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Dairy Australia
National Centre for Dairy Education
Your Levy at Work

Buttermilk: the valuable, yet overlooked food ingredient

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National Centre for Dairy Education webinar

October 18, 2017

Mission San Luis Obispo de Tolosa
(St. Louis, the Bishop of Toulouse)

City of San Luis Obispo
Population 47,000
First settled by Chumash nation
Spanish mission settlers in 1772

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Factors that affect milk composition

- Age of cow
- Breed of cow
- Stage of lactation
- Bacteriological state of milk
- Seasonality
- Diet of cow
- Milking frequency
- Processing effects: homogenization, storage temperature

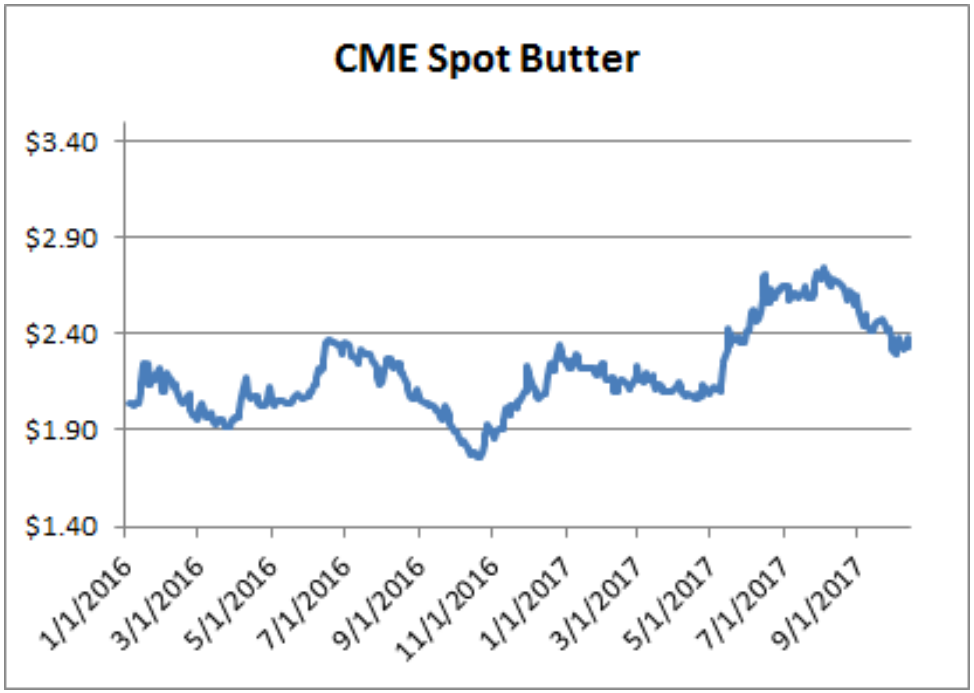
What is buttermilk?

- High in lactose
- About ~1% fat, of which $^1/_5$ are phospholipids
- Secondary product with low value (due to microbial counts)
- Good emulsifier (primarily due to casein contamination)
- May improve the flavour of low fat cheese
- Key ingredient: the milk fat globule membrane (MFGM)

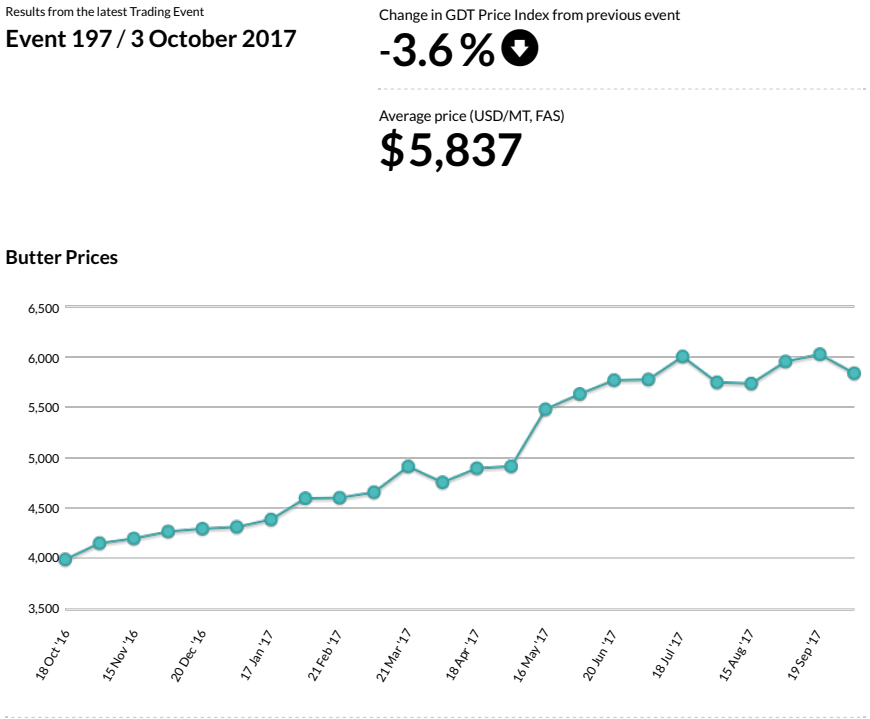
TABLE 17.1 Approximate Composition (% w/w) of Some Types of Powder

	Powder from			
Constituent	Whole milk	Skim milk	Whey	Sweet cream buttermilk
Fat	26	1	1	5
Lactose	38	51	72	48
Casein	19.5	27	0.6	26
Serum protein	4.8	6.6	8.5	6.2
"Ash"	6.3	8.5	8	8
Lactic acid	—	—	0.2–2	—
Water	2.5	3	3	3

Market price of butter



US market price per lb



Global Dairy Auction

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All prices in USD

Buttermilk powder market price

Results from the latest Trading Event

Event 197 / 3 October 2017

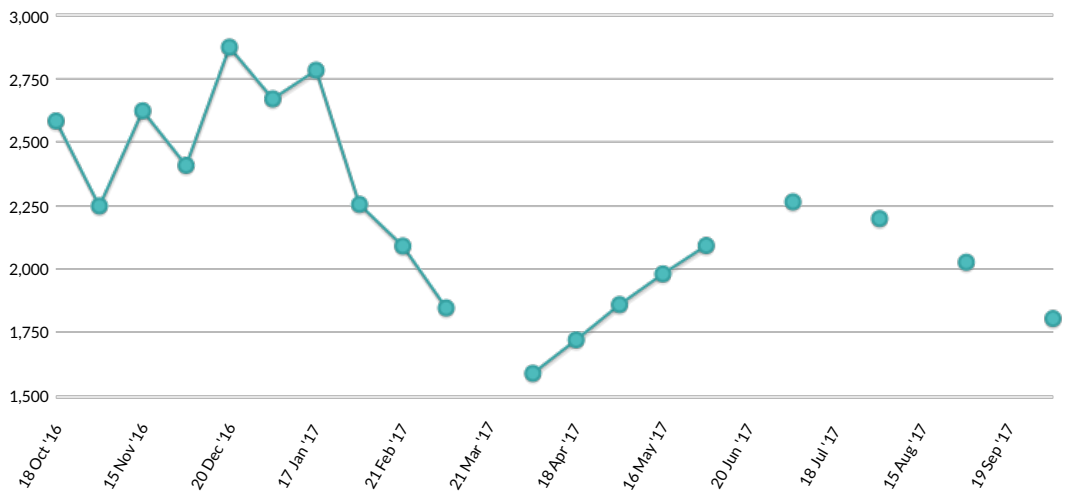
Change in GDT Price Index from previous event

-10.3%

Average price (USD/MT, FAS)

$1,804

Butter Milk Powder Prices



Global Dairy Auction prices

Product usage:

Bakery products

Frozen desserts

Prepared dry mixes

Beverages

Frozen foods

Dairy products

Salad dressings

Snack foods

Cheese products

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All prices in USD

U.S. regulations

- Dry buttermilk (DBM) is light cream in colour with a clean, pleasing, sweet dairy taste.
- Typically, dry buttermilk is obtained by drying liquid buttermilk that was derived from the churning of butter and pasteurized prior to condensing.
- DBM has a protein content not less than 30% (dry buttermilk product can be <30%)
- It may not contain, or be derived from, non-fat dry milk, dry whey or products other than buttermilk and contains no added preservative, neutralising agent or other chemical.
- By removing moisture to the greatest extent possible, microbial growth is prevented.
- Product should be stored and shipped in a cool, dry environment with temperatures below 27ºC and relative humidity below 65%.
- Stocks should be rotated and utilized within 8-9 months.
- Applications include bakery products, frozen desserts, dry mixes, beverages, dairy products, frozen foods, salad dressings and snack foods.

U.S. extra grade dry buttermilk (DBM)

American Dairy Products Institute

Classifications	Fat	Moisture	Protein	Titratable Acidity	Solubility Index	Scorched Particles
Spray Dried Extra Grade DBM	Min 4.5%	Max 4.0%	Min 30.0%	Min 0.10% Max 0.18%	Max 1.25 mL	Max 15.0 mg Disc B
Atmospheric Roller Dried Extra Grade DBM	Min 4.5%	Max 4.0%	Min 30.0%	Min 0.1% Max 0.18%	Max 15.0 mL	Max 22.5 mg Disc C

Standard Plate Count 75,000 cfu/g; Coliforms ≤ 10 cfu/g

Salmonella	negative
Listeria	negative
Coagulase positive Staphylococci	<10 cfu/g
Yeast & Mold	≤ 100 cfu/g

U.S. standard grade dry buttermilk (DBM)

American Dairy Products Institute

Classifications	Fat	Moisture	Protein	Titratable Acidity	Solubility Index	Scorched Particles
Spray Dried Standard Grade DBM	Min 4.5%	Max 5.0%	Min 30.0%	Min 0.10% Max 0.20%	Max 2.0 mL	Max 22.5 mg Disc C
Atmospheric Roller Dried Standard Grade DBM	Min 4.5%	Max 5.0%	Min 30.0%	Min 0.1% Max 0.20%	Max 15.0 mL	Max 32.5 mg Disc D

Standard Plate Count 75,000 cfu/g; Coliforms ≤ 10 cfu/g

Salmonella	negative
Listeria	negative
Coagulase positive Staphylococci	<10 cfu/g
Yeast & Mold	≤ 100 cfu/g

Butter and buttermilk manufacture

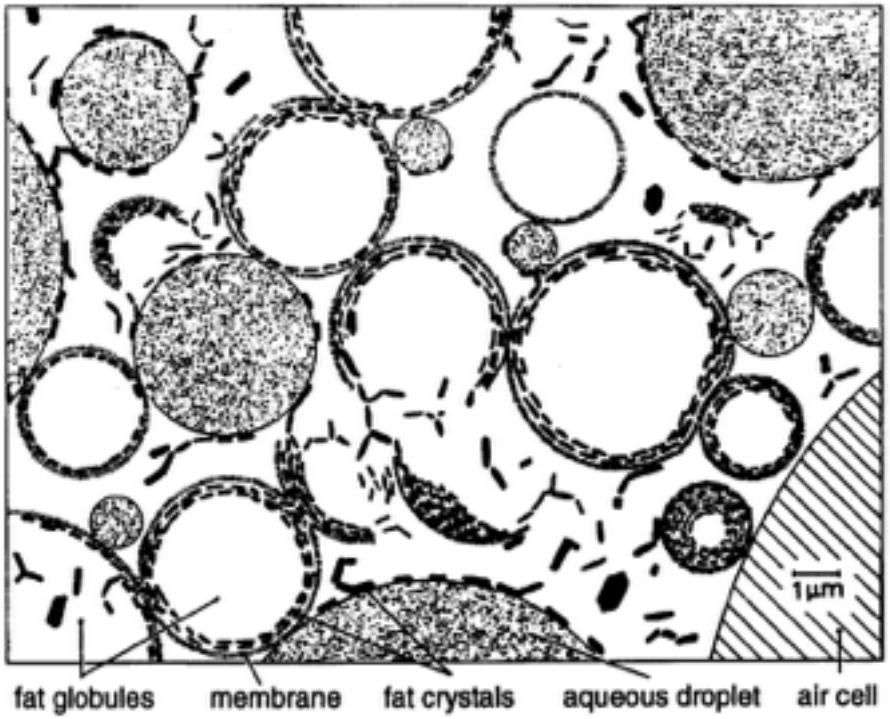


Figure 19.11 Butter microstructure at room temperature. Liquid fat is white. Membrane thickness is much (about 10 times) exaggerated. After H. Mulder and P. Walstra, *The Milk Fat Globule* (Wageningen: Pudoc, 1974).

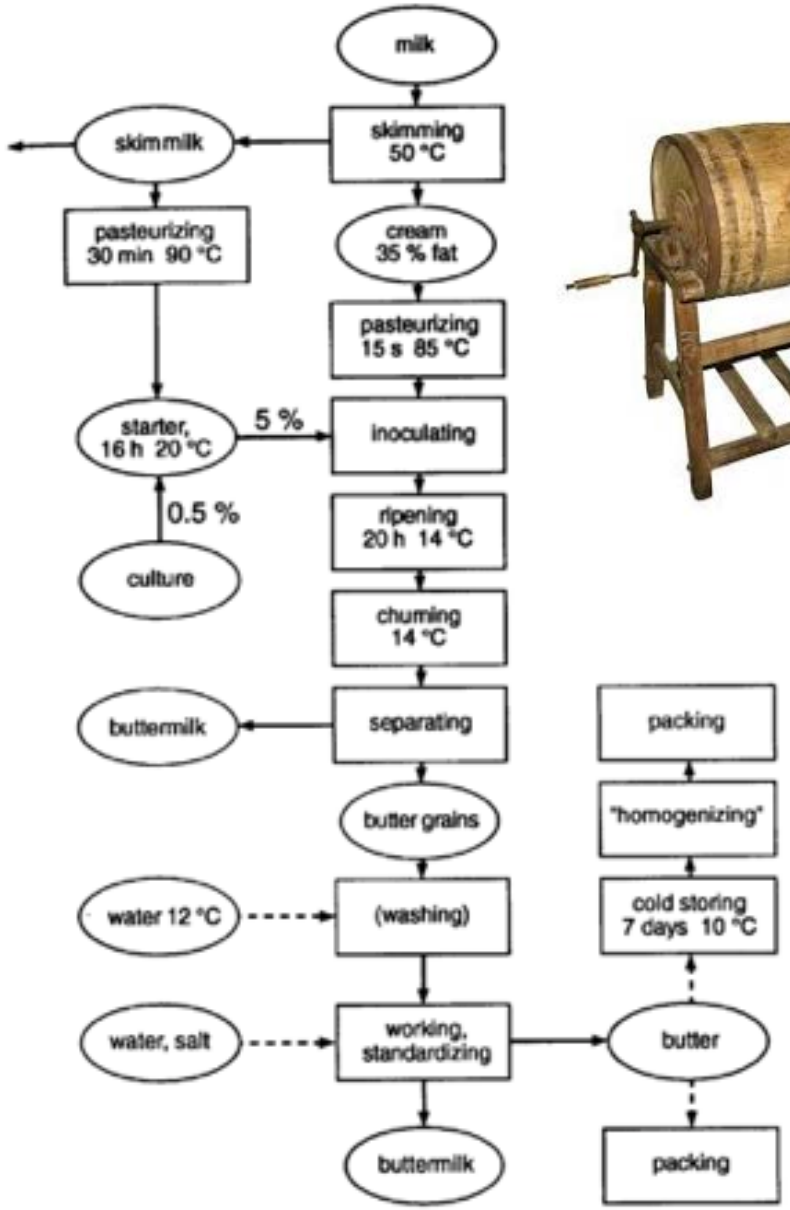


Figure 19.1 Example of butter making from ripened cream.

Butter and buttermilk manufacture

Commercial cream separation

Buttermilk powder available on a large scale, is inexpensive, but has functional problems

Microfiltration of skimmed buttermilk can be employed to reduce microbial counts

Cream churning

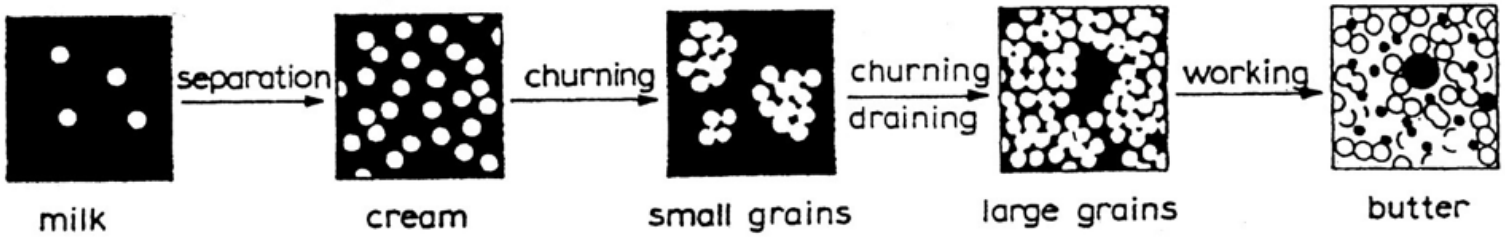
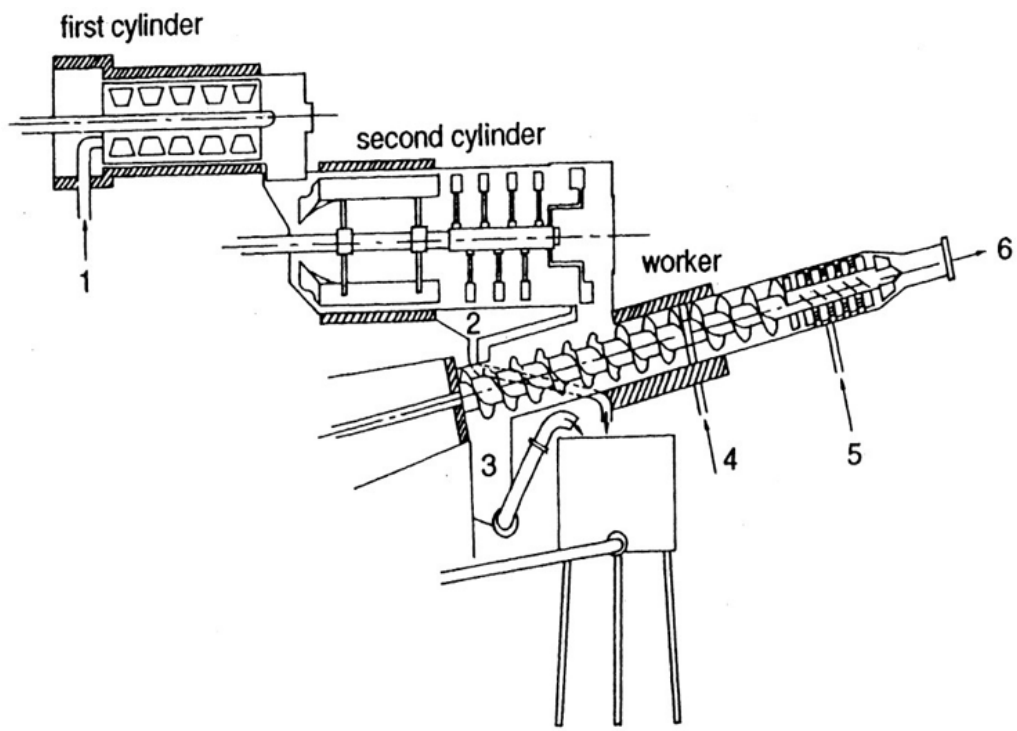
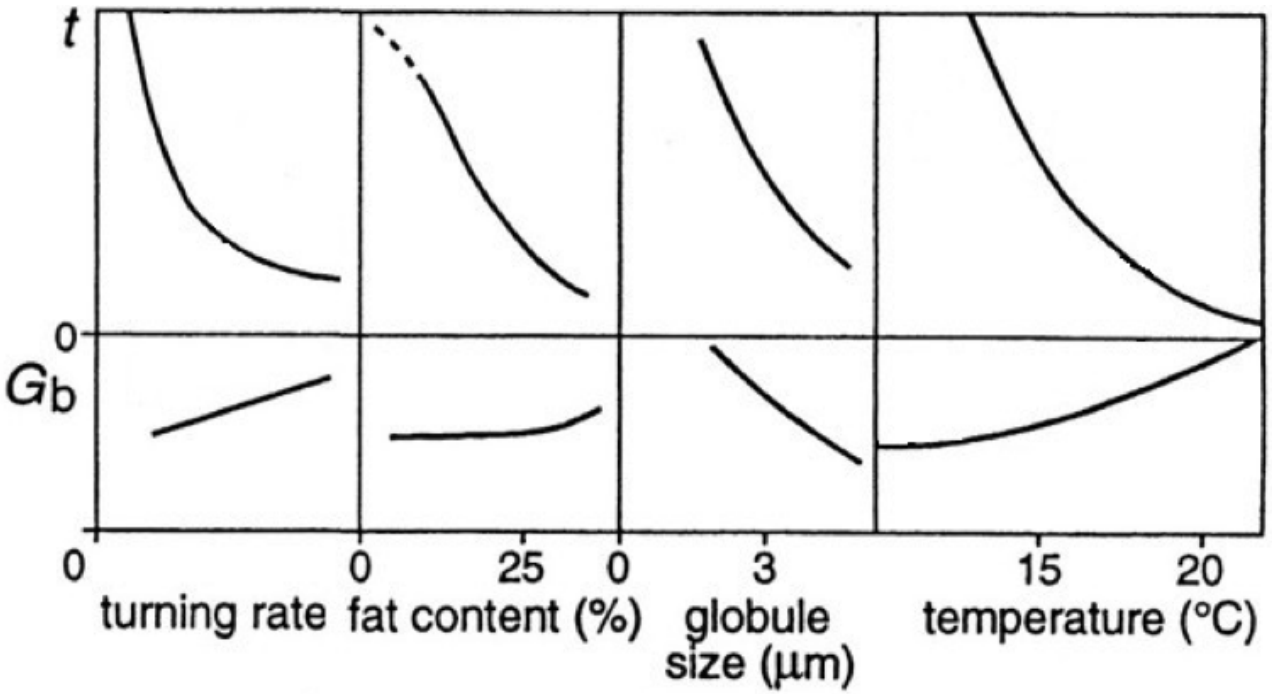
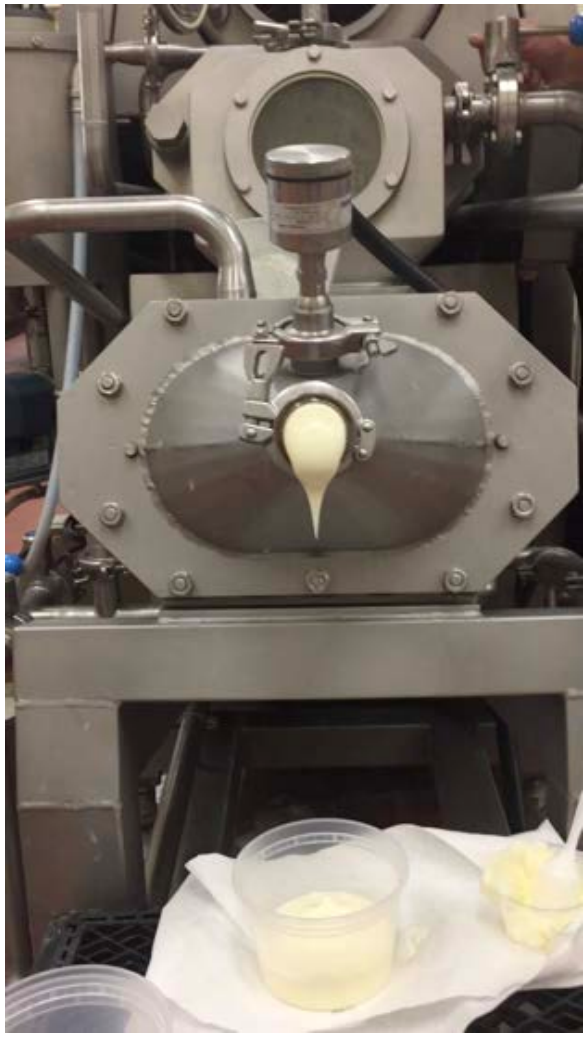


FIGURE 19.2 Stages in the formation of butter. Greatly simplified, not to scale. Black is the aqueous phase; white is fat. From H. Mulder and P. Walstra, *The Milk Fat Globule* (Wageningen: Pudoc, 1974).



Cream churning





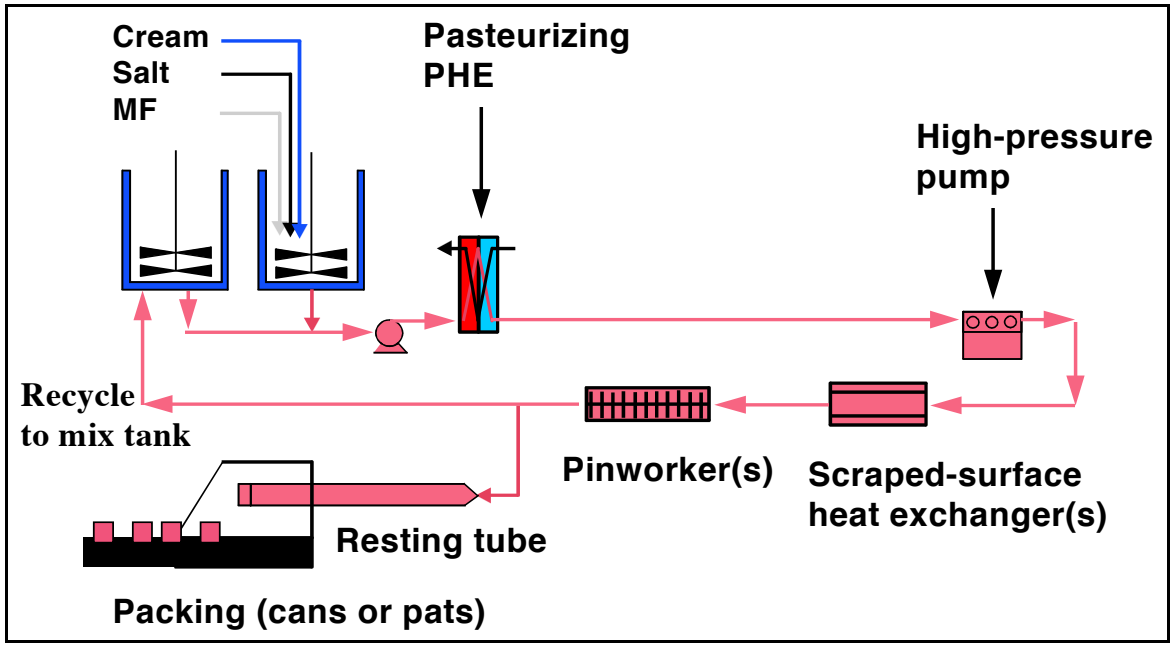
t = turning time to produce butter from cream
Gb = efficiency of churning (% fat in buttermilk)

Walstra, P., T. J. Geurts, A. Noomen, A. Jelema, and M. A. J. S. van Boekel. 1999. Dairy Technology: Principles of Milk Properties and Processes. Marcel Dekker, Inc., New York.

Fritz butter churning process

Developed from the traditional batch churning process of crystallised cream

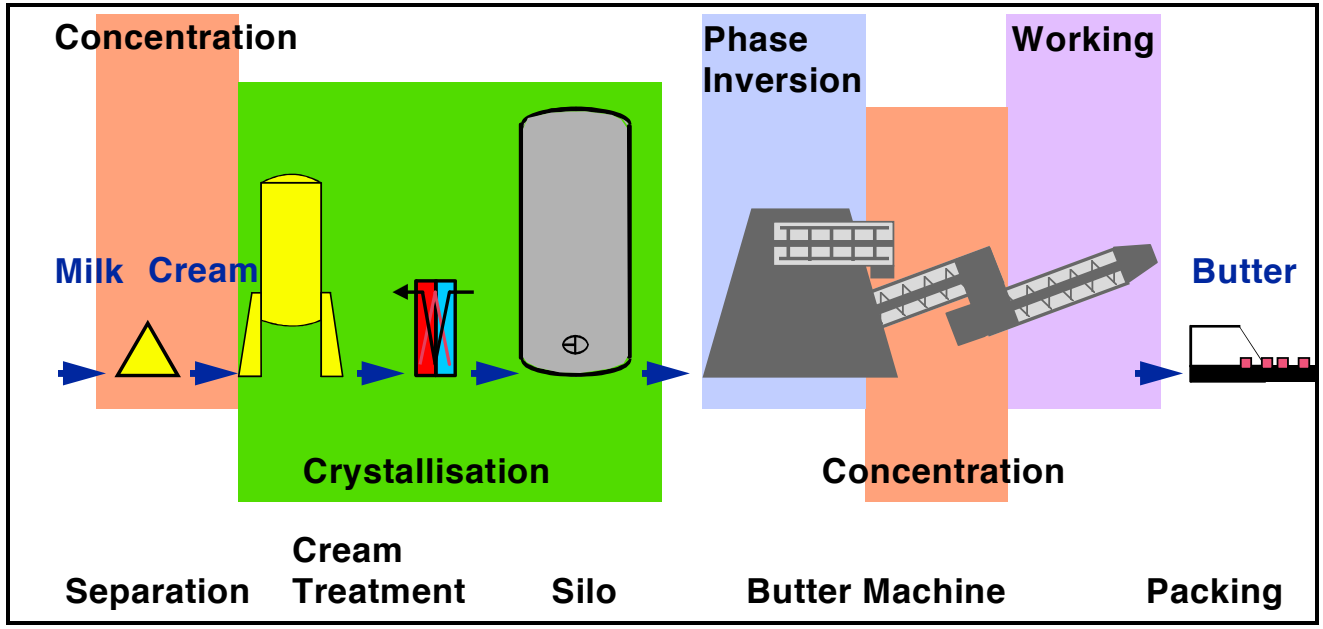
About half of New Zealand butter manufacturing uses the Fritz process



Concentration of the milk to cream (40% fat)
Crystallisation of the fat in the cream
Phase inversion of the cream (and further concentration by buttermilk draining)
Working of butter to achieve fine moisture dispersion

Ammix butter churning process

Fresh milk fat is mixed with cream and salt and shock cooled to give rapid crystallisation



Concentration of the milk to cream (75% fat)
Phase inversion of the cream (and further concentration to fresh milkfat)
Crystallisation of fat in milkfat/serum mixture
Working of butter to achieve fine moisture dispersion

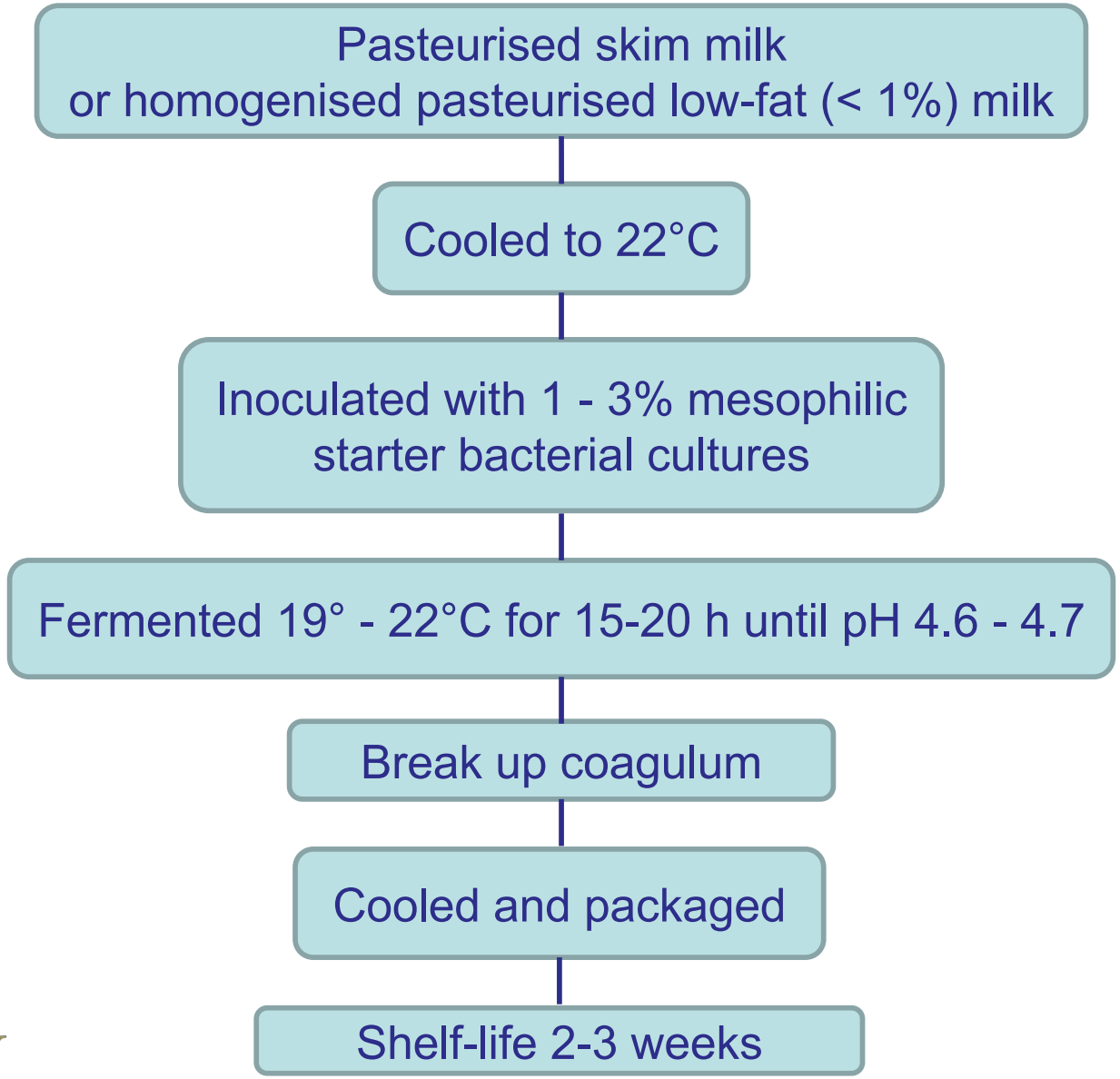
Types of liquid buttermilk

- Produced from the churning and separation of butter or cultured butter
- Mostly a consumer drinking product in Europe, and an ingredient in the United States
- Cultured buttermilk containing *L. lactis* ssp. *lactis* and spp. *cremoris* (ingredient and digestive aid); also can *use Lb. delbrueckii* ssp. *bulgaricus*
- *L. lactis* ssp. *lactis* biovar *diacetylactic* or *Lc. mesenteroides* ssp. *cremoris* sometimes used to impart a more buttery flavour from the chemical compound, diacetyl
- Buttermilk (cultured or otherwise) now more commonly made from skim milk with < 1% fat; *traditional buttermilk* is made from churning cream
- Acidity in cultured buttermilk due to lactic acid (transformed from lactose in the milk)
- Slight curdling of casein proteins makes this thicker than skim milk
- Sensitive to oxidation – metallic off-flavour

*

* Bulgarian buttermilk is thicker and more acidic, incubated 38° - 42°C for 10-12 h (popular only in Bulgaria!)

Manufacture of cultured buttermilk



Composition of buttermilk (g /100g)

Component	Conventional	Cultured
Total solids	9.5 – 10.6	9.0 – 10.6
Fat	0.3 – 0.7	0.1 – 1.0
Phospholipids	0.07 – 0.18	~0.02
Protein	3.3 – 3.9	3.1 – 3.5
Lactose	3.6 – 4.3	3.6 – 4.3
Lactic acid	0.55 – 0.9	0.55 – 0.9

Conventional: made from buttermilk
Cultured: made from skim milk

Other types of liquid buttermilk

- Dhallë, a type of buttermilk from Albania
- Chaas, a buttermilk drink native to the Rajasthan region
- Clabber, a Southern United States soured milk drink
- Doogh, a yogurt drink from Iran
- Filmjölk (Swedish)/Kulturmelk (Norwegian), a type of buttermilk from Scandinavia
- Ghol, an Indian buttermilk drink
- Kefir, a fermented milk drink from the Caucasus
- Lassi, a yogurt drink native to the Punjab region
- Mala or Maziwa lala, a type of buttermilk in Kenya
- Mattha, an Indian buttermilk drink
- Mor Kuzhambu, a buttermilk and curry dish native to the Tamil Nadu region
- Pomazánkové máslo, from the Czech Republic
- Žinčica, sheep milk whey from Slovakia

Consider the probiotic effect of drinking fermented dairy products

https://en.wikipedia.org/wiki/Buttermilk

Buttermilk powder isolation

Washing of cream

Wash with water, simulated milk ultrafiltrate, dissociating agents, or surfactants

↓

Churn cream into butter ← Butter

Cool temperatures ~15°C

↓

Buttermilk

↓

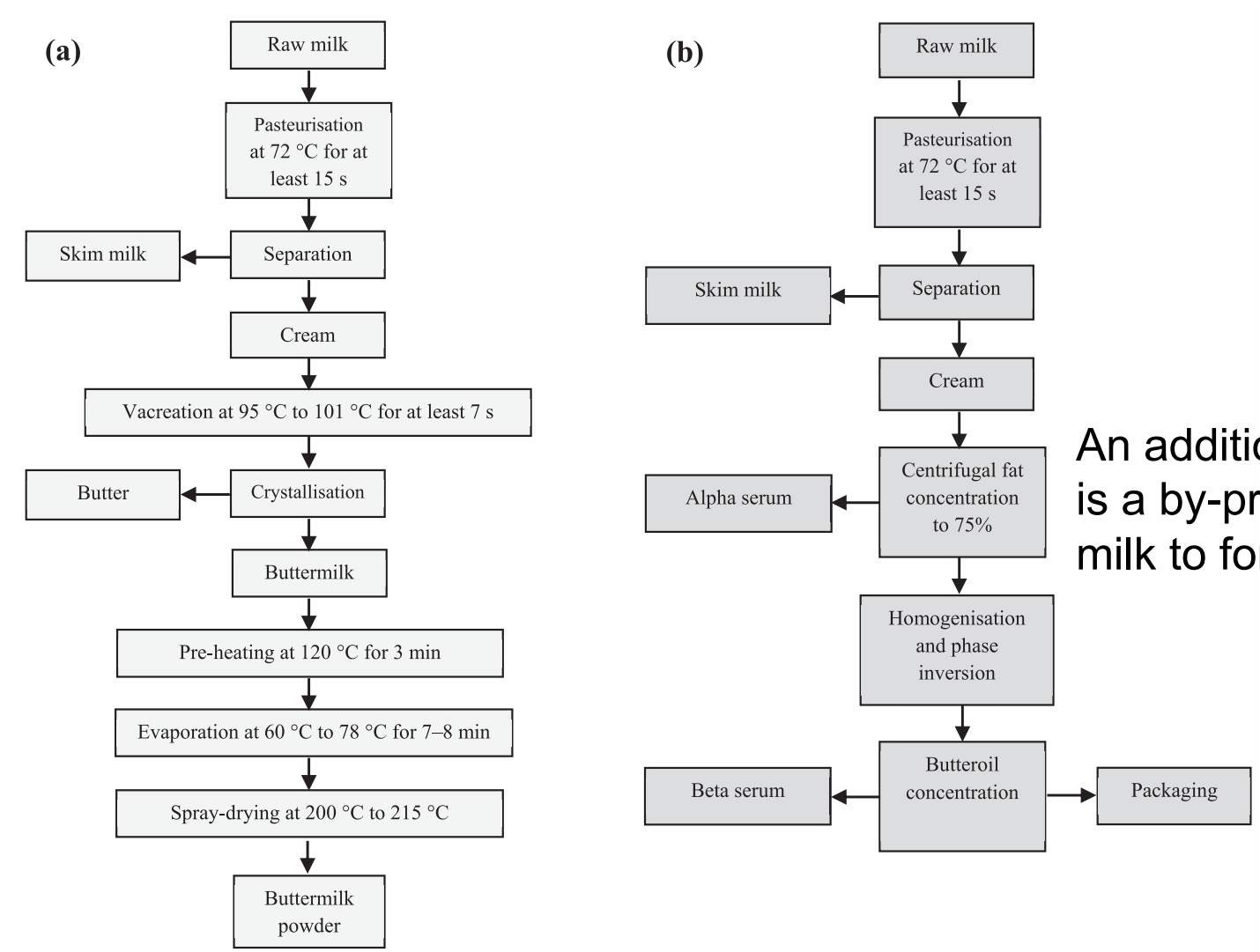
Lyophilisation or heat drying

- Removal of caseins by dissociation with citrate
- Rennet to remove casein aggregates
- Aggregation of MFGM fragments at low pH
- Ultracentrifugation, dialysis, microfiltration
- Super-critical fluid extraction of non-polar lipids

U.S. buttermilk powder prices US$2000 - $2200 per ton, October 13, 2017

Cold-drying retains functionality of labile components

Buttermilk and serum



An additional stream, α-serum, is a by-product of concentrating milk to form cream

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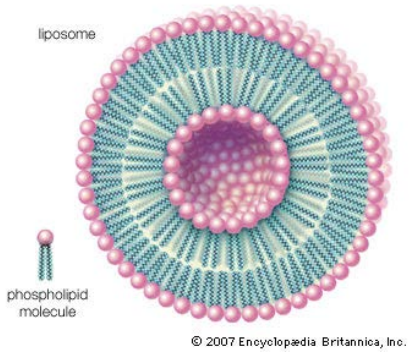
Haddadian, Z., Eyres, G. T., Carne, A., Everett, D. W., & Bremer, P. (2017). Impact of different milk fat globule membrane preparations on composition, xanthine oxidase activity, and redox potential. *International Dairy Journal*, 64, 14-21.

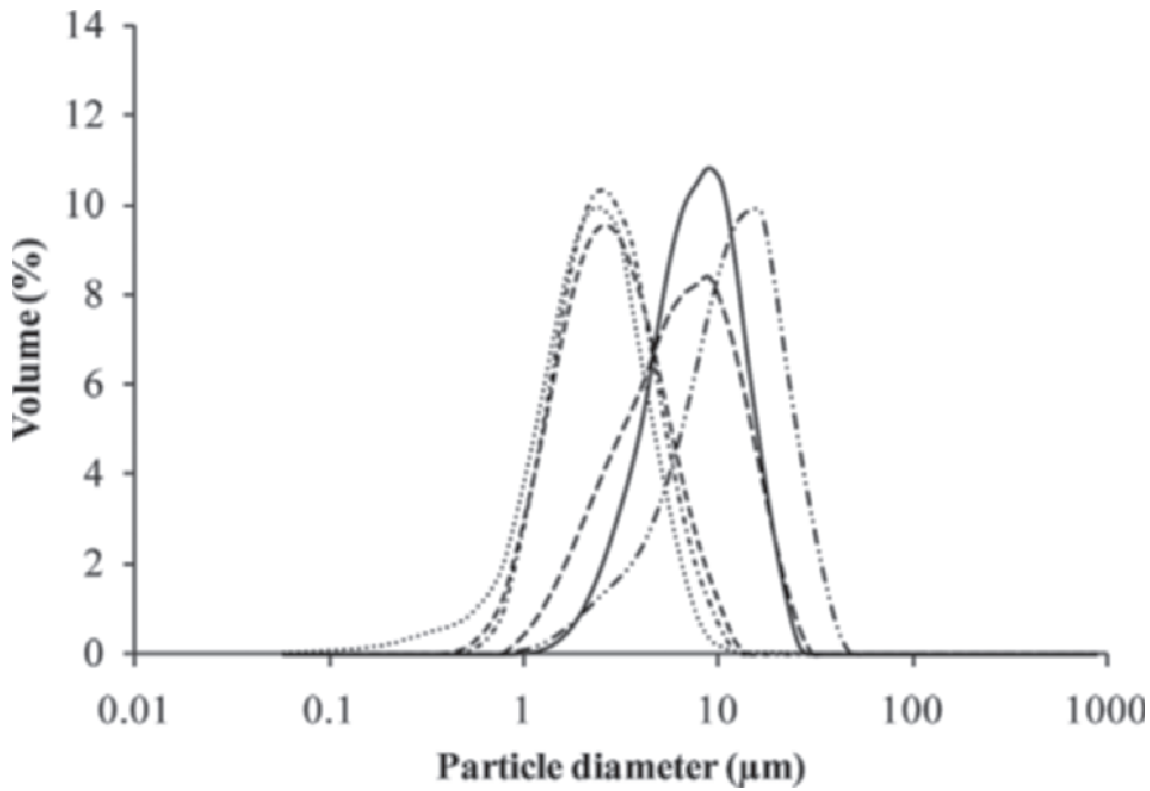
Buttermilk functionality

- Comprises most of the milk fat globule membrane (MFGM) layer that protects fat globules in milk
- Biologically relevant membrane with multitude of components
- Functional flavour and texture properties
  - Emulsification
  - Liposomes as carriers and flavour masking agents
  - Impact of isolation procedure
  - Improves heat-stability of recombined evaporated milk[1]
  - Improves whipping properties of recombined cream[2]
  - Increases water-holding capacity and firmness of yoghurt[3]



[1] Kasinos, M., Tran Le, T., & Van der Meeren, P. (2014). *Food Hydrocolloids*, 34, 112-118.
[2] Phan, T. T. Q., Moens, K., Le, T. T., Van der Meeren, P., & Dewettinck, K. (2014). *International Dairy Journal*, 39, 16-23.
[3] Le, T. T., van Camp, J., Pascual, P. A. L., Meesen, G., Thienpont, N., Messens, K. et al. (2011). *International Dairy Journal*, 21, 798-805.

Emulsifying efficacy



Buttermilk (BM) milk fat globule membrane (BM- MFGM100); ····], microfiltered BM whey (whey-MFGM100; —), Lacprodan PL-20 (Lac100; Arla Foods Ingredients Group P/S, Viby, Denmark; ----), mixture of microfiltered BM and BM powder (4:6, wt/wt; BM-MFGM40; – · –), mixture of microfiltered BM whey and BM powder (4:6, wt/wt; whey-MFGM40; · ·), and mixture of Lacprodan PL-20 and BM powder (4:6, wt/wt; Lac40; – – –).

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Phan, T. T. Q., Le, T. T., Van der Meeren, P., & Dewettinck, K. (2014). Comparison of emulsifying properties of milk fat globule membrane materials isolated from different dairy by-products. Journal of Dairy Science, 97, 4799-4810.

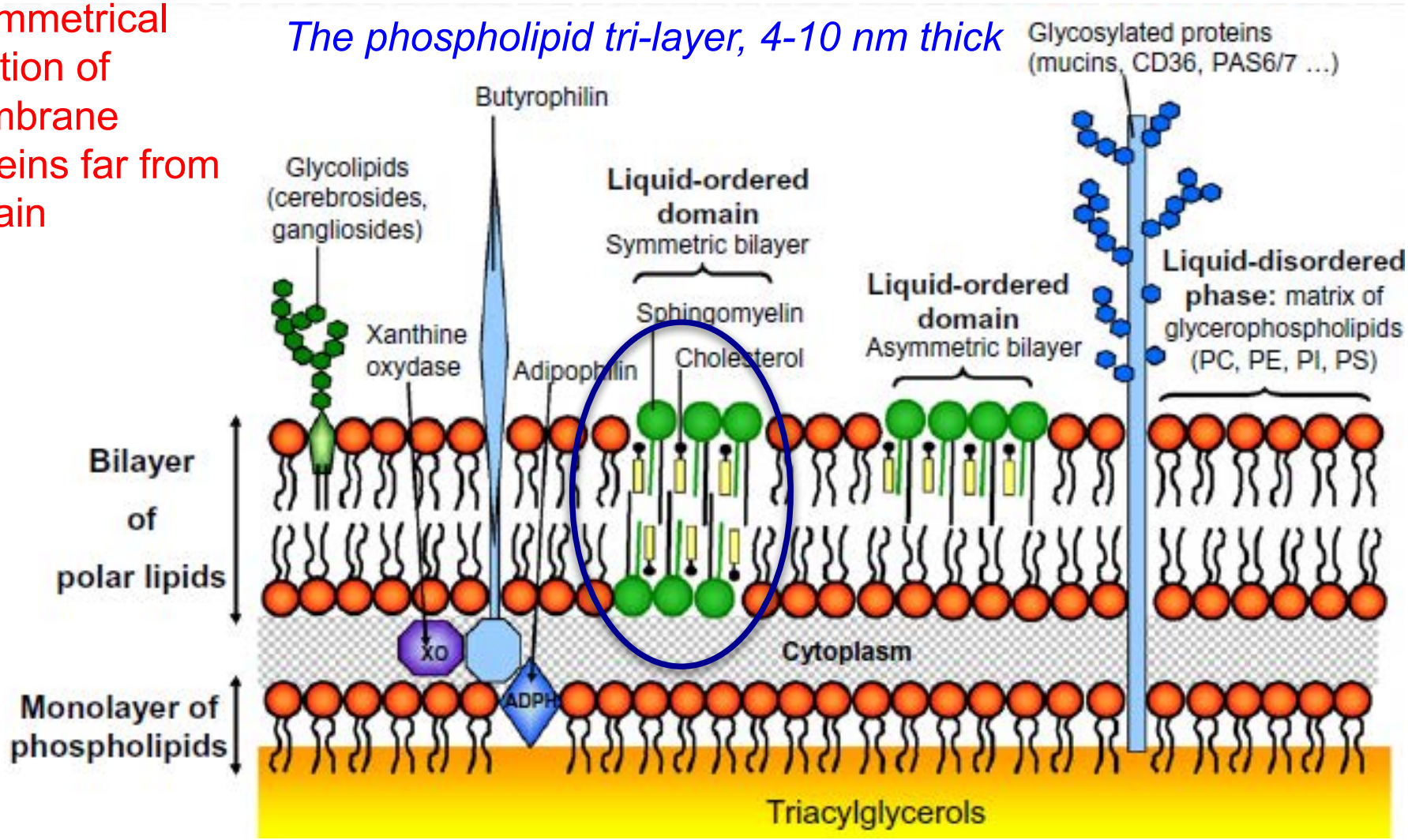
Buttermilk functionality

- Impact on cheese (added as buttermilk)
  - Increases moisture content and yield[1]
  - Impairs casein aggregation during curd cooking
  - Decreases free oil in pizza cheese[2]
  - Improves flavour (bacteria congregate near fat globule interface, and MFGM components may provide a carbon source), particularly reduced-fat cheese[3,4,5]
  - Increases pizza cheese moisture and decreases melt and stretch[6]

[1] Gauvin, M.-P., Pouliot, Y., & Britten, M. (2018). *International Dairy Journal*, 76, 10-17.
[2] Poduval, V., & Mistry, V. (1999). *Journal of Dairy Science*, 82, 1-9.
[3] Foda, E., Hammond, E., Reinbold, G., & Hotchkiss, D. (1974). Role of fat in flavor of cheddar cheese. J. *Dairy Sci.*, 57, 1137-1142.
[4] Law, B., Sharpe, M., Chapman, H., & Reiter, B. (1973). *Journal of Dairy Science*, 56, 716-723.
[5] Mayes, J., Urbach, G., & Sutherland, B. (1994). *Australian Journal of Dairy Technology*, 49, 39-41.
[6] Govindasamy-Lucey, S., Lin, T., Jaeggi, J., Johnson, M., & Lucey, J. (2006). *Journal of Dairy Science*, 89, 454-467.

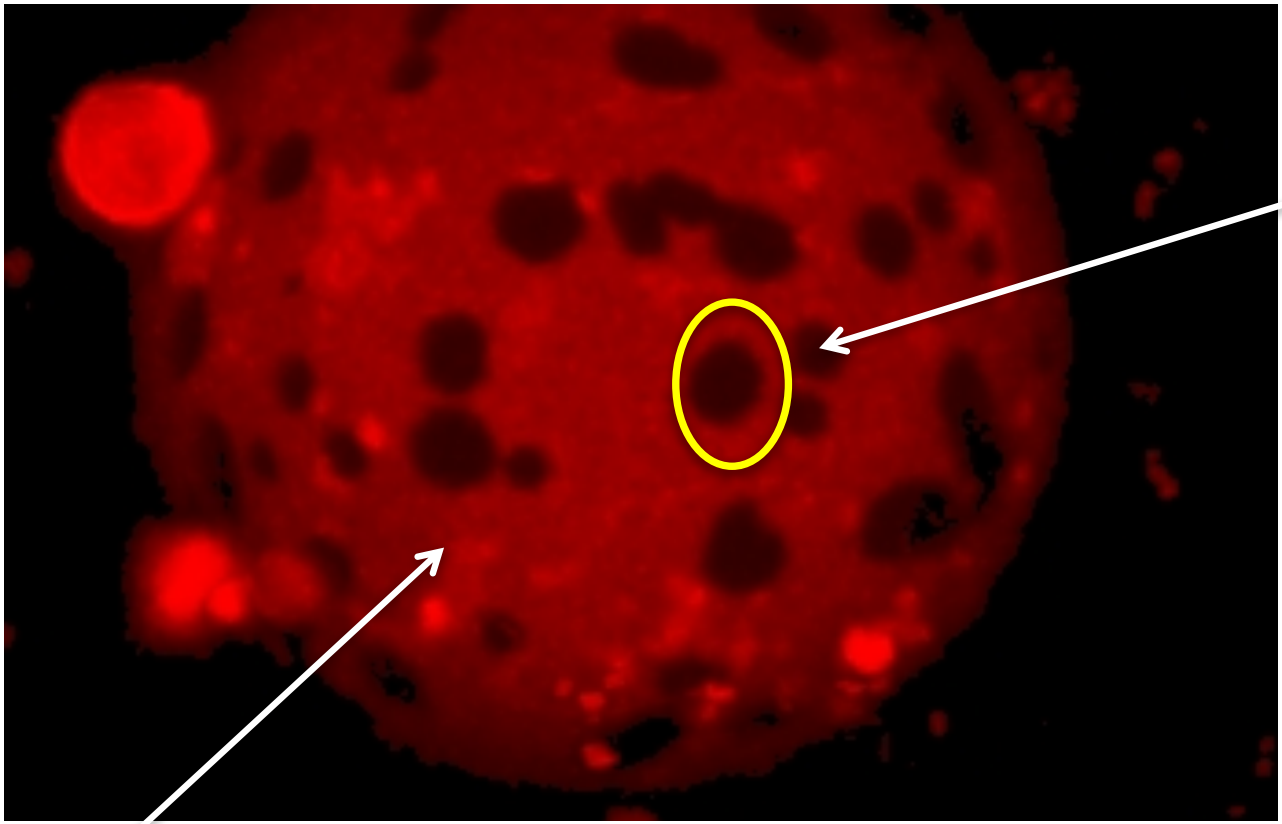
MFGM topological model

Asymmetrical location of membrane proteins far from certain



Lopez C. et al., *Food Chemistry* 125: 355-368 (2011)

Surface chemistry and structure – the milk fat globule



Liquid ordered L_0 regions rich in sphingomyelin (highly saturated, longer chain) and cholesterol

Liquid disordered region

Two-dimensional reactions on emulsion and other colloidal surfaces to generate texture and flavour reactions

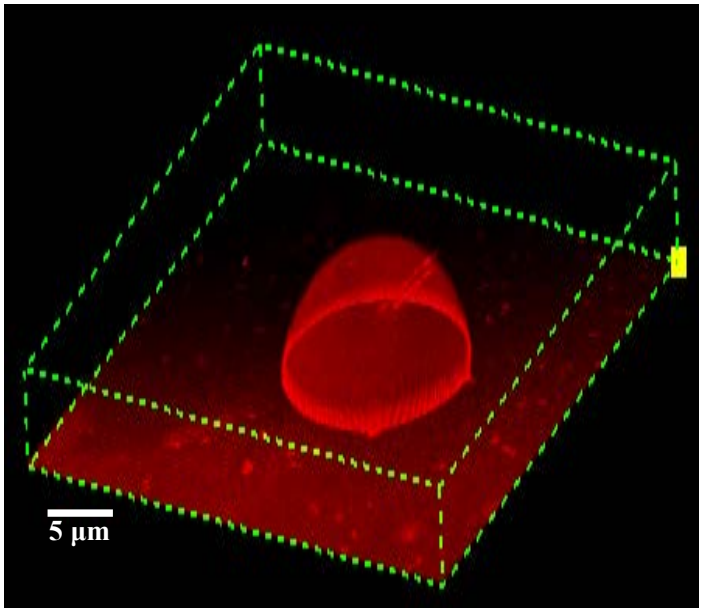
Gallier, S., Gragson, D., Jiménez-Flores, R., Everett, D.W., *J. Agric. Food Chem.* 58: 4250–4257 (2010)

Purported health benefits of the dairy matrix

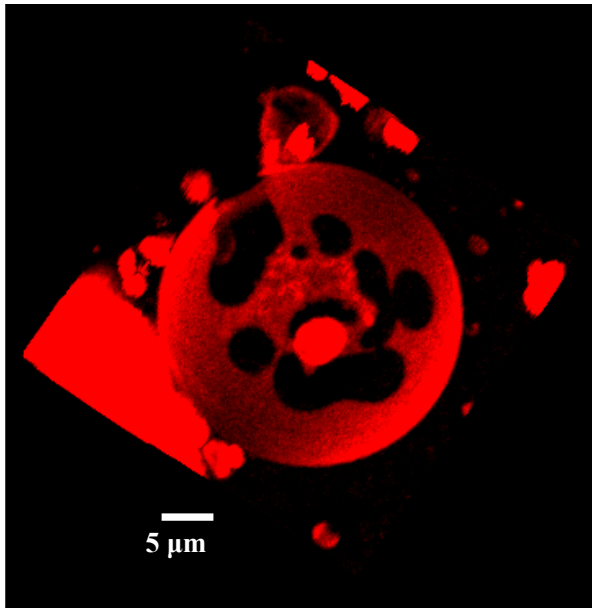
- Cholesterol and sphingomyelin in close association in the MFGM
- Raw cream buttermilk treated with pepsin and microfiltered lowered cholesterol micelle solubility by 57%, but only 17% with pasteurised cream[1]
- Superior antioxidant activity from MFGM peptides[2]
- Slight *in vivo* lowering of cholesterol absorption through intestinal epithelial cell layer by consumption of 45 g/day of buttermilk[3]
- Implicated inhibition of infectivity by rotavirus activity, attributed to the glycoprotein and carbohydrate components[4]

[1] Conway, V., Gauthier, S. F., & Pouliot, Y. (2010). *Dairy Science & Technology*, 90, 449-460)
[2] Conway, V., Gauthier, S. F., & Pouliot, Y. (2013). *Journal of Agricultural and Food Chemistry*, 61, 364-372
[3] Conway, V., Couture, P., Richard, C., Gauthier, S. F., Pouliot, Y., & Lamarche, B. (2013). *Nutrition, Metabolism and Cardiovascular Diseases*, 23, 1255-1262.
[4] Fuller, K. L., Kuhlenschmidt, T. B., Kuhlenschmidt, M. S., Jiménez-Flores, R., & Donovan, S. M. (2013). *Journal of Dairy Science*, *96*, 3488-3497.

Giant unilamellar vesicle model systems



GUV generated from electroformation.

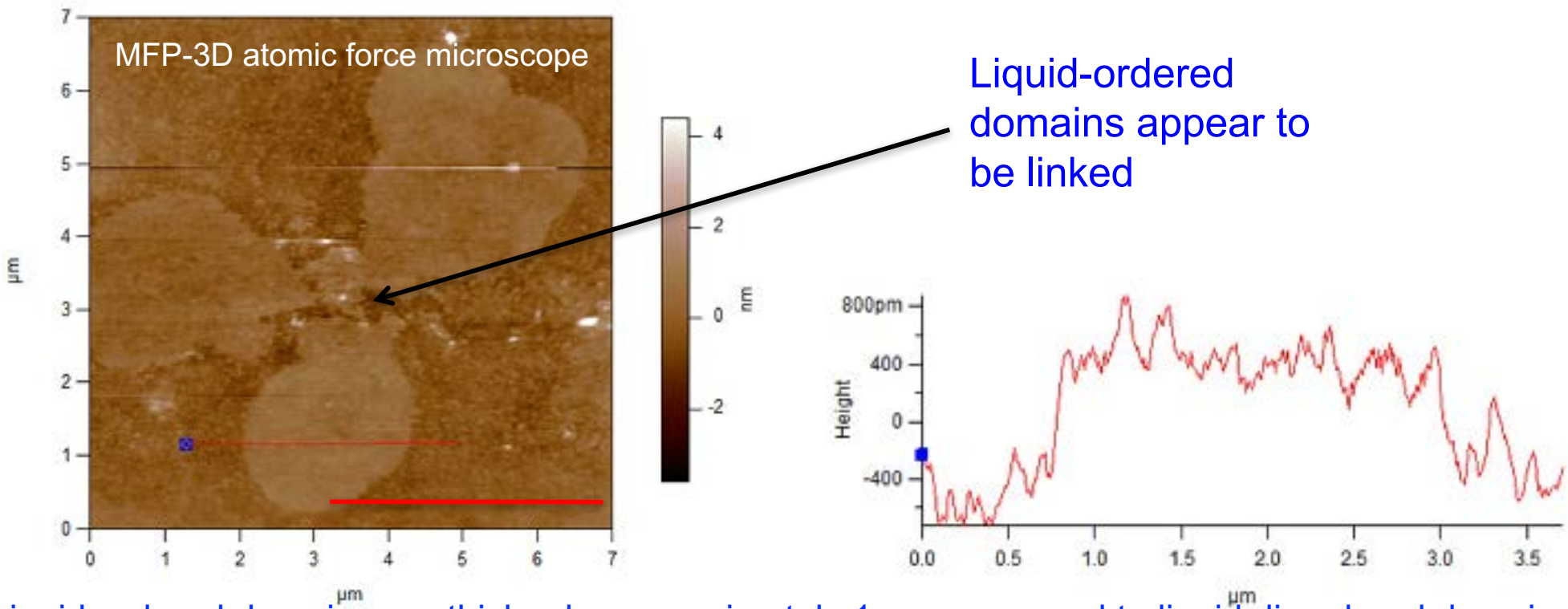


Non-fluorescent lipid domains formed with DPPC/DOPE 3/7 mol/mol in a GUV system.

Model milk fat globule vesicles to examine surface structures

Zheng, H., Jiménez-Flores, R., Gragson, D. & Everett, D.W. *J. Agric. Food Chem., 62*, 3236-3243 (2014)

Fat globule surface structure



Liquid-ordered domains appear to be linked

Liquid-ordered domains are thicker by approximately 1 nm compared to liquid disordered domains

Gallier, S., Gragson, D., Jimenez-Flores, R., & Everett, D. W. (2010). Surface characterization of bovine milk phospholipid monolayers by Langmuir isotherms and microscopic techniques. *Journal of Agricultural and Food Chemistry*, 58, 12275-12285.

Buttermilk powders

Valio sweet butter milk powder

Historically considered a low-value product…but huge potential!

Current global market (3-10-2017) price US$1840 per ton

Global prices dropped 30% over last 12 months

Compare with SMP US$1895; WMP US$3037; rennet casein US$6123 per ton

Fonterra Dairy for life

Fonterra butter milk powder

Products usually promoted for their good solubility, clean flavor, and emulsifying efficacy.

Westland Milk Products Hokitika · New Zealand

High heat butter milk powder

MFGM health claims

Functional health properties* of MFGM phospholipids

- Sphingolipids, including sphingomyelin and metabolites (ceramide, sphingosine, sphingosine-1-phosphate, cermaide-1-phosphate)
  - colon anti-carcinogenic properties
  - cholesterol and LDL adsorption lowering effects by lowering liposome membrane fluidity, raises HDL levels (milk more potent than egg sphingomyelin)
  - trans-membrane signal transduction and regulation of immune cell development
  - cell growth and apoptosis
  - lipoprotein formation
  - mucosal growth in the gut
  - associated with age-related diseases, such as Alzheimer's
  - ameliorate inflammatory processes in atherosclerosis
  - treatment for insulin resistance, dyslipidemia, cardiovascular diseases
  - protection against bacterial and virus infections
- Fatty acid binding protein
  - anti-carcinogenic properties (colon, breast)

* Scientific literature reports - evidence in some cases is weak, and in some cases insufficient

MFGM health claims

Functional health properties* of MFGM phospholipids

- Phosphatidylserine
  - positive effects on Alzheimer's patients
  - restoration of memory
  - alleviate muscular soreness
- Phosphatidylcholine
  - support liver recovery
  - protect human gastrointestinal mucosa against toxic attack
  - reduced life-threatening necrotizing enterocolitis
- Lactadherin
  - protection against gut viral infection
- Butyrophilin
  - suppression of multiple sclerosis
- Lyso-phosphatidylcholine and xanthine oxidase
  - bacteriocidal and bacteriostatic properties (*S. aureus, E. coli, Sal. enteritidis*)

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* Scientific literature reports - evidence in some cases is weak, and in some cases insufficient

Snow Brand

snowbrand.com.my

Neo Kid-Plus

Sphingolipids
Gangliosides
Arachidonic acid
Nucleotides
Galactosyllactose

Sialic acid
Docosahexaenoic acid
Choline
Phospholipids

Fonterra

www.fonterra.com

Phospholipid concentrates: sphingomyelin
Cell growth and regulation

Gangliosides: mono-sialo ganglioside 3 (GM3), di-sialo ganglioside (GD3) and phosphatidylserine
Infant learning and development, maintain gut health and balancing the immune system

FrieslandCampina

frieslandcampina.com

Nutritional milk powders for children
5x Docosahexaenoic acic
Sialic acid

Dutch Lady Growing Up Milk 123 for ages 1+
Dutch Lady Growing Up Milk 456 for ages 3+
Dutch Lady Growing Up Milk 6+ for ages 6+

Arla Foods

www.arlafoodsingredients.com

Lacprodan® PL-20
Phosphatidylserine and sphingomyelin
Performance boost, contributes to healthy ageing, promotes cognitive development in infancy

Lacprodan® MFGM-10 for infant nutrition.
Lactoferrin, IgG, sialic acid, phospholipids and gangliosides
Neonatal gut maturation and myelination of the central nervous system
Gangliosides for beneficial gut microflora, and intestinal maturation and cognitive development
MFGM components for anti-pathogenic effects
Lactoferrin protects against microbial infections

Meiji – Global Brands Marketing

Meiji FM-T
Meiji mamilac
Meiji Fu

Fortified with docosahexaenoic acid
Cerebral and retinal development

Novel ingredients from milk

Case study: the milk fat globule membrane (MFGM)

Originates from lipid droplet extrusion from the mammary epithelial cells

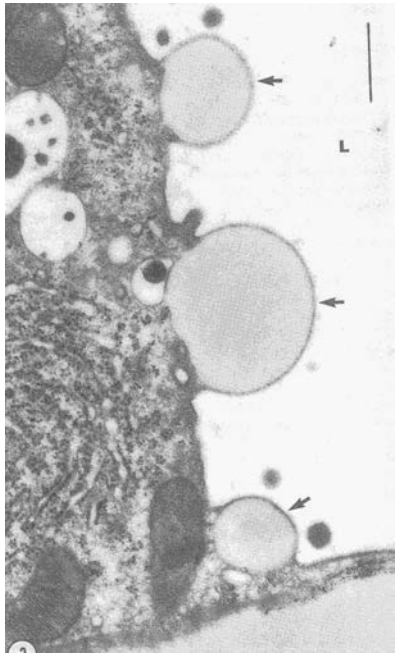
Protects milk fat globule from lipolysis and coalescence

Contains components with bioactive functionality

Major component of buttermilk

Emulsification, carriers of flavour compounds

Implicated inhibition of infectivity by rotavirus activity, attributed to the glycoprotein and carbohydrate components



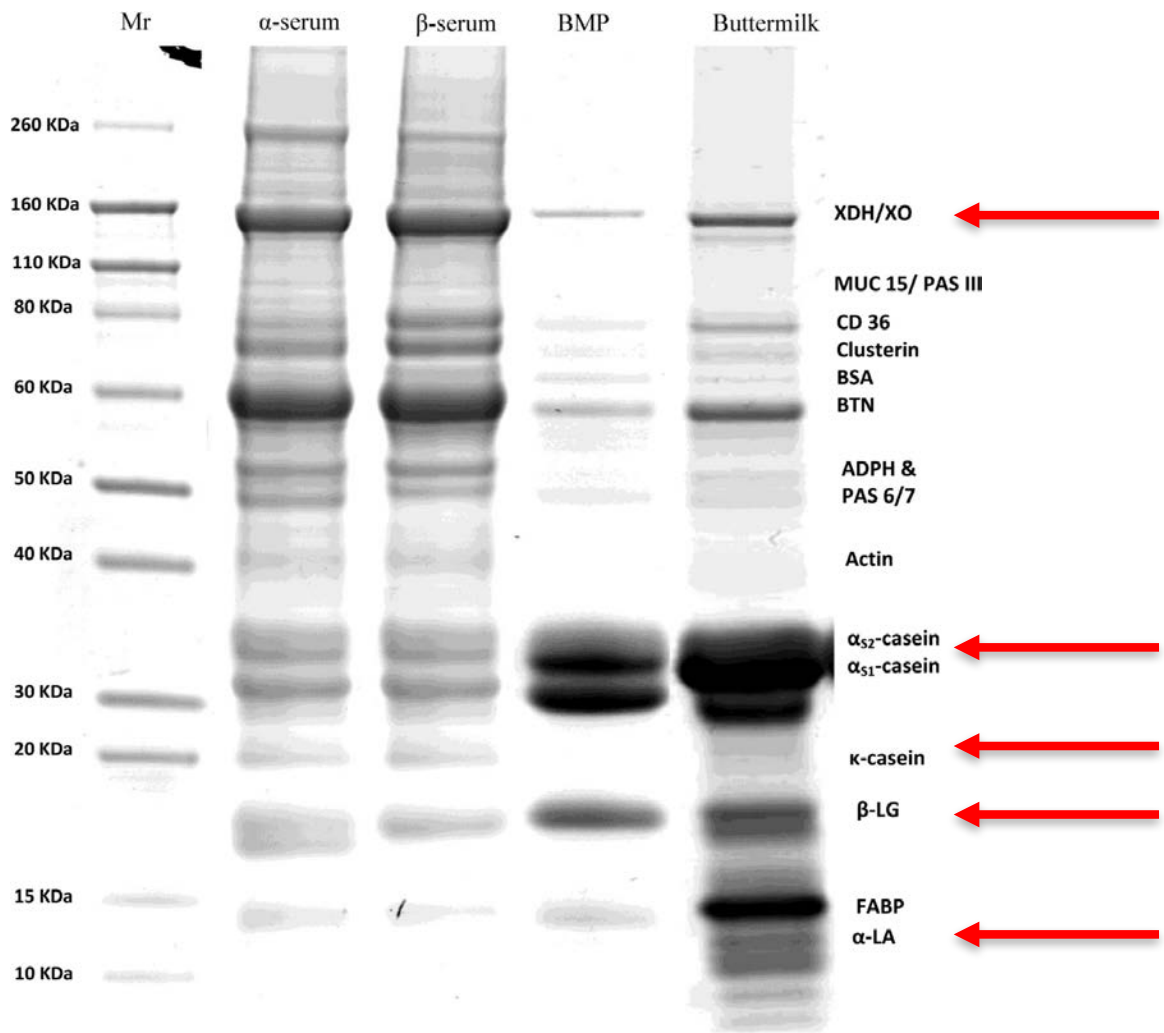
Keenan, Mather & Dylewski, Physical Equilibria Lipid Phase, In N.P. Wong, *Fundamentals of Dairy Chemistry*, 3rd ed. (1988)

Composition of the MFGM

Component	mg/100g fat	mg/100mg MFGM
Proteins	1800	70
Phospholipids	650	25
Cerebrosides	80	3
Cholesterol	40	2
Monoacylglycerides	Present	Unknown
Water	Present	0
Carotenoids	0.04	0
Total	>2570	100

Composition depends upon the method of extraction

Proteins in MFGM extractions



XO accounts for around 20% of membrane proteins

Heat treatment can cause association of whey proteins with MFGM surface layers

Note the large amount of caseins and whey proteins in the extractions

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Haddadian, Z., Eyres, G. T., Carne, A., Everett, D. W., & Bremer, P. (2017). Impact of different milk fat globule membrane preparations on composition, xanthine oxidase activity, and redox potential. *International Dairy Journal*, 64, 14-21.

Compartmentalisation of enzymes

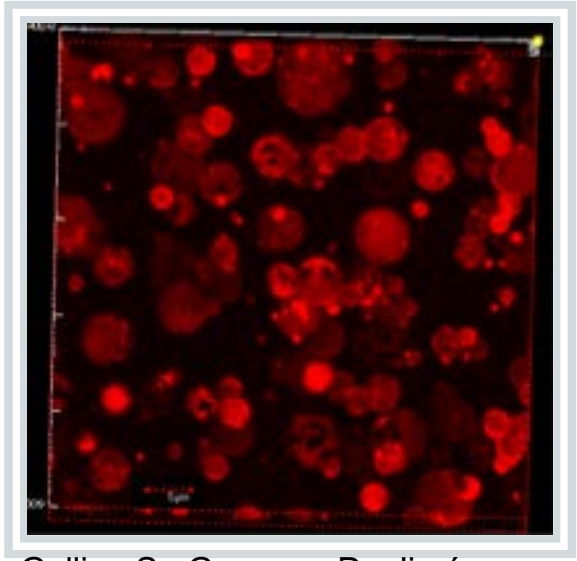
Milk fat globule membrane

Redox enzymes
Xanthine oxidase
Cytochrome C reductase

Hydrolases
Acetylcholine esterase
Alkaline phosphatase
Acid phosphatase
5'-Nucleotidase
Glucose-6-phosphatase
Phosphodiesterase
Adenosine triphosphatase

Lyases
Aldolase

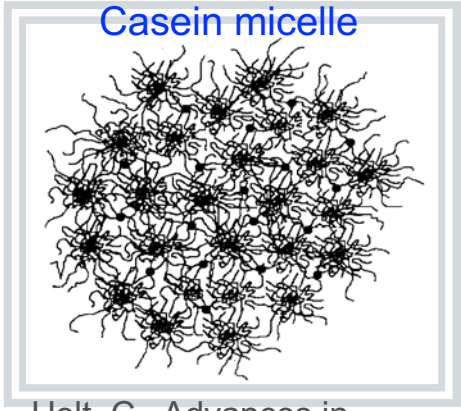
Transferases
γ-Glutamyl transferase
Galactosyl transferase



Gallier, S., Gragson, D., Jiménez-Flores, R., Everett, D.W., *J. Agric. Food Chem.* 58: 4250–4257 (2010)

Sulfhydryl oxidase
Lactoperoxidase
Superoxide dismutase
Ribonuclease

Casein micelle



Holt, C., Advances in Protein Chemistry, vol. 43: 63-151 (1992)

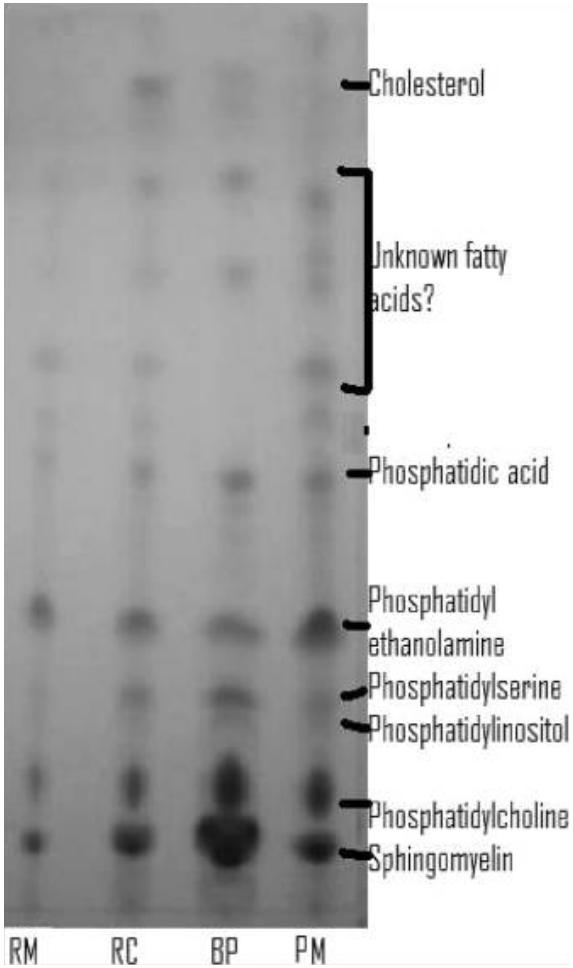
Serum phase
Lipoprotein lipase
Plasmin (lower pH)

Polar lipids in MFGM

Polar lipid class	% of total polar lipids
Phosphatidylcholine (PC)	36
Phosphatidylethanolamine (PE)	27
Sphingomeylin (SM)	22
Phosphatidylinositol (PI)	11
Phosphatidylserine (PS)	4
Lysophosphatidylcholine (LysoPC)	2

Composition depends upon the method of extraction

Polar lipids in the MFMG



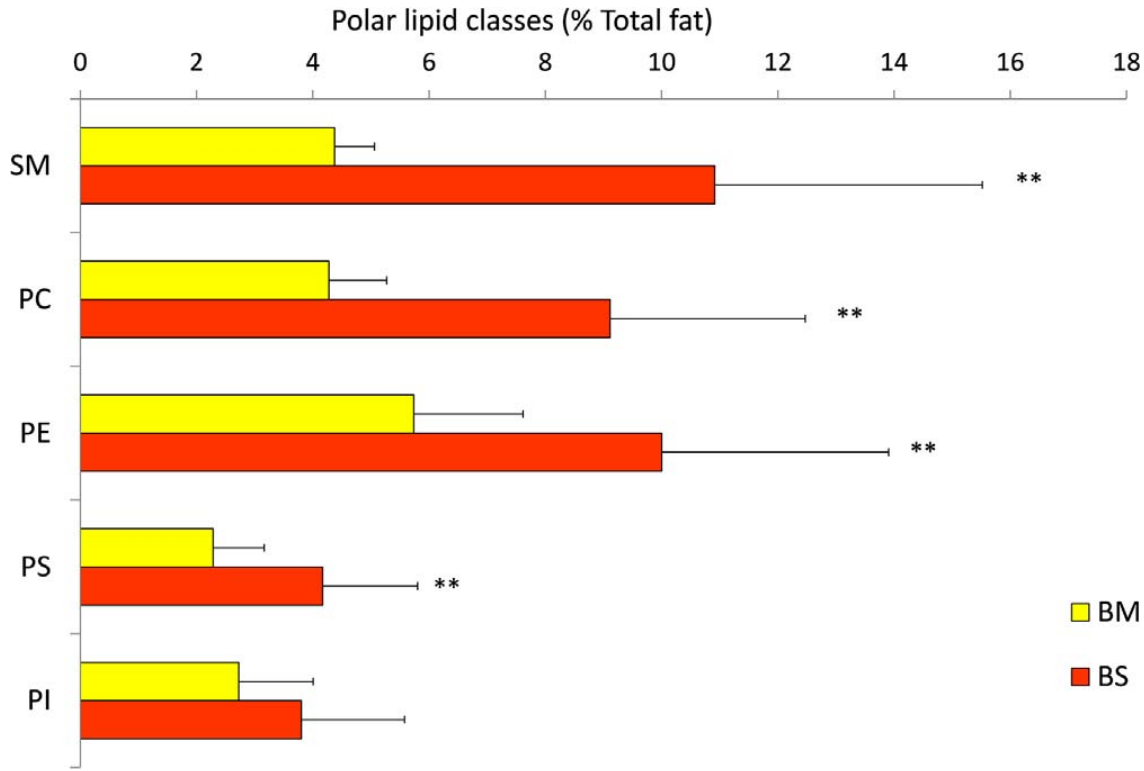
Seemingly minor processing steps can affect lipid composition–

Cooling
Heating
Churning
Homogenization

RM: Raw milk
RC: Recombined cream
BP: Buttermilk powder
PM: Processed milk (homogenized and pasteurised)

Gallier, S., Gragson, D., Cabral, C., Jimenez-Flores, R., & Everett, D. W. (2010). Composition and fatty acid distribution of bovine milk phospholipids from processed milk products. *Journal of Agricultural and Food Chemistry*, 58, 10503-10511.

Selective enrichment of polar complex lipids



BM Buttermilk from butter manufacture

BS Butter serum from melting and centrifuging butter

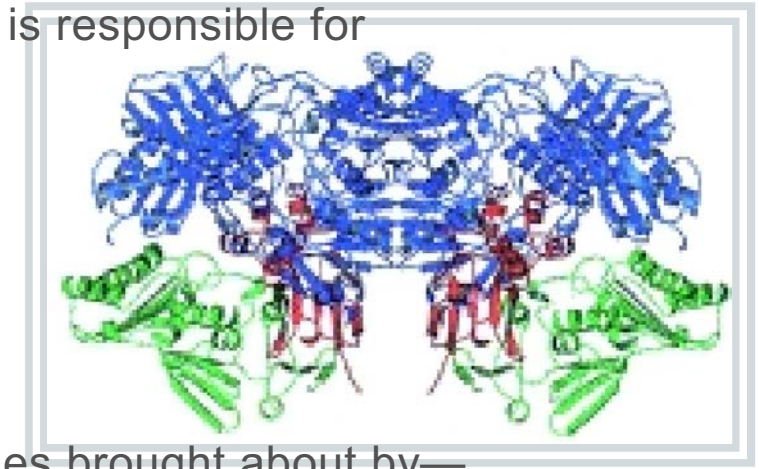
Bourlieu, C., Cheillan, D., Blot, M., Daira, P., Trauchessec, M., Ruet, S. et al. (2018). Polar lipid composition of bioactive dairy co-products buttermilk and butterserum: Emphasis on sphingolipid and ceramide isoforms. *Food Chemistry*, 240, 67-74.

Case study: xanthine oxidase (XO)

In bovine milk, xanthine oxido-reductase is in the XO form

Capable of oxidising a wide range of aldehydes

Oxidises retinol to retinal, then to retinoic acid which is responsible for most of the activity of vitamin A[1]

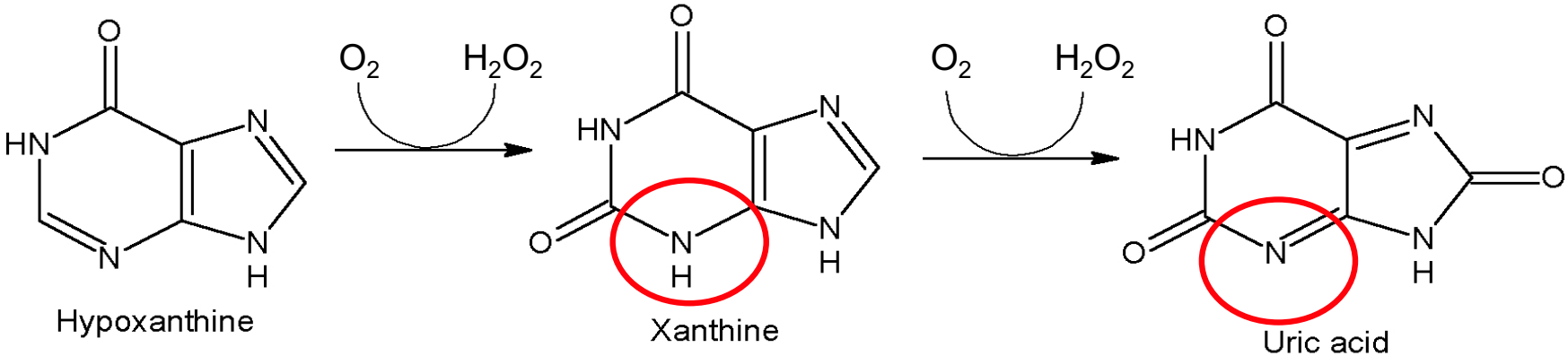


XO has both bacteriocidal and bacteriostatic properties brought about by—

1. Production of reactive superoxide and hydrogen peroxide in the gut
2. Reduction of nitrite to nitric oxide, and to peroxynitrite
3. Stimulating lactoperoxidase system in milk (reductant + H_2O_2 → oxidant + H_2O)

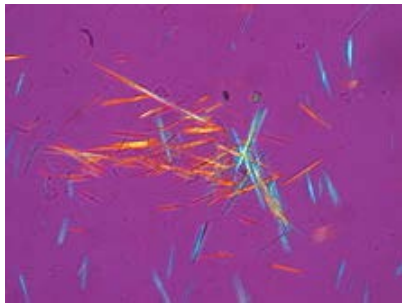
[1] Taibi, G., & Nicotra, C. M. A. (2007). *Journal of Enzyme Inhibition and Medicinal Chemistry*, 22, 471-476.

Oxidation reactions of XO



Uric acid elevated in blood; crystals implicated in gout*.

XO is the target of the widely used anti-gout drug, Allopurinol, an isomer of hypoxanthine and a xanthine oxidase inhibitor.



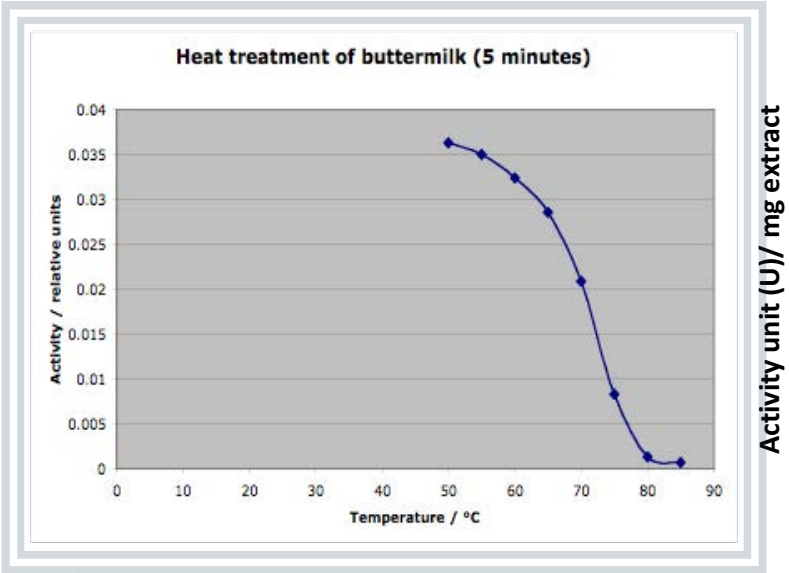
Xanthine oxidase	$XH + H_2O + O_2 \longrightarrow$	$X{=}O + H_2O_2$
Xanthine dehydrogenase	$XH + H_2O + NAD^+ \longrightarrow$	$X{=}O + NADH$
Aldehyde oxidase*	$RCHO + H_2O + O_2 \longrightarrow$	$RCOOH + H_2O_2$

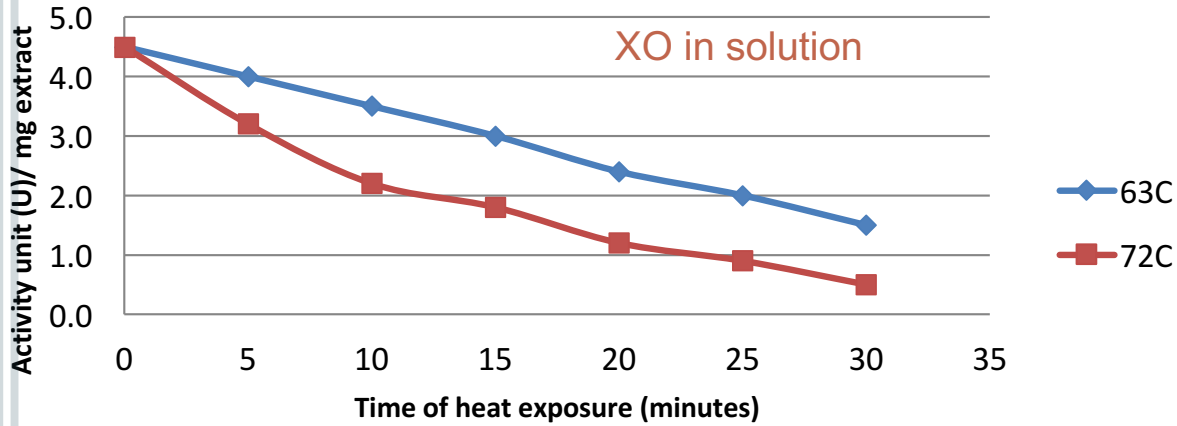
* Found mainly in liver

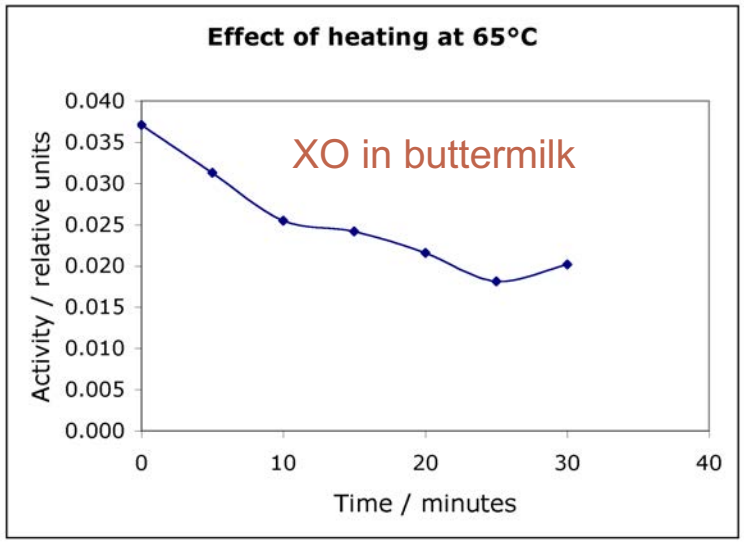
*Genetic, diet, and lifestyle causes
Consumption of alcohol, fructose-sweetened drinks, meat, seafood
Known as “rich man’s disease, or “the disease of kings”

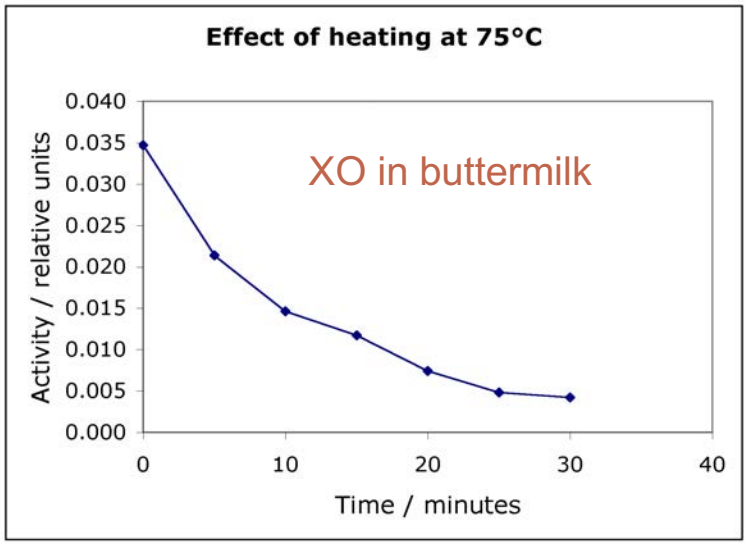
Dairy matrix effect on XO activity

XO in solution and in buttermilk









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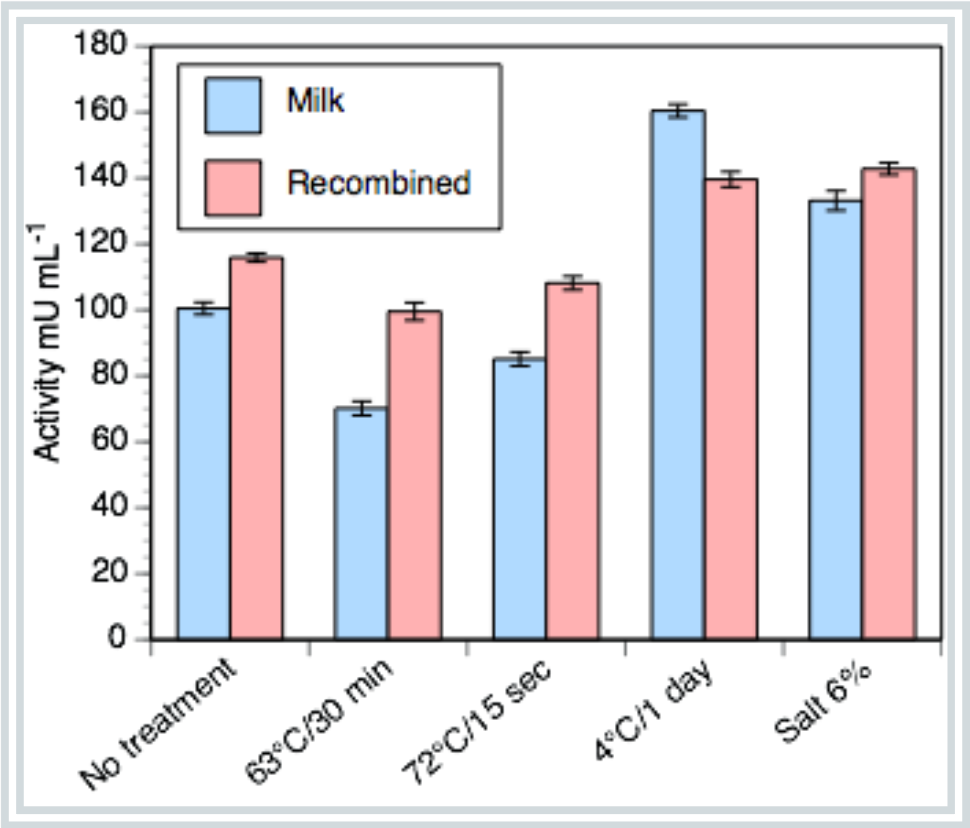
Xanthine oxidase activity in processed milk

$$XH + H_2O + O_2 \longrightarrow X{=}O + H_2O_2$$

Located in the cytoplasmic region of the MFGM

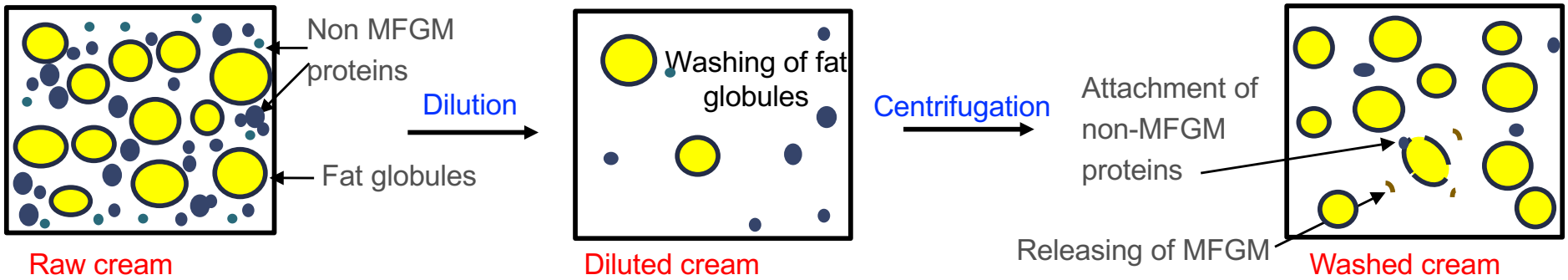
Oxidation of aldehydes to acids

Increase in n-fatty acids leading to methyl ketones, γ- and δ-lactones.



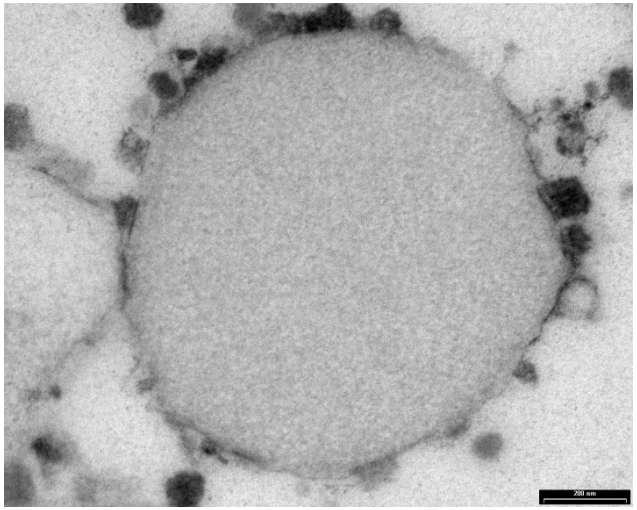
Kathriarachchi, K., PhD thesis, University of Otago (2015)

Washing cream with either simulated milk ultrafiltrate (SMUF) or water

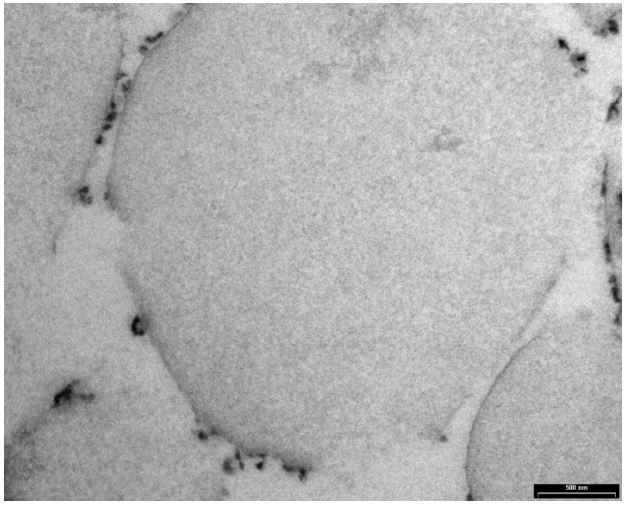


Washing fat globules

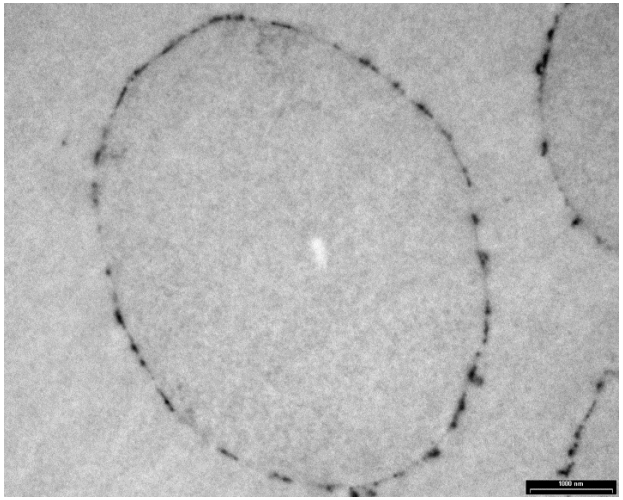
Scale bars: 5 μm



Native fat globule

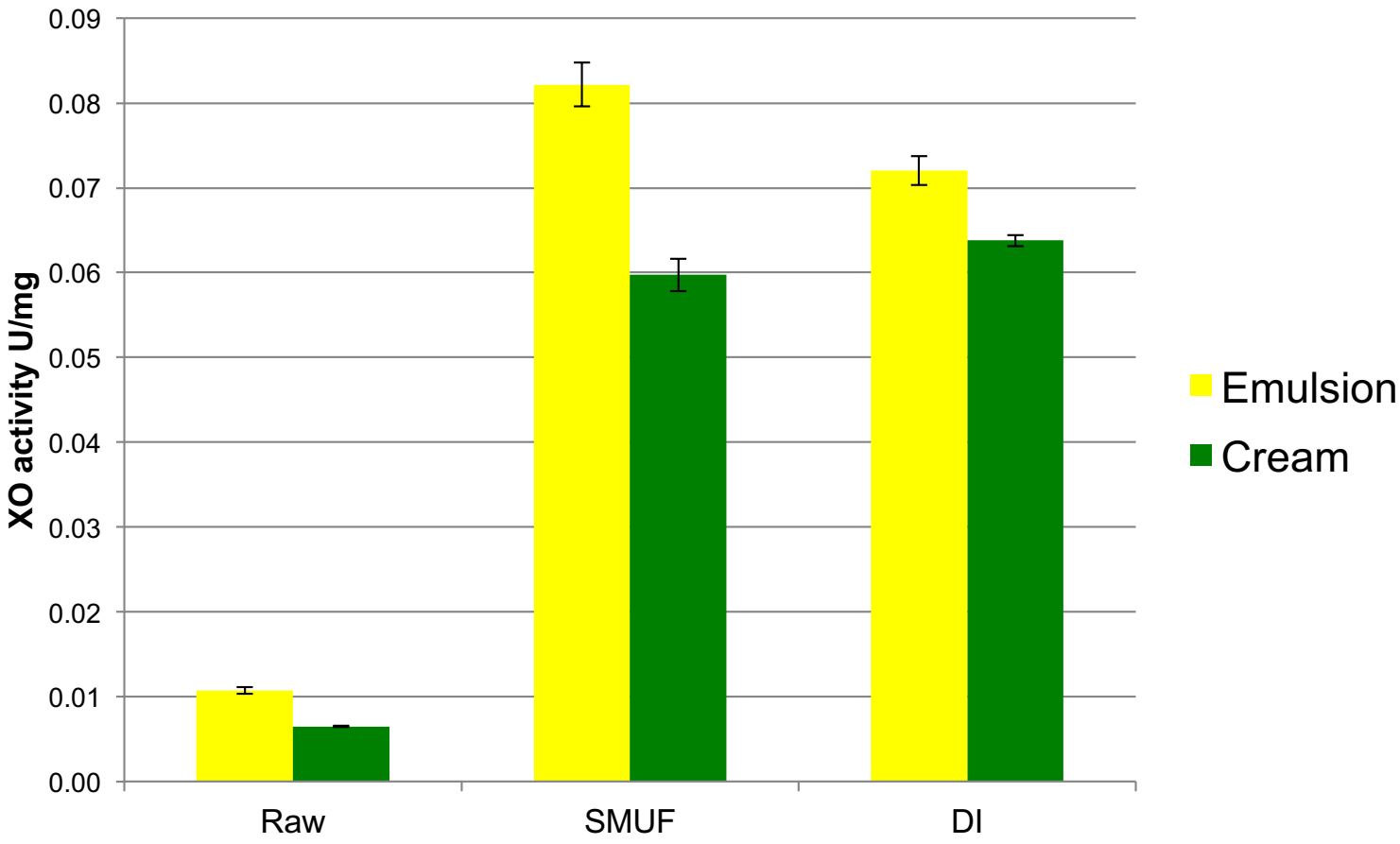


Fat globule washed with simulated milk ultrafiltrate (SMUF)



Fat globule washed with water

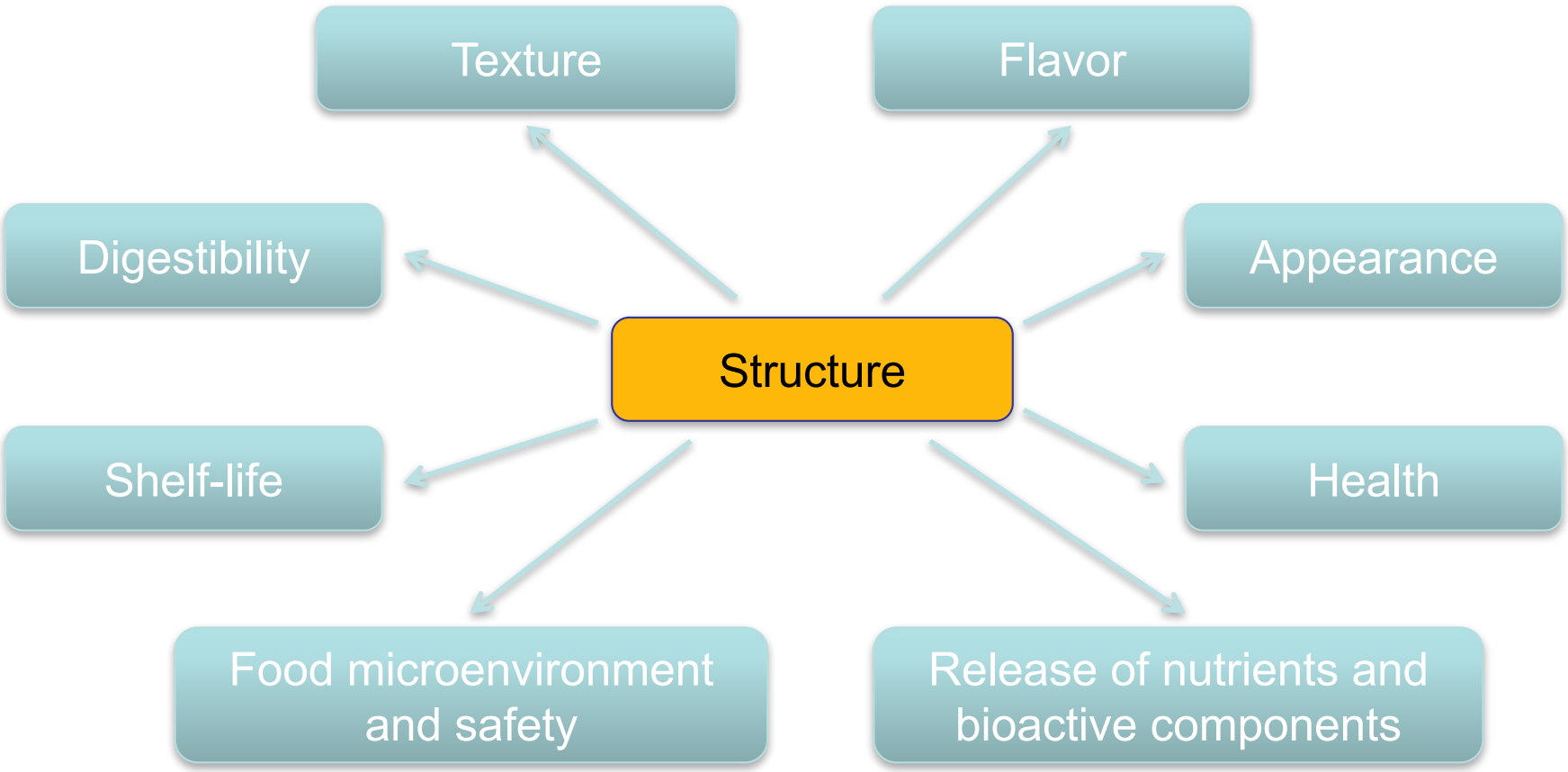
Xanthine oxidase activity on emulsion surfaces



* Specific activity of XO (mU mg^{-1} of protein)

Kathriarachchi, K., PhD thesis, University of Otago (2015)

The importance of dairy food structure



Conclusions

- Milk has a complex native structure that impacts upon release of nutrients and, therefore, human health
- Extraction of MFGM components must take into account the impact of heat treatments
- Processing of milk can have a profound effect on dairy product flavor, release of nutrients, and health:
  - Location of complex lipids and enzymes on the milk fat globule surface
- Appropriate extraction methods can add value to buttermilk and buttermilk powders
- Understanding the structure-induced functionality of dairy products is a relatively new field that requires interdisciplinary research by food physicists, manufacturing technologists, and gastrointestinal physiologists

Time for questions