Controlling quality in UHT and ESL milk for export

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NCDEA Webinar 11 November 2015

Outline

UHT and ESL milk: a brief overview

Key issues for exported UHT and ESL milks

UHT milk - quality issues, causes & remedies

- Flavour
- Age gelation
- Fat separation
- Sedimentation
- Non-sterility
- Package damage*

ESL milk - quality issues, causes & remedies

- Shelf-life limitation due to bacterial growth
- Psychrotrophic spore-formers
- Flavour issues

UHT processing

- 138-145ºC for 2-10 seconds
- Destroys:
  - all non-spore-forming bacteria
  - almost all spore-forming bacteria
- Main bacteria of concern are very heat-resistant *Bacillus* species
- Packed aseptically
- Stored at room temperature
- Has shelf life of ≥ 6 months
- Used for white milk, flavoured and modified milk, cream, custard and non-dairy beverages

ESL processing

- Heated at 20-138ºC for < 5 seconds; in USA, “ultrapasteurisation “is 138ºC for ≥ 2 seconds (also by microfiltration plus pasteurisation)
- Destroys:
  - all non-spore-forming bacteria, including pathogenic bacteria
  - most spore-formers
- Packaged under :
  - Very clean conditions OR
  - Aseptically
- Main bacterial issues:
  - post-heat treatment contamination (if not packaged aseptically)
  - psychrotrophic spore-forming bacteria, e.g., *Bacillus cereus, B. circulans*
- ESL milk is stored refrigerated
- Has a shelf life of 30+ days – depends on heat treatment and packaging
- Used for white milk, flavoured and modified milk, custard

UHT versus ESL

UHT milk	ESL milk
Commercially sterile	Not commercially sterile: contains some spore-formers which could grow at room temperature
Always packaged aseptically	Packaged under either very clean or aseptic conditions
Stored at room temperature	Stored refrigerated
Has long shelf-life (≥ 6months)	Shelf-life 30-45 days, more if aseptically packaged
Has definite cooked/heated flavour	Has little if any cooked flavour

Key issues for exported milks

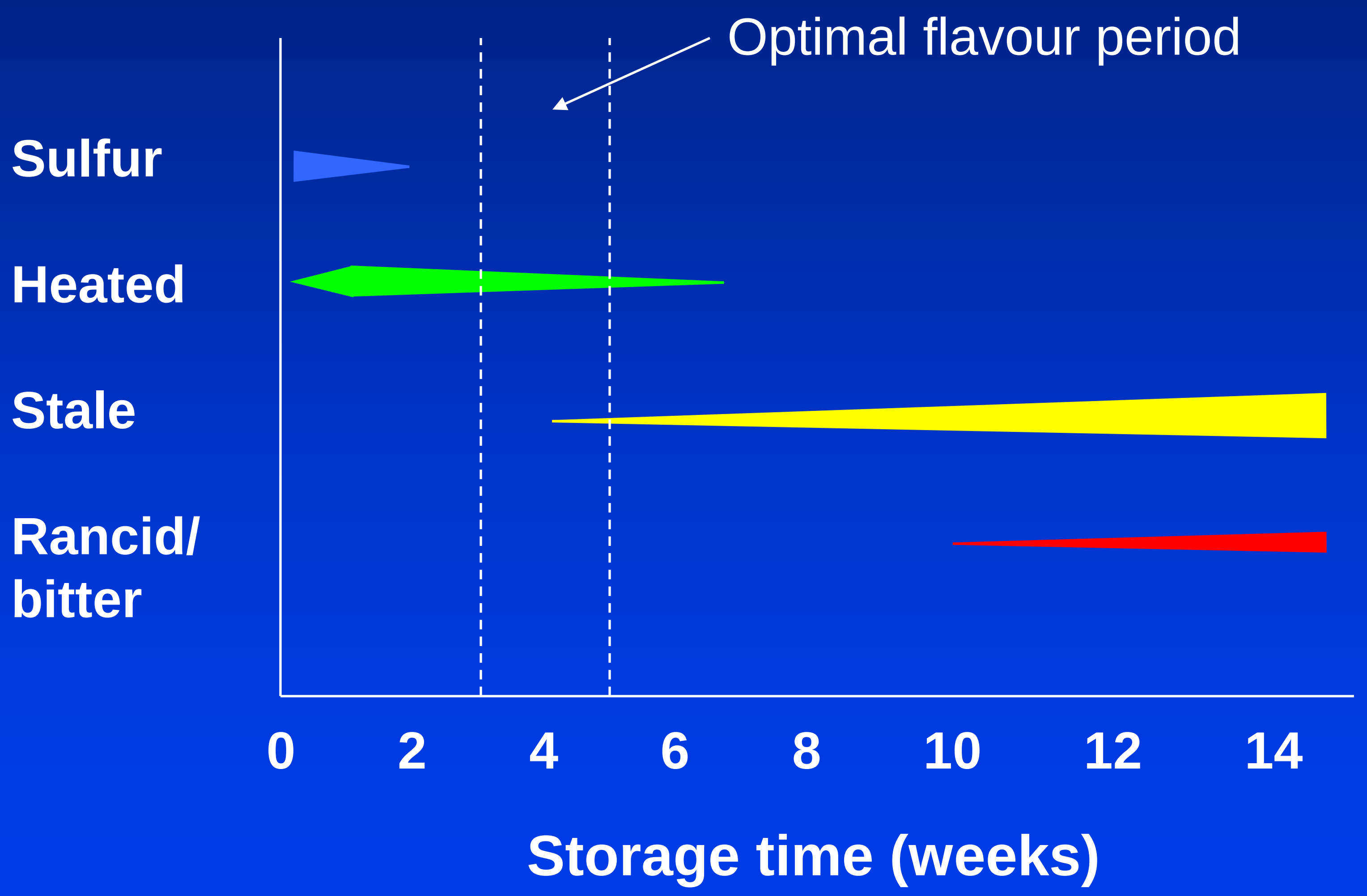
- Quality of raw material - milk
- Processing conditions - temperature–time profile
- Temperature and duration of transport and storage – including variability
- Temperature can vary from < 0°C to > 50°C as product is transported across climatic zones – and stored in uninsulated warehouses where temperature can reach > 50°C
- Package integrity

UHT milk

Quality issues, causes & remedies

Flavour

UHT milk flavour profile during storage



Flavour issues in stored UHT milk

- Cooked – due to heat treatment
- Stale, oxidised - mainly due to aldehydes (C7, C9)
- Maillard reaction products
- Bitter - due to bitter peptides caused by residual proteases – bacteria or plasmin
- Rancid, soapy - due to free fatty acids caused by residual bacterial lipases
- Acid, sour – due to bacterial fermentation

Flavour issues and remedies

Cooked flavour

- Minimise severity of UHT process (i.e. minimise C*)

Stale/oxidised flavour

- minimise air/O_2 content: Direct processing (1-2 mg/L) better than indirect (7-9 mg/L)
- minimise headspace in package: *Tetrabrik* (~ 8 mL/L) better than *Combibloc* (~ 34 mL/L) better than HDPE bottles (~58 mL/L)

Flavour issues and remedies (cont)

Bitter and rancid flavours

- Minimise bacterial count in raw milk; this mimimises residual bacterial enzyme content – preferably < 100,000/mL
- Minimise somatic cell count, preferably to < 200,000/mL; this minimises plasmin content
- Use pre-heat conditions to minimise residual plasmin

Sour/ acid flavour

- Can be due to bacterial growth, with or without gas production (flat sour effect)
- Flat sour can be due to growth of thermophilic spore-formers when product temperature is > ~50°C

Age gelation

Age gelation

- A major issue which limits shelf-life of UHT milk
- Gradual increase in viscosity, then quite rapid increase in viscosity, then formation of custard-like gel – sometimes lumps, sometimes flakes, sometimes thick layer on bottom, sometimes layer at top
- Gel formation is irreversible
- Occurs more rapidly in concentrated milks

Factors affecting age gelation

- storage temperature
- protease activity
- severity of heat treatment
- quality of the raw milk
- season/stage of lactation
- additives

Effect of storage temperature on age gelation

- Storage at low (~4ºC) and high (~35-40ºC) temperatures delays onset of gelation.
- Storage at ~25-30ºC is optimum for gel formation – unfortunately

Protease activity

- Good correlation between proteolysis and age gelation *Usually!*
- Can be due to (heat-stable) bacterial proteases &/or the native milk plasmin

Bacterial proteases

Bacterial proteases :

- considered the major cause of gelation in unconcentrated milk
- produced in raw milk by psychrotrophic bacteria
- survive UHT heat treatment
- mostly attack κ-casein (similar to rennet)

Plasmin

Plasmin :

- is stable to some UHT heat treatments
- can be inactivated by preheatng at ~90°C for 30-60 s – MOST SIGNIFICANT
- is higher in early and late lactation milk
- is higher in mastitic milk
- increases during storage due to conversion of plasminogen to plasmin
- attacks mostly β-casein to give γ-casein

Protease levels in milk

- age gelation can be caused by very low levels of protease in UHT milk – as little as 1 ng/mL
- very low levels of protease activity are difficult to measure - most assays are too insensitive
- can monitor increase in proteolysis over time as good indication of protease activity and shelf-life

Severity of heating

- The more severe the heating, the less age gelation
- More gelation in direct-processed (steam injection or steam infusion) milk than indirect-processed
- Mostly related to inactivation of proteases but also to increased denaturation of whey proteins which attach to casein and protect it from protease action

Quality of the raw milk

- Most important
- Poor quality milk has high bacterial count and/or high somatic cell count
- High bacterial count leads to production of heat-resistant proteases (and lipases)
- High somatic cell count leads to increased plasmin levels

Season/stage of lactation

- Early-lactation milk gels faster than late-lactation milk
- In southern Australia, this corresponds to spring milk.
- Seasonal effects can be due to variations in mineral balance, casein/whey protein ratio and plasmin levels.

Additives

- Several additives have been tested for their ability to delay age gelation
- The most effective is sodium hexametaphosphate (polyphosphate, Calgon)
  - some companies add it routinely
  - it can be added before or after heat treatment
  - delays gelation without affecting proteolysis
  - effect due to stabilisation of casein micelles via a calcium caseinate-polyphosphate complex.
- Other phosphates such as disodium hydrogen phosphate, commonly used as a stabiliser to neutralise ionic calcium, enhances gelation
- Added whey proteins tend to delay gelation

Fat separation

Fat separation

- A fat layer forms on top of milk or remains clinging to side of container when emptied
- Often due to insufficient homogenisation
- Decreases with homogenisation pressure (up to 400 bar or 40 MPa)
- Can be due to damaged homogeniser valves!!
- Related to size of fat globules - both average (should be < 1μm) and range; large globules are major problem
- Number of large globules (rule of thumb: < 2% should be ≥5μm and < 5% should be ≥2μm)

Fat separation (cont)

- Number of large fat globules increases with time of storage due to coalescence
- Cause unclear
- Can be associated with age gelation due to aggregation of casein associated with the homogenised fat globules

Sedimentation

Sedimentation

- Most milks have slight sediment (~0.1% V/V)
- Can give milk a chalky taste
- Most sediment forms during processing not during storage
- Often not apparent at manufacture; settles during storage
- Cause of sedimentation not always obvious; can present intermittently
- Low pH (≤ 6.5) at processing is a major cause; related to heat stability of the caseins
- Mineral balance important – high ionic calcium is another major cause
- Increases with severity of heating

Sedimentation (cont)

Can be higher in :

- goat milk *[has high ionic calcium level]*
- calcium-fortified milk *[fortification usually by insoluble salts such as Ca* CO_3*]*
- chocolate milk *[sediment of cocoa particles reduced with stabilisers]*

Sediment is similar to fouling material

- More sediment in directly heated UHT milk because less fouling deposit attaches to walls of heat exchanges and stays in milk

Sediment formation (cont)

- Can be reduced by adding sodium citrate [increases pH and also chelates calcium and magnesium ions]
- Decreased by homogenisation
- Can be quantified by centrifugating milk under defined conditions and measuring pellet (dry or wet)

Non-sterility

Microbial contamination

Microbial contamination in UHT is not common

It has 2 causes:

1. Contamination with spore-formers whose highly heat-resistant spores survive the UHT treatment
2. Post-sterilisation contamination

Heat-resistant spore-formers

- Spores can accumulate in plant, eg under seals, in cracks, etc
- Can form biofilms and produce proteases
- 2 major types:
  - Thermophilic – can only grow at > 45°C
  - Mesophilic – prefer to grow at room temperature

Thermophilic spore-formers

- *Main one is Geobacillus stearothermophilus*
  - Some spores can survive 156°C for 6 sec
  - Gives ‘flat sour’ detect (acid, no gas)
  - Normally not a problem; does not grow at < 45°C
  - Has caused problems in very hot climates, e.g. Middle East, in containers crossing Equator
  - A potential problem in sterilised milk in vending machines (e.g., in Japan) which are kept hot (~ 60°C) until purchased

Mesophilic heat-resistant sporeformers

Major one of concern is Bacillus sporothermodurans

- Mesophilic but very heat-stable is an unusual and bad combination
- Has caused major problems in Europe, Brazil, South Africa, China etc
- Caused factories to close down in Europe because it could not be eradicated from plants
- Not a spoilage problem, only defect reported was pink discoloration
- Recycling of milk implicated; practice now ceased (we hope!)
- Rare in Australia and New Zealand

Mesophilic heat-resistant sporeformers (cont)

Another one is *Paenibacillus*

- Has been isolated with *Bacillus sporothermodurans* from UHT milk in Germany
- Can also be a psychrotroph
  - Common spoiler of pasteurised milk in New York State
- Appears to be able to be thermophilic, mesophilic or psychrotrophic
- Is proteolytic and hence causes spoilage
- Not common in Australia; we hope it stays that way

Post-sterilisation contaminants

- The most common form of contamination in UHT milk
- Spore-formers and non-spore-formers have been isolated
- Sometimes it is unclear whether spore-former contaminants are post-sterilisation contaminants or have very heat-resistant spores that survive the heat treatment
- Two major recalls of UHT milks in recent years have been due to *Bacillus subtilus* and *Bacillus coagulans*
    - Normally spores of these would not survive UHT

Post-sterilisation contaminants (cont)

A common contaminant is the mould ***Fusarium oxysporum***

- produces cheesey flavour, ropey texture
- contamination during aseptic packaging
- an environmental contaminant associated with plants
- has occurred in many UHT plants, including juice plants
- maintenance of positive (sterile)air pressure in filler important
- difficult to decontaminate

ESL milk

Quality issues, causes & remedies

Quality issues with ESL milk

Very different issues to those of UHT milks due to:

- Short shelf-life and storage at low temperature means defects seen in UHT milks do not occur

Main issue is bacterial growth

Most ESL milk is packaged under very clean but not aseptic conditions

- Post-processing contamination is inevitable and is the major factor limiting the shelf-file of these milks
- Several different bacteria, both non-spore-formers and spore-formers have been isolated
- Most are Gram-positive not Gram-negative as seen in pasteurised milk
- Plant and filler should be decontaminated with hot water for ~120°C for 30 min

Psychrotrophic spore-formers in ESL milk

- Psychrotrophic spore-formers are a major concern
  - ESL milks processed at < 130°C probably contain them
  - *Bacillus cereus* is a concern as a small percentage of strains are psychrotrophic and pathogenic; they form endotoxins
  - For ESL milks packaged aseptically without post-process contamination, psychrotrophic spore-formers are the only possible spoilage organisms
  - It appears that heating at ≥ 134°C will destroy spores of almost all psychrotrophic spore-formers

Post heat treatment contamination

- A major problem in milks NOT packaged aseptically
- Bacteria isolated are generally not those in raw milk or even pasteurised milk
- Bacteria are often specific to plant
- Contamination can be due to biofilm build-up in filler
  - Very difficult to remove/decontaminate
  - *Bacillus cereus* has been isolated from filler heads

Flavour issues with ESL milk

- Bitter flavours can be encountered in ESL milk
  - Almost certainly due to bacterial proteases produced in the raw milk before processing
  - Proteolysis by plasmin does not occur at refrigeration temperatures

- Light-induced oxidised flavours can develop if the ESL milk is not packaged in light-impermeable packaging.
  - ESL milks can be stored for > 30 days in lighted display cabinets and hence even low light-permeability packages may lead to off-flavour development.

Thank you for your attention