taken with whole milk powders as they are hygroscopic and can oxidise during storage giving the final ice cream a stale flat flavour.

Buttermilk powders (containing lecithin) can improve the whippability of mixes and provide a rich buttery/creamy flavour. Again staleness can develop if not stored correctly.

Whey powders are often used in ice cream as they are a relatively cheap source of milk solids and improve ice cream body and texture due to the presence of denatured whey proteins. A potential disadvantage of whey powders is their relatively high lactose content. Excessive lactose in ice cream can result in lactose crystallising, giving ice cream an unpleasant gritty, sandy texture. Care needs to be taken when selecting milk concentrates and milk and whey powders that they do not contain

Typical Composition	% Water	% Fat	% Protein	% Lactose
Skim milk	91	0	3.6	5.1
SMP	4	0	37	52
Condensed milk	27- 28	0	10- 11	15
Whey powder	4	0	13	73
Ultrafiltered whey powder	4	2- 3	30	53- 56

excessive amounts of lactose.

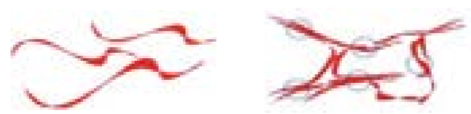
When using dried milk powders and other dry ingredients, care needs to be taken to prevent lumps forming during mixing and blending. Lumps can be avoided by pre-mixing dry ingredients (eg milk powders) with dry sugar, by sifting the dry ingredients, and by the slow addition of dry ingredients to the warm liquid ingredients (30ºC – 50ºC). High shear mixers (e.g. triblenders) and the use of powder funnels can also help to minimize lumping.

4. *What is the function of stabilizers in ice-cream?*

A common defect in ice cream is the presence of large ice crystals, resulting in a coarse icy product. These large ice crystals are often the result of "heat shock" i.e. temperature fluctuations during production, storage and distribution cause some ice crystals to melt then upon refreezing large ice crystals are formed. Each time heat shock occurs, the ice crystals become larger upon refreezing. The addition of stabilisers to an ice cream mix helps to minimise the effects of heat shock.

Stabilisers (hydrocolloids) bind up free water, preventing ice crystal growth which results in a smoother ice cream. The water binding effect of stabilisers can affect the ice cream's mix viscosity, texture/body, mouthfeel, melting resistance, tolerance to heat shock and flavour release (see table below). Commonly used ice cream stabilisers include sodium alginate, locust bean gum (LGB), carboxy methyl cellulose (CMC), carrageenan, guar and xanthan gums. These stabilisers bind water either by gelation, increasing viscosity, hydrogen bonding, and/or creating cross linking between molecules. Guar gum is popular with ice cream manufacturers because of it ability to produce a suitable texture at a lower cost. Locust bean gum is very effective stabiliser, but is also quite expensive. Often stabilisers are used in combination (e.g. locust bean gum and carrageenan). Carrageenan is often used as a secondary stabiliser to reduce or prevent wheying off of mix which can be induced by other stabiliser gums.

Hydrocolloids have the ability to thicken, stabilize or gel aqueous systems.



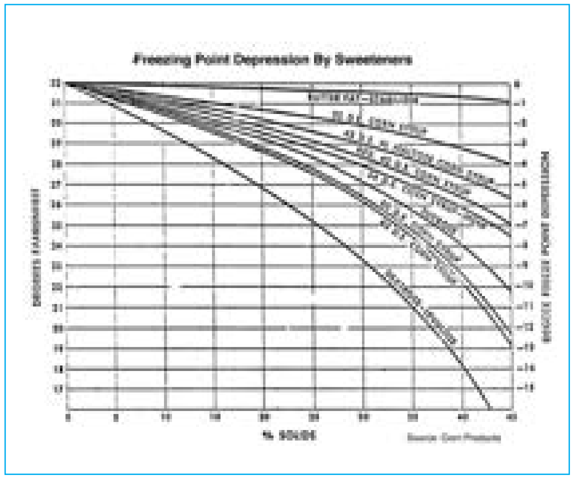
Thickening effect Very few or No interactions — *Gelation Many junctions zones*

Characteristics of commonly used ice cream stabilisers (source Danisco)

Properties	Alginate E401	LBG E410	CMC E466	Carrageenan E407	Guar E412	Xanthan E415
Mix	Medium	Medium	High	Low	High	Medium
Texture/	Short brittle	Medium	Long	Short Brittle	Chewy	Chewy
Mouthfeel	Cold	Warm	Creamy&	Cold	Medium	Medium
Melting resistance	Good	Very good	Fair	Fair	Good	Fair
Heat shock	Fair	Very good	Good	Fair	Bad	Good
Flavour release	Good	Very good	Fair	Good	Bad	Good
Synergy	No	Yes	No	Yes	Yes	Yes

Sugar	Relative Sweetness	Freezing pt Depres-
*Sucrose	1.00	1.0
Glucose (Dextrose)	0.75	1.9
Fructose	1.73	1.9
Invert	1.27	1.9
HFCS (42% Fructose)	1.00	1.8
Glucose syrup (68 DE)	0.72	1.28
Glucose syrup (62 DE)	0.68	1.15
Glucose syrup (52 DE)	0.58	0.99
Glucose syrup (42 DE)	0.48	0.8
Glucose syrup (32 DE)	0.4	0.61
Glucose syrup (25 DE)	0.28	0.48
Glucose syrup (20 DE)	0.23	0.38
Maltose	0.32	1.0
Lactose	0.16	1.0

*Sucrose is used as a reference point and given a value of 1.



5. *How do carbohydrates affect the mouth-feel and texture of final products?*

Typically ice cream will contain the following carbohydrates: lactose (from dairy ingredients), sucrose (main sweetening agent used in ice cream), and glucose syrup (sweetening agent often used in ice cream to improve body).


Ageing tank

Lactose (milk sugar) is not intentionally added, but is a component of dairy ingredients such as milk, milk concentrates, and milk and whey powders which are added to the ice cream mix. Excessive lactose in ice cream can result in lactose crystallisation resulting in an unpleasant gritty, sandy texture. Care needs to be taken when selecting milk concentrates and milk and whey powders that they do not contain excessive amounts of lactose.
Sucrose is primarily added to impart a clean sweet flavour, and also to improve the texture by lowering the freezing point depression of the ice cream.

Glucose syrup can act as a bulking agent giving ice cream a firmer, chewier body and also improve texture by lowering the freezing point depression of the ice cream. Glucose syrup's effect on ice cream body and texture will vary depending on the dextrose equivalents (DE) content. Glucose syrups with a high DE can cause excessive freezing point depression resulting in a soft, sticky ice cream. Glucose syrups with a low DE can cause off flavours (eg metallic flavours) in ice cream, so to avoid this, such sugars should be limited to less than 30 % of the total sweeteners. An advantage of glucose syrups with a low DE is that they can be used as a bulking agent, increasing total solids without causing excessive sweetness.

If the freezing point is not depressed enough, too much water will be converted to ice during freezing resulting in a hard, unscoopable ice cream. If the freezing point is excessively depressed, not enough water will be converted to ice during freezing resulting in a soft, sticky ice cream.

14.2.2 Ice Cream Processing

1. *What is the mechanism of aging and how to control it properly?*

Aging involves rapidly cooling the pasteurised mix and holding it at 2-4 C for 1-4 hours (24 hrs for gelatine). The aging process improves the whippability of the ice cream mix resulting in an improved body and texture.

The changes taking place during aging are not fully understood. The major changes, however, are:

- Fat crystallization
- Hydration of Milk Proteins and Stabilizer, increasing mix viscosity
- Partial coalescence of fat globules

Aging helps to ensure the ice cream develops the correct structure in terms of air cell and fat globule size.

If ice cream mix is not correctly aged, the product is likely to develop body and texture defects during freezing. Uncrystallised fat will not coalesce correctly during churning, resulting in a weak structure. Mix viscosity is important for air incorporation.

14.2.3 Ice Cream Freezing

1. *How to test the overrun of ice cream?*

Overrun is expressed as a percentage and can be calculated from the formula below:

$$\% \text{ Overrun} = \frac{\text{weight of 1 litre of mix - weight of 1 litre of ice cream}}{\text{weight of 1 litre of ice cream}} \times 100$$

This formula uses weight per litre, but it is equally correct to use the weight of any other known volume, so long as the same measure is used throughout the calculations. It is also possible to base overrun calculations on volume.

$$\% \text{ Overrun} = \frac{\text{volume of ice cream made - volume of ice cream mix}}{\text{volume of ice cream mix}} \times 100$$

Example

In a standard ice cream made without any fruit additions, the weight of 1 litre of ice cream mix is 1.1kg. One litre of ice cream extruded from the freezers weighed 0.5kg. (using the weight overrun formula)

$$\% \text{ Overrun} = \frac{1.1\text{kg} - 0.5\text{kg}}{0.5\text{kg}} \times 100$$

$$= \frac{0.6\text{kg}}{0.5\text{kg}} \times 100$$

$$\% \text{ Overrun} = 120\%$$

Tables are usually available so that overrun can be calculated by simply weighing a known amount of product. It is important to determine the density of the mix, for each type of mix, and use the appropriate table for each product. It is also important to consider the effect on overrun of fruit additions as these add weight without air being incorporated, and so the product appears to have a lower overrun than it actually has.

The amount of air that can be incorporated into a mix is limited by several factors. An overrun that is too high results in an ice cream which becomes fluffy and weak bodied. If insufficient air is included, the ice cream will have a soggy, heavy body. The maximum overrun that can be obtained will be limited by the machine capacity, the ingredients used in the mix formulation and the processing steps used during manufacture.


Tetra Pak Hoyer KF N model

The air used should be good quality and may need to be filtered. The supply pressure should be uniform for the air to be evenly incorporated into the mix. Although research workers have investigated the use of other gases such as nitrogen and carbon dioxide, air is still the most common.

2. *What factors affect the overrun of ice-cream and how to control it properly?*

Overrun refers to the amount of air incorporated into the ice cream mix during freezing. Standard ice creams generally have 100% overrun (or more) i.e. the finished product contains 50 % mix and 50% air. Premium ice creams have lower overrun levels of 30% to 60% to give a heavier body and richer flavour.

During freezing, ice crystals are formed and fat globules coalesce causing air (overrun) to be incorporated into the ice cream mix. Initially the air cells are quite large but are then reduced in size as freezing progresses. In batch freezers air is incorporated by the folding/whipping action of the dashers. Each batch freezer is designed to give a particular overrun (generally low 30 -60 %), the operator is not able to adjust the overrun on a batch freezer. Continuous freezers can be easily adjusted to give a desired overrun (20 - 100 % or more). In continuous freezers air is injected as small bubbles under pressure, overrun can be controlled by adding more or less air, by controlling the mix pump speed and or by controlling the back pressure. Overrun control will vary according to the freezer design, in the Tetra Pak Hoyer KF N models, air incorporation is controlled manually by regulating air inlet pressure from a constant cylinder pressure maintained by the outlet pump. In other freezers overrun control is completely automated by the use of PLC s. Manufacturers need to consult with equipment designers to determine optimal overrun control.

14.2.4 Ice Cream Storage and Distribution

1. *What is Heat Shock?*

Temperature fluctuations and repeated thaw and refreeze cycles often occur during ice cream storage and distribution. As temperatures increase some ice crystals melt then when refreezing occurs, free water is deposited on existing ice crystal nuclei resulting in larger ice crystals. Repeated exposure to such temperature fluctuations during storage/distribution can lead to heat shock. Heat shock refers to the deterioration in product quality as a result of repeated thaw and refreeze cycles that occur during product storage and distribution. A heat shock product will tend to have a coarse icy texture due to the presence of large ice crystals. Products that have undergone severe heat shock may also show signs of shrinkage due to the collapse of air cells in the ice cream.

The addition of stabilisers helps to minimise the effects of heat shock by controlling the movement of free water.

2. *Why does ice cream develop off flavours during storage ?*

Oxidised flavours: Ice cream can develop oxidised flavours during storage if its packaging does not protect it from UV light exposure. Ice cream is constantly exposed to the UV lights in distribution warehouses and in retail cabinets. Oxidation of milkfat results in unpleasant cardboardy, fishy or metallic flavours. Methods for reducing oxidation off-flavours include: using opaque packaging, incorporating antioxidants and UV-light blockers into packaging films, and minimizing exposure to UV light and metals such as copper and iron.

Absorbed flavours: Ice cream can absorb volatile flavours from the environment. Products held in a stale storage room may absorb these stale flavours. Incorrectly stored ice cream has absorbed off flavours such as paint, detergent, onion and other volatile flavours, that were present in the storage area.

3. *What is the shelf life of ice cream?*

The shelf life of ice cream can be up to 1-2 years if stored under ideal conditions. Ice cream needs to be stored in a clean environment otherwise it may absorb volatile flavours (see above) and needs to be stored at a consistent temperature < - 18°C. Excessive temperature fluctuations and repeated thaw and refreeze cycles will reduce the shelf life due to the development of icyness and possibly shrinkage (see above).

14.2.5 Ice Cream General

1. *What are typical defects in Ice Cream Products?*

Texture

There are four major defects which affect texture.

- *Coarse or icy*

  This is caused by the presence of large ice crystals in the ice cream. Common causes of this may be too much water in the mix, slow freezing, insufficient freezing and heat shock which is caused by fluctuating storage temperatures resulting in melting and refreezing of the ice cream.

- *Snowy or flaky*

  With this defect, too much air is present making the ice cream light. The total solids level may be too low or the ice cream may have been withdrawn from the freezer before the correct temperature is reached.

- *Sandiness*
  This is caused by the presence of very hard crystals of lactose which are the result of too much MSNF in the mix. Heat shock, incorrect stabiliser and the use of too much whey powder may also give rise to this defect.
- *Buttery*
  This term refers to the presence of hard particles of fat. Poor homogenisation of the mix, lack of emulsifier and prolonged agitation during freezing may cause the problem. Very low overrun with high fat (~15%) may also cause this particular defect.

Body

In ice cream, the term body is used to describe the general appearance and the mouthfeel or chewiness of the products.

- *Heavy/soggy* is the term used to describe a heavy, wet, colder than usual ice cream. The defect is caused by not enough air in the product.
- *Light and fluffy* is the reverse of the previous defect and is caused by too much air in the product.
- *Gummy* is used to describe a product which will not melt easily in the mouth. The lack of melt is usually caused by the addition of too much stabiliser to the mix.
- *Crumbly* is used to describe any ice cream which breaks into pieces instead of holding together. Possible causes are too little stabiliser, too little sugar, too low total solids or the incorporation of too much air.
- *Weak and watery* ice cream melts quickly. This defect is caused by insufficient total solids and insufficient freezing in the ice cream freezer.
- *Meltdown* When ice cream melts, it should produce a creamy homogeneous liquid similar to the mix it was made from. Sometimes the air may not come uniformly away causing the mix to foam. This is caused by the use of too little stabiliser and the air being incorporated as large air cells. When a clear greenish liquid is observed, an interaction between some stabilisers and the milk proteins has occurred causing precipitation and a curds and whey effect similar to that which occurs during cheesemaking.
- *Shrinkage* is a defect specific to ice cream and occurs when the ice cream loses volume and shape during storage. To minimise this problem, the correct levels of total solids should be used in the mix, rigid packaging should be used as far as possible, and heat shock and mechanical shock should be avoided during storage and handling.

2. *Troubleshooting common ice cream processing problems*

Overrun control problem: ice cream may have a lower than required overrun because of

- High mix viscosity, which makes it difficult to incorporate air in a mix
- Poor homogenisation which affects the fat globule size, reducing the milkfats ability to correctly coalesce to form air cells
- Incorrect air supply e.g. blocked air inlet valves or incorrect pressure
- Blunt freezer blades which reduce the efficiency of whipping
- Over churning ice cream which can force air out of the product

Ice cream structure problem: ice cream may be too soft coming from the freezer because

- The temperature of the aged mix entering the ice cream churn is too high
- The speed of the pumps feeding the ice cream churn is too fast
- The ice cream churn blades are blunt, resulting in inefficient freezing
- The ice cream mix has not been correctly formulated, e.g. incorrect sugar balance affecting the freezing point depression or not enough stabiliser and emulsifier added to provide the correct structure and dryness

Ice cream buttering - off problem: small globules of butter can form in the ice cream churn if

- The temperature of the aged mix entering the ice cream churn is too high and excessive churning is required for freezing
- The ice cream mix has not been correctly formulated for the equipment being used, e.g. a high fat mix in a churn with a long residence time
- Poor homogenisation which affects the fat globule size, reducing the milkfats ability to correctly coalesce
- The ice cream churn blades are blunt and excessive churning is required for freezing
- Ice cream churn drawing temperatures are too low

Ice cream cooked flavour problem: the final product may have this off flavour because

- Poor quality raw materials are being used, e.g. using milk powders which have been excessively heat treated
- Excessive heat treatment has been used during processing e.g. during mixing or pasteurisation

Ice cream icy texture problem: the final product may have this body defect (large ice crystals) because

- The ice cream mix has not been correctly formulated, e.g. low total solids, not enough stabiliser
- The ice cream mix has been slowly frozen
- The ice cream has been heat shocked

3. *Ice cream trends*

Co-branding

A continuing trend in the ice cream industry is co-branding. Co-branding involves partnering ice cream with successful branded products for increased product awareness. Brands include well-known candy (e.g. Cadbury, Mars), well-known biscuits, alcohol, fruit and flavoring manufacturers.

Indulgence

In many western countries there is a trend towards indulgent premium and superpremium quality ice creams products. These products contain premium ingredients, are richer (contain more milkfat), have a low overrun, come in rich flavours and contain rich syrups and inclusions such as biscuits/cookies, candy and cake.

Functional foods

"Functional Foods" are foods or dietary components that may provide a health benefit beyond basic nutrition. Some manufacturers and researchers are adding ingredients such as extra calcium, omega-3 fatty acids or probiotic bacteria to make ice cream a "functional food".

Flavours

The most popular flavours in many western countries are vanilla, chocolate, strawberry, neapolitan and nut/caramel flavours. However, ice cream flavors are only limited by the imagination. Manufacturers are constantly developing new and exciting flavours, such as tiramisu, baklava, guava, gingerbread, crème de menthe, kaluha, green tea, apple pie, cheesecake, etc.

Healthier ice cream

In many western countries there is a trend towards healthier ice creams such as low-fat, reduced-fat, fat-free, low-carbohydrate, "no sugar added," added calcium or other nutrients, or lactose-free ice cream.

Natural ingredients

There is a growing trend for "natural" foods including "natural ice cream". Although there are no clear legal definitions, generally ingredients must be derived from a plant or animal source (not created in a laboratory) to be called natural. Modifying agents such as lecithin, gelatine, locust bean gum, guar gum, alginates and pectin are regarded as "natural". Colours such as Turmeric, Beta-carotene, Annatto and carmine dye are regarded as "natural".

New stabilisers

New stabilisers are continuely being developed, and some recent examples include PrimaCel™, a cellulose-based thickener and stabilizer, and N-SURANCE™, a new type of ice cream stabilizer consisting of a blend of food starch and maltodextrin. Recently "antifreeze proteins", also called "ice structuring proteins" (ISP), have been discovered in arctic fish and winter wheat. These proteins function by inhibiting ice crystallization and minimizing ice crystal growth. Research has shown that the addition of ISP to ice cream results a product with less ice crystal growth during heat shock as compared to ice crystal growth in a control product (no added ISP).

Glossary

Ageing

Process of cooling the pasteurised mix to 0-5° C to allow fats to crystallize and proteins and stabilisers to fully hydrate.

Bulking agent

Bulking agents are additives used to increase the bulk of a food, often without affecting its nutritional value.

Emulsifier

is a substance which stabilizes an emulsion (such as oil and water in ice cream).

Food acids

Acids such as lactic acid and citric acid are sometimes added to ice cream to give a "sharper" flavour.

Freezing point

The temperature at which the ice cream mix begins to freeze; standard ice cream generally freezes at – 2.8°C to -2.2°C.

Freezing point depression

The ability of a sugar to lower the freezing point of an ice cream mix; the lower the molecular weight, the greater the ability of a molecule to depress the freezing point for any given concentration.

Hardening

Process of cooling ice cream mix to -30° C to -40° C to allow some 80 % of the water to freeze.

Heat shock

refers to the deterioration in product quality as a result of repeated thaw and refreeze cycles that occur during product storage and distribution.

Overrun

is a measure of how much air is in ice cream.

$$\frac{\text{volume of ice cream - volume of mix}}{\text{volume of mix}} \times 100 = \text{percent overrun}$$

Milk solids not fat (MSNF)

consist of milk proteins, lactose and minerals.

Stabilisers

are thickeners and gelling agents which bind up free water in ice cream resulting in an improved smoother texture (avoid large ice crystals).

References

Marshall, W.S. and Arbuckle T 1996 Ice cream 5 th edition. Published New York : Chapman & Hall.

Dr. Steven Young, (1999) Whey Products In Ice Cream And Frozen Desserts, By SYW, Dairy & Food Technology Development, Sugarland, Texas, USA Published by U.S. Dairy Export Council

Dairy processing handbook 2003. Author Danish Dairy Board Published Denmark : International Dairy Books, 2003.

Klahorst, S 1997. (Contributing Editor Food Product Design) Ice Cream: Combination Chemistry. http://www.foodproductdesign.com/archive/1997/0897AP.html

Grindsted of Denmark, Grindsted products A/S, Technical papers

Keeney, Philip G., Commercial Ice cream and other frozen desserts/prepared by Philip G. Keeney. Pennsylvania : Pennsylvania State University. 50p.

Rothwell, J. Ice cream making: a practical booklet by J. Rothwell, Reading (U.K.) : 1985 - 102p.

DAIRY AUSTRALIA

Delivering for the dairy industry

Australian Dairy Ingredient

REFERENCE MANUAL

■ SECOND EDIITION ■ AUGUST 2008