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UHT milk and aseptic packaging

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Outlines



- Background
- UHT milk -theory & chemistry
- Aseptic processing and packaging
- Innovations in UHT milk

UHT process

- A sterilization process is defined as a UHT (Ultra High Temperature) process, if the product is heat-treated in a continuous flow at a temperature of not less than 135°C for a very short time, aseptically packaged in sterile containers, and has undergone minimum chemical, physical and organoleptic changes in relation to the severity of the heat treatment required for sterilization.

UHT conditions

- High pH ($\text{pH} > 4.5$), low-acid foods, e.g. milk
 - 135-150°C for few seconds
- Low-pH ($\text{pH} < 4.5$), high acid foods, e.g. fruit juice
 - 90-95°C for 15-30 s

Sterilising equation

$$\text{Log } N/N_+ = K \times t$$

N = Number of microorganisms (spores)
originally present

N_t = Number of microorganisms (spores)
present after a given time of heat treatment (t)

K = a constant

t = time of treatment

Sterilising efficiency

- Logarithmic reduction of spores
- Q_{10} value
- F0 value
- B^* and C^* values

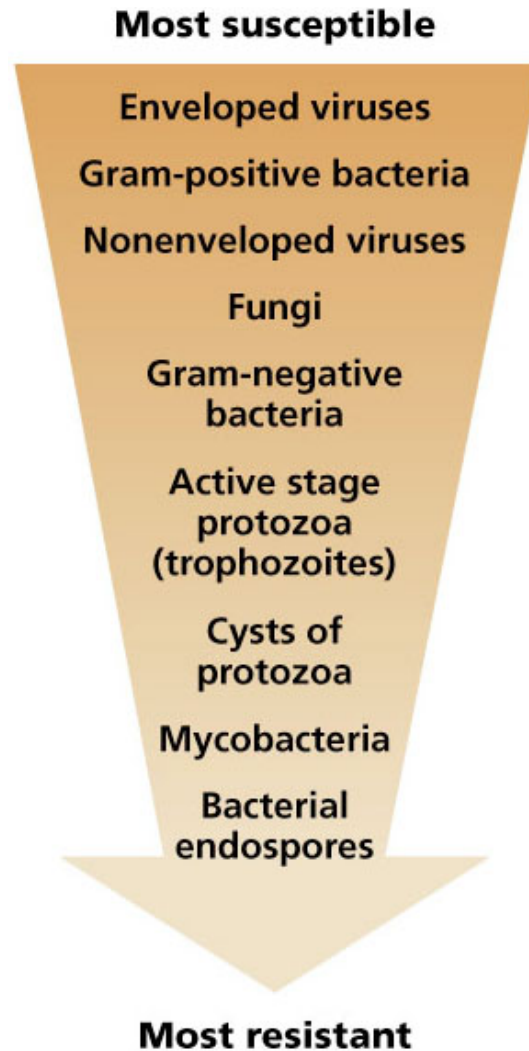
Sterilising efficiency

- Logarithmic reduction of spores
 - Number of decimal reductions in counts of bacterial spores achieved by a sterilising process
 - $\text{Log } 10^9 - \text{Log}10^0 = 9 - 0 = 9$
 - Sterilising efficiency is independent of the volume
 - Test organisms UHT - Spores of *B. subtilis* or *B. stereothermophilus*

Sterilising efficiency

- Depends on
 - Time-temperature combination
 - The heat resistance of bacteria and spores
 - Vegetative - easy to kill
 - Vegetative with spore - bacteria easy to kill, spores are difficult to kill
 - The product composition

Relative susceptibility of micro-organisms



Sterilising efficiency

- Q_{10} value
 - Generally relates to the speed of chemical reaction occurring as a consequence of heat treatment
 - How many times the speed of a reaction increases if the temperature is raised by 10°C
 - For most chemical reactions or flavour changes - $Q_{10} = 2$ to 3 (i.e. if the temperature is raised by 10°C , the speed of reaction doubles or triples)
 - Can be used for bacterial spores (8 to 30)

Sterilising efficiency

- F_0 value - relationship between temperature and time of sterilisation

$$F_0 = t/60 \times 10^{(T-121.1)/Z}$$

t = sterilisation time in seconds at $T^\circ\text{C}$

T = sterilisation temperature in $^\circ\text{C}$

Z = a value expressing the increase in temperature to obtain the same lethal effect in the $1/10^{\text{th}}$ of time ($\sim 10^\circ\text{C}$)

$F_0 = 1$ after product is heated at 121.1°C for 1 min

Commercial $F_0 = 5-6$

Thermal death time (TDT)

- Time required to kill a given number of microorganisms at a specified temperature
- Example: TDT for *C.botulinum* (pH 7.0)

100°C

TDT = 260 min

105°C

TDT = 120 min

110°C

TDT = 36 min

115°C

TDT = 12 min

120°C

TDT = 5 min

D-value

- The D-value, which denotes the decimal reduction time, is the time required at a specific temperature and under specified conditions to reduce a microbial population by one decimal (from 100 to 10). The decimal reduction time is dependent on the temperature, the type of microorganism and the composition of the medium containing the microorganism.

Effect of pH on D values

- C. botulinum* spores in three food products at 111°C

pH	spaghetti in tomato cheese sauce	macaroni creole	spanish rice
4.0	0.128	0.127	0.117
4.2	0.143	0.148	0.124
7.0	0.515	0.568	0.550

Z-value



- The Z-value is the increase or decrease in temperature required to reduce or increase the decimal reduction time by one decimal. It is a measure of the change in death rate with a change in temperature

Sterility - Factors affecting heat resistance of micro-organisms

- Water
 - decreasing moisture increases resistance
- Fat, protein and carbohydrate
 - presence in solution tends to increase resistance of some micro-organisms
- Salts
 - effect is variable
- pH
 - microbes are most heat-resistant at optimum pH

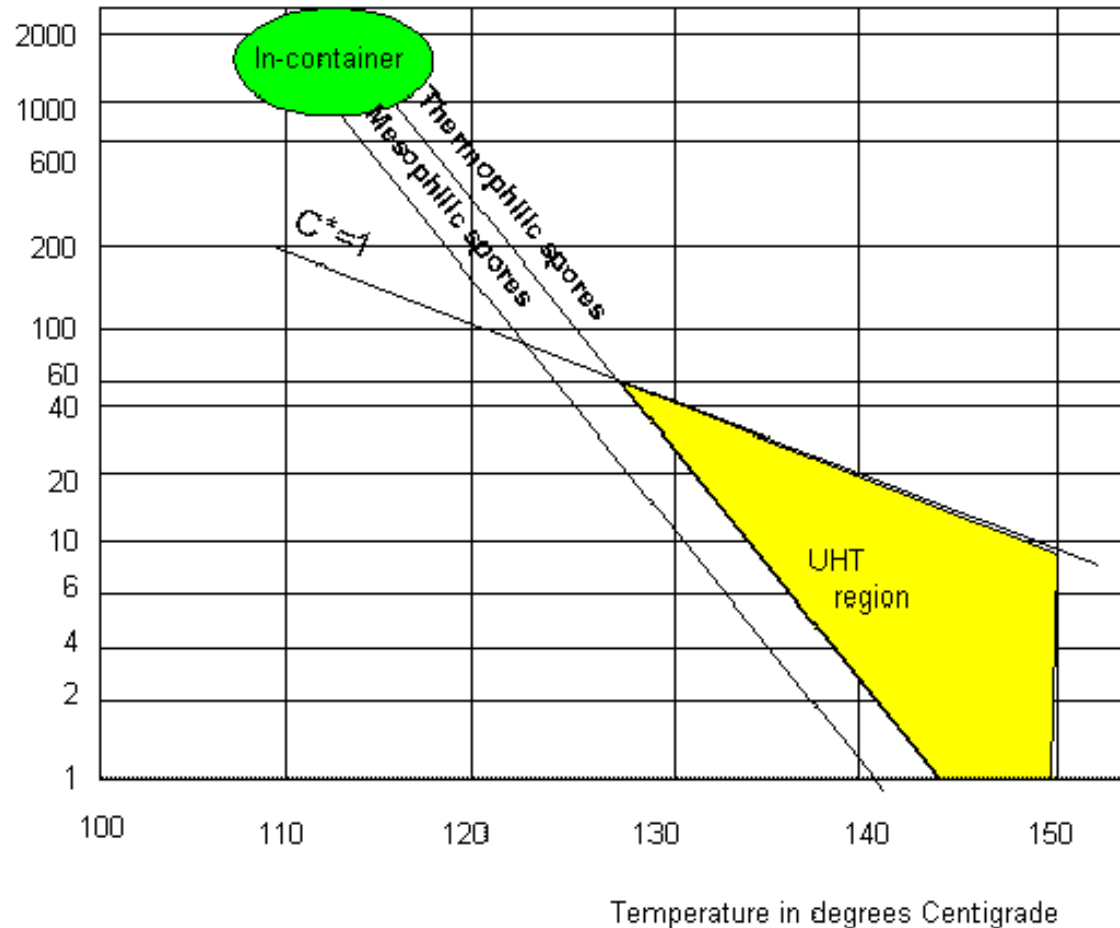


Sterility - Factors affecting heat resistance of micro-organisms

- Number of organisms
 - Larger numbers lead to higher degree of resistance
- Age of organisms
 - Most resistant in stationary phase, least resistant in exponential phase
- Growth temperature
 - Resistance tends to increase with incubation temperature; mechanism not clear

Sterilisation region

Heating time in seconds

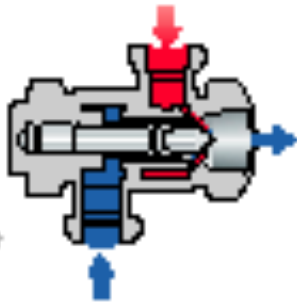


Dairy Processing Handbook, 2003

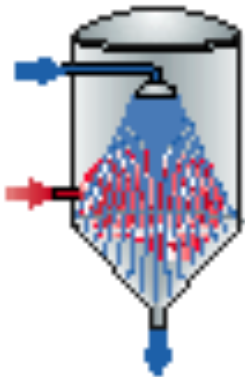
Heating methods

- Direct heating methods
 - Steam injection
 - Steam infusion
- Indirect heating methods
 - Plate heat exchanger
 - Tubular heat exchanger
 - shell and tube
 - shell and coil
 - double tube
 - triple tube
 - Scraped surface heat exchanger
 - Double-cone

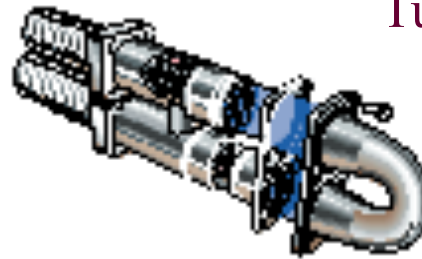
UHT heat systems



Steam injection nozzle



Steam infusion



Tubular heat exchanger

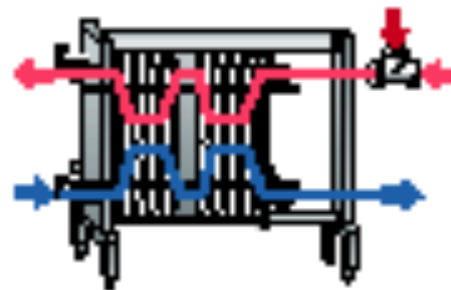
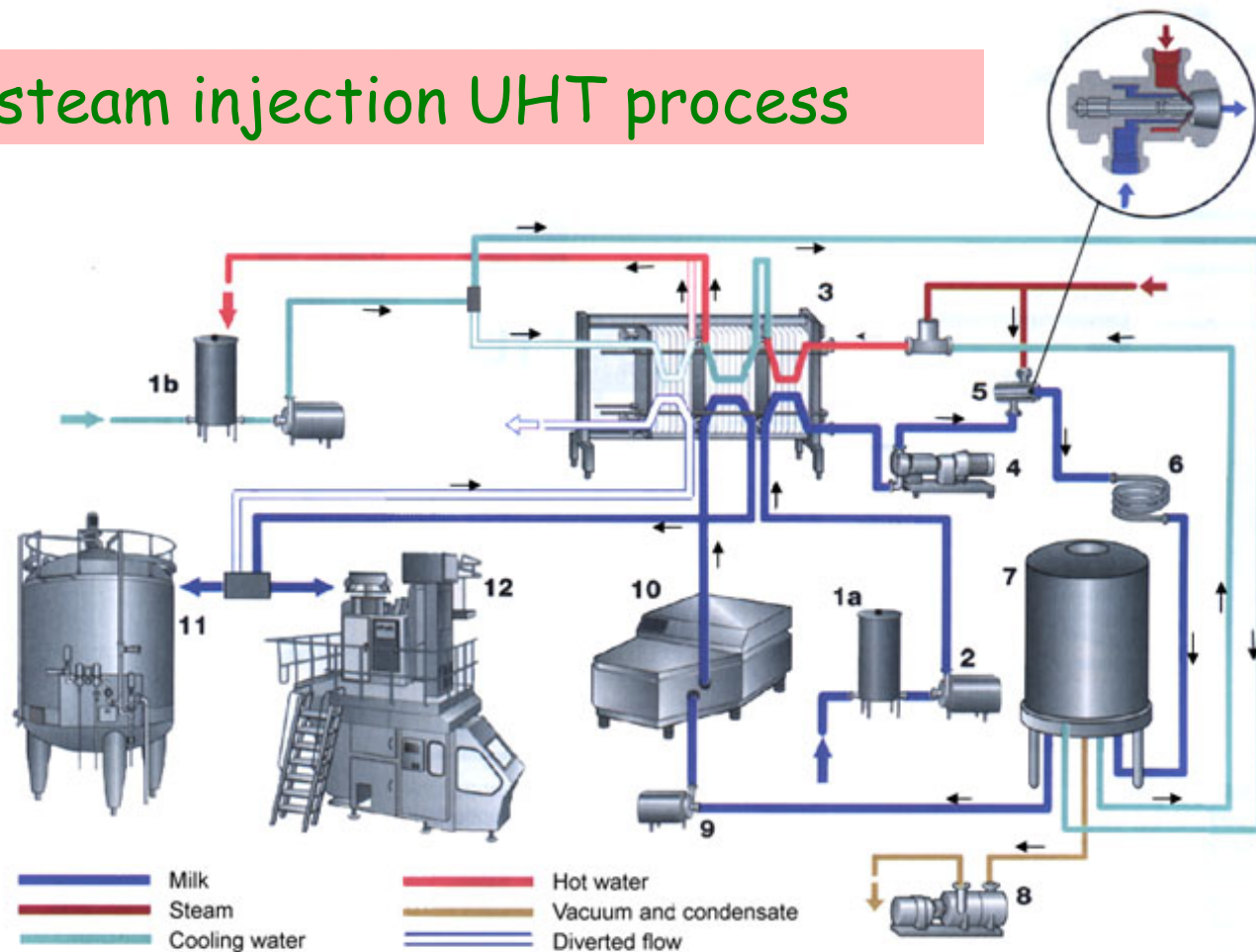


Plate heat exchanger



Scrapped surface heat exchanger

Direct steam injection UHT process

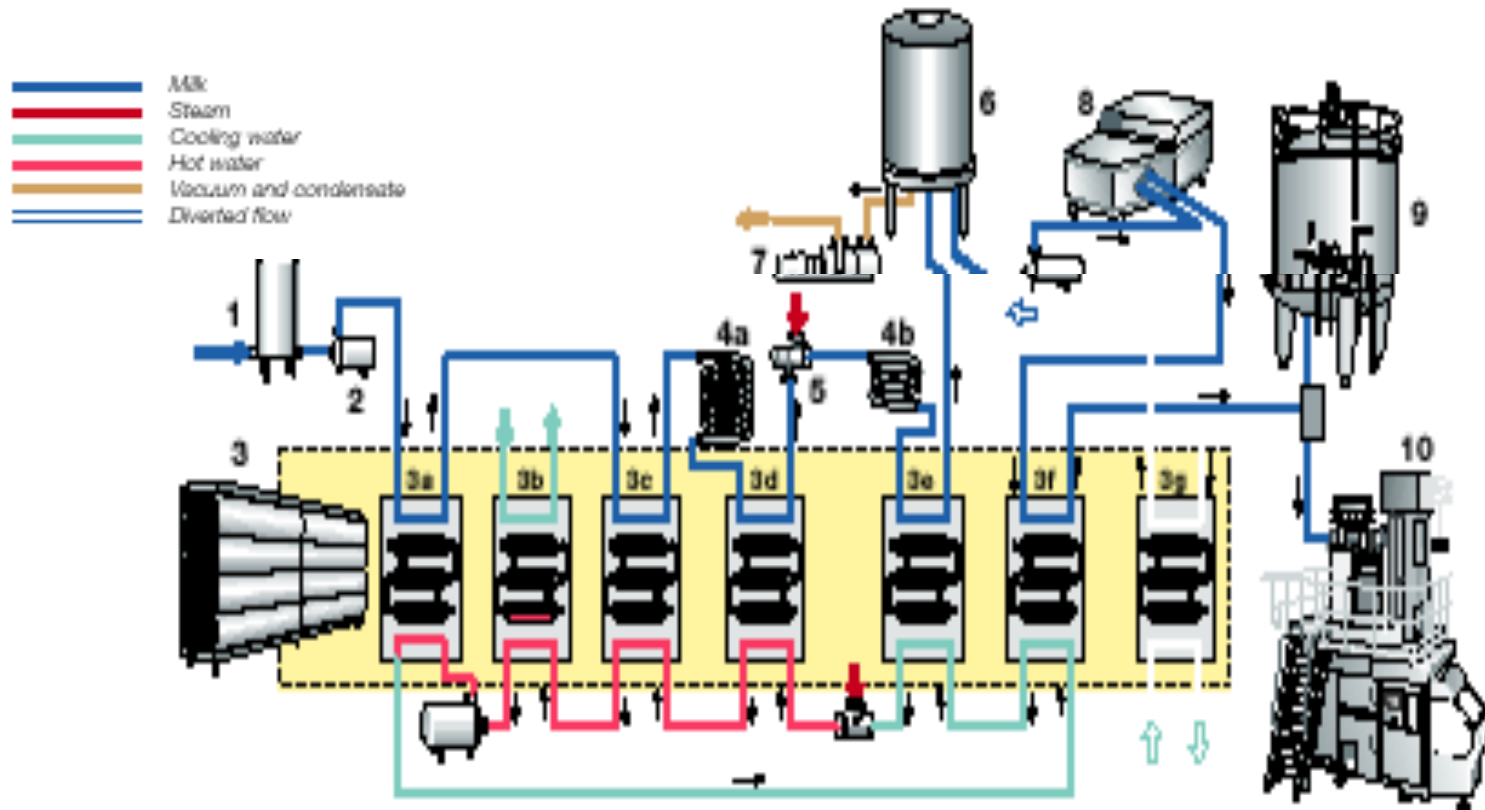


- 1a Balance tank milk
- 1b Balance tank water
- 2 Feed pump
- 3 Plate heat exchanger
- 4 Positive pump

- 5 Steam injection head
- 6 Holding tube
- 7 Expansion chamber
- 8 Vacuum pump
- 9 Centrifugal pump

- 10 Aseptic homogenizer
- 11 Aseptic tank
- 12 Aseptic filling

Combined direct and indirect heating system



Dairy Processing Handbook, TetraPak

Indirect UHT system

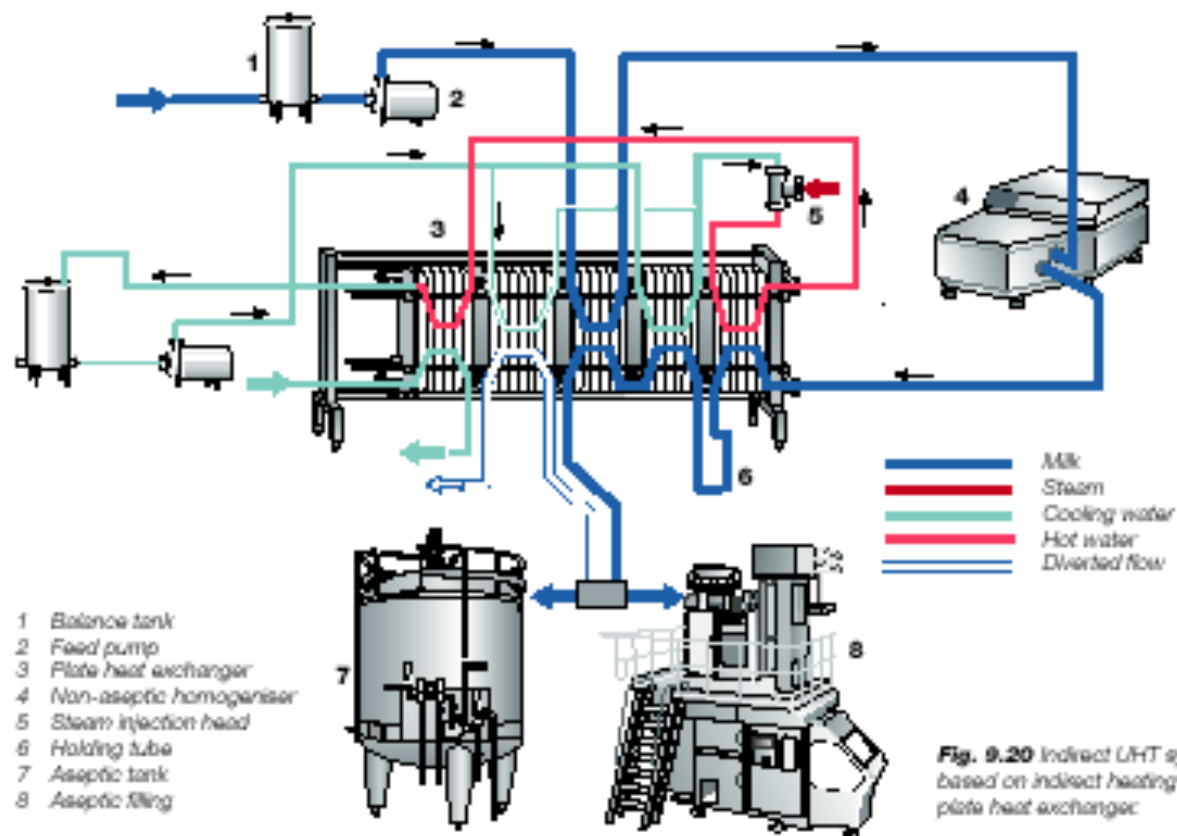
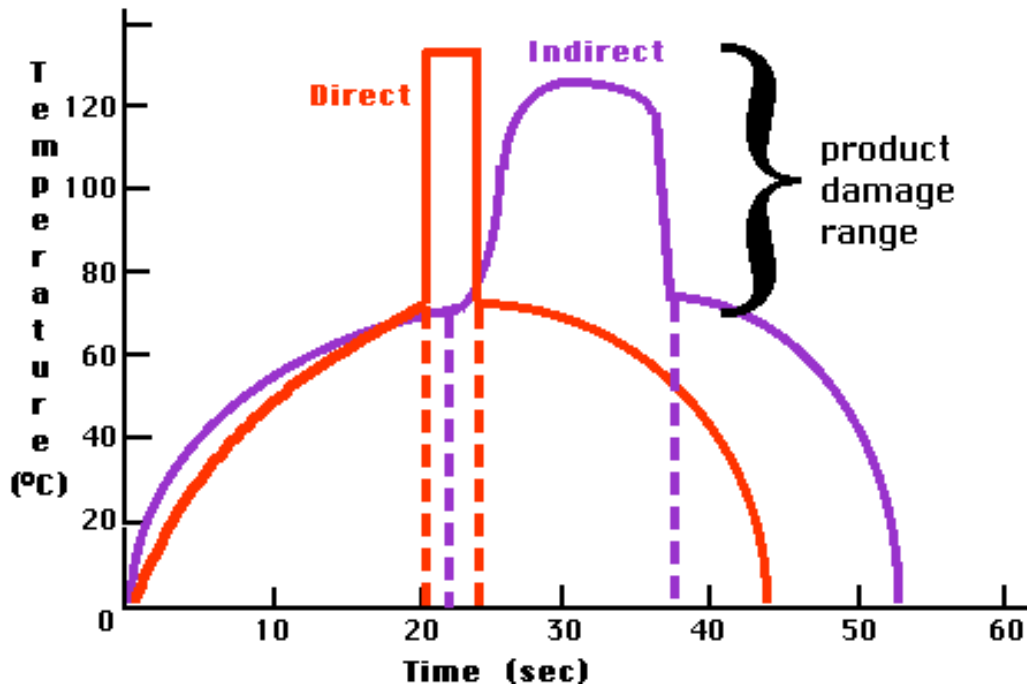


Fig. 9.20 Indirect UHT system based on indirect heating in a plate heat exchanger.

Direct vs indirect - product damage

Direct and Indirect Continuous Sterilization



<http://www.foodsci.uoguelph.ca/deicon/uht.html>

Changes during UHT processing

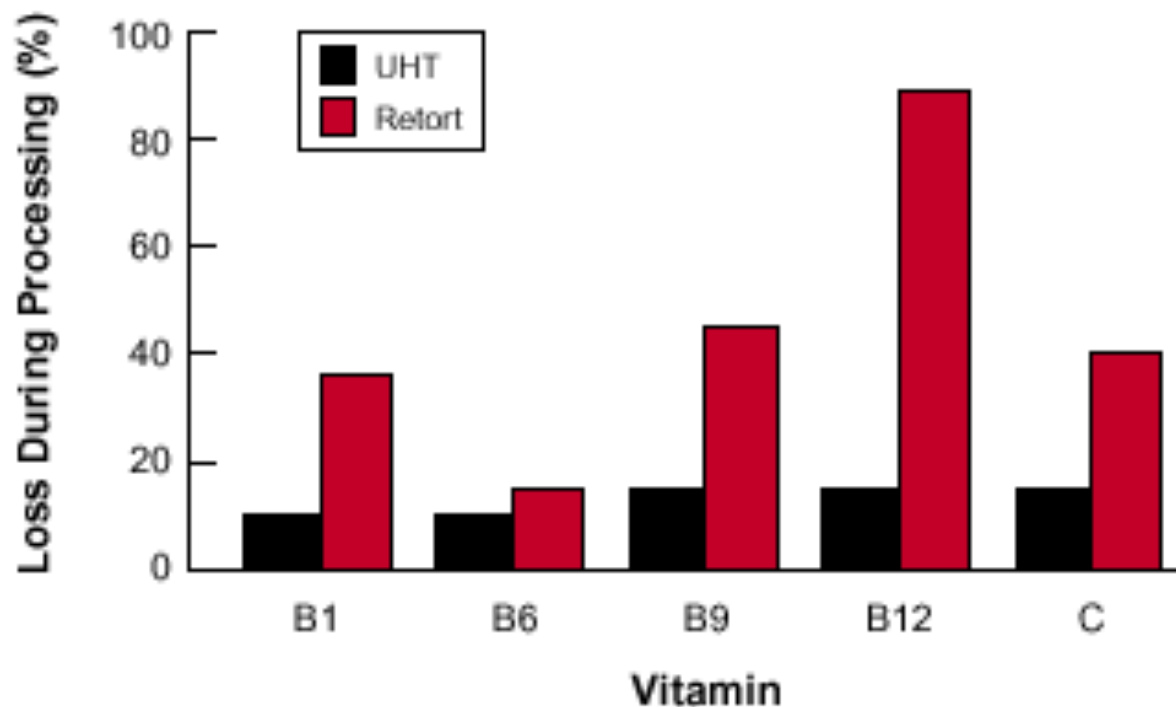
- Inactivation of enzymes
- Maillard browning reactions
- Losses of vitamins
- Losses of amino acids
- Denaturation and complex formation

Nutritional effects

Constituents	Heat effects
Fat	No changes
Lactose	Marginal changes
Proteins	Partial denaturation of whey proteins
Mineral salts	Partial precipitation
Vitamins	Marginal losses

Dairy Processing Handbook, 2003

Vitamin loss



(Source: M. Rosenberg, University of California/Davis, in *Encyclopedia of Dairy Sciences*, 2003.)

Age gelation

- Age gelation is an aggregation phenomenon that affects shelf-stable, sterilized dairy products, such as concentrated milk and UHT milk products. After weeks to months storage of these products, there is a sudden sharp increase in viscosity accompanied by visible gelation and irreversible aggregation of the micelles into long chains forming a three-dimensional network. The actual cause and mechanism is not yet clear, however, some theories exist:
 - Proteolytic breakdown of the casein: bacterial or native plasmin enzymes that are resistant to heat treatment may lead to the formation of a gel
 - Chemical reactions: polymerization of casein and whey proteins due to Maillard type or other chemical reactions
 - Formation of kappa-casein- β -lactoglobulin complexes

Advantages of UHT processing

- High quality:
 - The D and Z values are higher for quality factors than microorganisms. The reduction in process time due to higher temperature (UHTST) and the minimal come-up and cool-down time leads to a higher quality product.
- Long shelf life:
 - Greater than 6 months, sealed without refrigeration

Advantages of UHT processing

- **Packaging size:**
 - Processing conditions are independent of container size, thus allowing for the filling of large containers for food-service or sale to food manufacturers (aseptic fruit purees in stainless steel totes).
- **Cheaper packaging:**
 - Both cost of package and storage and transportation costs; laminated packaging allows for use of extensive graphics

Difficulties with UHT

- **Sterility:**
 - Complexity of equipment and plant are needed to maintain sterile atmosphere between processing and packaging (packaging materials, pipework, tanks, pumps); higher skilled operators; sterility must be maintained through aseptic packaging
- **Particle Size:**
 - With larger particulates there is a danger of overcooking of surfaces and need to transport material - both limits particle size
- **Equipment:**
 - There is a lack of equipment for particulate sterilization, due especially to settling of solids and thus overprocessing
- **Keeping Quality:**
 - Heat stable lipases or proteases can lead to flavour deterioration, age gelation of the milk over time - nothing lasts forever! There is also a more pronounced cooked flavour to UHT milk.



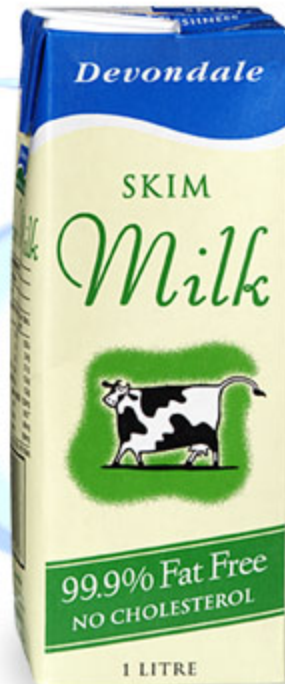
UHT recombined and non-recombined milk products

- Plain UHT milk
- Fat-modified UHT milk
- UHT filled milk
- Lactose-free milk
- Fortified UHT milks

Organic UHT milk



Devondale,
Australia



Beyti, Egypt



Rachel's
Organic, UK

Innovations challenges for UHT milk

- UHT milk with bioactive components
 - Minerals (Calcium, Magnesium, Iron)
 - Omega-3 fatty acids
 - Conjugated linoleic acids (CLAs)
 - Phytosterol
 - Lactoferrin
 - Peptides
 - Fibre

UHT milk with omega fatty acids



Omega-3, Parmalat, Uruguay

Dawn, Ireland uses the FlexDos from TetraPak (AromaPak) - injects flavourings, colourings and functional food substances into products immediately before filling.



Dawn, Ireland

UHT fortified milk



Mg (Candia, Fr)



Iron (Candia, Fr)



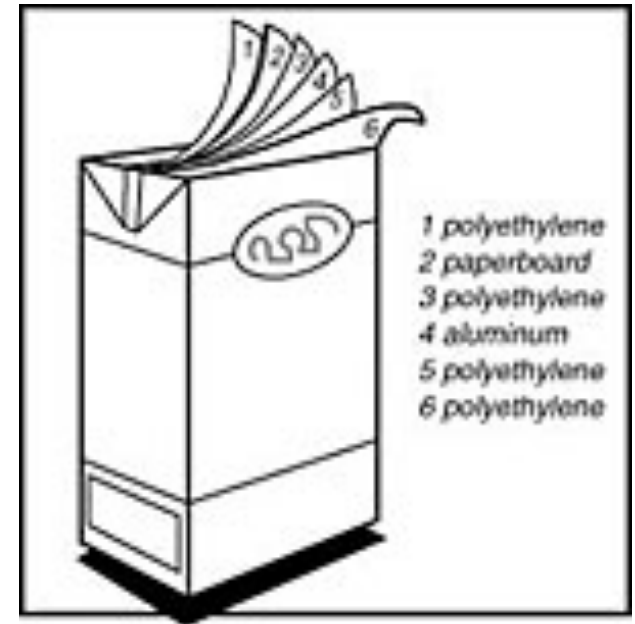
Vitamins (Clover,
South Africa)

Aseptic packaging

- Commonly called "drink boxes," aseptic packages are the result of a beverage and liquid food system that allows perishable food products to be distributed and stored without refrigeration for periods up to six months or more
- Aseptic processing is a major advance over traditional canning techniques.

Composition of aseptic packaging

- Paper (70 percent) -- provides stiffness, strength and the efficient brick shape
- Polyethylene plastic (24 percent) -- forms the seal on the innermost layer that makes the package liquid-tight, and a protective coating on the exterior keeps the package dry.
- Aluminum (6 percent) -- forms a barrier against light and oxygen, eliminating the need for refrigeration and preventing spoilage without using chemical preservatives.



Benefits of aseptic packaging

- **Convenience**
 - Aseptic packages are portable, lightweight, and shatterproof and easily transportable
- **Food Safety**
 - the aseptic process and carton together ensure that the liquid food or beverage inside is free from harmful bacteria and contaminants.
- **No refrigeration required**
- **Long shelf life**
- **More nutrition**
 - Compared with canning, products can retain more nutrients as well as natural taste, colour and texture

OzScientific

Environmental benefits

- Low packaging to product ratio -- typically 96 percent product and only 4 percent packaging material by weight
- Drink boxes save energy at every stage of their lifecycle.
 - Empty packages are stored flat or on rolls, rather than pre-formed like glass, metal and most plastic containers. As a result, one standard semi-trailer truck can transport 1.5 million empty drink boxes versus only 150,000 glass bottles.

<http://www.worldwise.com/recaspacpam.html>



Environmental benefits

- Filled drink boxes conserve energy in transport.
 - Their brick shape is space-efficient, and because they are light weight, more product can be shipped in fewer trucks than heavier beverage packages.
- Because drink boxes preserve their contents without refrigeration, no refrigerated trucks, special warehouses, or retail freezers or coolers are needed. This saves both electricity and gas

<http://www.worldwise.com/recaspacpam.html>



Environmental issues

- The downside is that at this time, aseptic packaging has limited facilities for recycling, and drink boxes that are not recycled sit in landfills, because they are not biodegradable.

<http://www.worldwise.com/recaspacpam.html>

Recycling aseptic packaging

- **Hydropulping**

- Soaking & blending of of cartons
- Separation of paper fibre from layers of polyethylene and aluminium
- Pulp fed directly to papermaking machine for making paper towels, tissues and writing paper (no de-inking required as the ink is separated off with plastic)
- Can be used for UHT milk and juice cartons

<http://www.worldwise.com/recaspacpam.html>

Thank you!

- OzScientific offers innovative ingredient solutions for functional & bioactive dairy/food ingredients
 - Business intelligence: Market intelligence, Strategic analysis and Innovation management
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