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2nd Biennial Ultra-High Temperature (UHT) Symposium

Various Authors
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SECOND BIENNIAL UHT SYMPOSIUM.
Western Center
Utah State University
March 19-20, 1996

Agenda

Tuesday, March 19

7:30  Registration/continental breakfast

Effect of UHT processing on product ingredients - Chair: Začow
8:30  Don McMahon, USU - Heat effects on β-lactoglobulin,
9:15  Paul Savello, USU - Effect of UHT processing on flavors
10:00 Break
10:30 Steven Dimler, Ross Labs - Vitamin and nutrient degradation
11:15 Woodrow Monte, Arizona State University - Ingredients for UHT products
12:00 Lunch

New product development - Chair: Fehling
1:30  Paul Savello, USU - Modifying skim milk using UHT equipment
2:15  Paul Scharfman, Specialty Cheese Co. - New product marketing
3:00  Break
3:30  Pat Fehling, Fehling Associates - Product development
4:15  Charles Watkins, Robert Bosch Company - UHT packaging options
5:00  Adjourn
6:30  Dinner

Wednesday, March 20

Safety and sanitation in UHT systems - Chair: Savello
8:00  Continental breakfast
8:30  Bart Weimer, USU - Milk quality for UHT processing
9:15  Chuck Sizer, Tetra Pak - Time/temperature relationships and destruction of spores.
10:00 Break

Where is UHT heading? - Chair: McMahon
10:30 Bob Simpson, APV Engineering - Choosing a UHT system
11:15 Greig Zadow, Zadow & Associates - Future directions of UHT
12:00 Lunch
1:30  Chuck Meek, Tetra Pak - Solving practical problems in UHT processing
2:15  Open Forum: Problems and Issues in UHT processing of milk
3:00  Adjourn
Heat effects on \( \beta \)-lactoglobulin - Donald McMahon

Effects of UHT processing on flavors - Paul Savello

Vitamin and nutrient degradation - Steven Dimler

Ingredients for UHT products - Woodrow Monte

Modifying skim milk using UHT equipment - Paul Savello

New product marketing - Paul Scharfman

Product development - Pat Fehling

UHT packaging options - Charles Watkins

Milk quality for UHT processing - Bart Weimer

Time/temperature relationships and destruction of spores - Chuck Sizer

Choosing a UHT system - Bob Simpson

Future directions of UHT - Greig Zadow

Solving practical problems in UHT processing - Chuck Meek
Heat-Induced Changes in β-Lactoglobulin and the Stability of UHT Milk

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ABSTRACT

A theory describing the age-gelation of UHT milk was developed based on changes in storage stability and microstructure of concentrated milk after UHT processing. This included studies on extent of whey protein denaturation during UHT processing and changes in casein micelle size, influence of lactose on protein crosslinking, influence of milk pH on casein micelle surface potential, influence of phosphates on shelf life, influence of UHT heating conditions on shelf life, and movement of milk proteins during storage of UHT milk.

It is proposed that age-gelation of UHT milk involves release of the β-lactoglobulin/κ-casein complex (βκ-complex) that is formed during heating from the casein micelles followed by subsequent aggregation of the βκ-complexes and formation of a three-dimensional network of crosslinked proteins. Release of the βκ-complex is observed as protuberances and tendrils on the micelle surface. Involvement of the casein micelles in age-gelation occurs through attached βκ-complex appendages and not via direct contact between micelle surfaces. The numerous observed phenomena related to age-gelation of UHT milk can be explained based upon this theory.

INTRODUCTION

Age-gelation is one factor that limits shelf-life and hinders commercial exploitation of UHT milks, especially concentrated milks. The mechanism of age-gelation, however, until now has remained unsolved. It has been described as coagulation, sweet curd formation, thixotropic gel formation, age thickening, partial gelation, or lumpiness. It is usually preceded by a sharp rise in viscosity culminating in gel formation within one to three weeks to a custard-like consistency. It is an irreversible condition.

Factors Affecting Age-gelation

Onset of age-gelation is affected by heat treatment, homogenization and sequence of processing steps, milk solids content, milk composition, milk quality, and storage temperature. Processing milk at higher temperatures and longer holding times typically retards gelation. However, at equivalent heating effectiveness, higher heating temperatures with shorter exposure times make the milk more susceptible to gelation. Direct heating methods, such as steam injection, thus offer less protection against gelation during storage than does indirect heating. The more severe the heat treatment, the more resistant the micelles become to changes that promote gelation.

There have been conflicting reports on the effect of storage temperature on age-gelation of UHT milk: some have suggested that lower temperatures accelerate gelation; others that higher temperatures accelerate gelation. Differences in milk or UHT methods have made it difficult to obtain a consensus on what is happening during storage of UHT milk. It is further complicated when it is realized that gelation is not the only phenomenon that limits shelf life of UHT milks. Product failure can also come about because of browning, formation of a fat layer, or irreversible (that is, non-dispersible) sedimentation.
Proposed Mechanisms for Age-gelation

Age-gelation has been attributed to various changes observed during storage of UHT milk that correlate with the gelation time. In general, it has been investigated in terms of what causes the casein micelles to aggregate. Therefore, most research has focused on what happens to the casein micelles during (and after UHT processing) that makes them lose colloidal stability and form a three-dimensional gel network.

Stability of casein micelles in milk has been attributed to the presence of surface κ-casein, colloidal calcium phosphate, a high surface potential, and steric stabilization. On that basis, gelation is preceded by changes at the casein micelle surface because they enhance interaction between micelles and allow them to aggregate. Such changes may initially take place slowly without affecting stability, then after exceeding some degree of surface alteration, the particles aggregate, culminating in gelation. What is suggested in this paper is an alternate approach. Rather than the casein micelles aggregating, they are considered only as acting as the source of the κ-casein/β-lactoglobulin complex (βκ-complex) which is slowly released into the milk serum.

As discussed in the review of UHT milk by Harwalkar [1] there have been two theories proposed to explain age-gelation of UHT milks. Observed proteolysis during storage of UHT milk suggested that enzymic modification of casein causes rearrangement of the milk proteins leading to gelation of the casein micelles. However, the absence of a quantitative relationship between gelation time and proteolytic activity has prompted others to attribute gelation to physicochemical processes rather than enzymic proteolysis. Included in this are: processes involving whey proteins, chemical modification of casein micelles by Maillard reactions, milk salts, modification of κ-casein during storage, sulfide-disulfide reactions, changes in casein micelle surface potential, and casein micelle dissociation.

Our research implicates an important role of dissociation of proteins (specifically the βκ-complex) from the micelles. These large protein complexes then accumulate in the serum phase until they reach a critical concentration and eventually form a gel. Consequently, age-gelation of UHT milk should be thought of as taking place in the serum phase (that is, comparable to gelation of whey proteins) rather than as aggregation of casein micelles. This theory can then be used to explain the multitude of observations that have been made about UHT milk so that they no longer need be considered contradictory but rather as complimentary facets of the same overall process. Some suggestions on how the proposed theory could be tested are listed in the appendix.

EXPERIMENTAL

The experiments upon which this age-gelation theory was built, were conducted using milk obtained from Utah State University Dairy Products Laboratory. To promote gelation, most experiments were conducted on milk concentrated by ultrafiltration, some by reverse osmosis. Typically, milk was pasteurized and then ultrafiltered to 3X (volume reduction) at 50°C using 20 kD polysulfone membranes. It was then cooled and stored overnight and UHT processed the following day. All UHT processing was conducted using an Alfa-Laval Sterilab pilot plant system by either plate-heat exchange or steam injection.

Product flow rate was 100 L/h. And for indirect heating a typical heating profile involved heating to 80°C in heat exchanger I (residence time 58 s) with 8 s holding time, followed by heating to 140°C in heat exchanger II (residence time 97 s) with a 4 s holding time, cooling to 60°C by heat exchanger III (residence time 36 s) for homogenizing, then further cooling to room temperature in heat exchanger IV (residence time 30 s) and packaging under hyperfiltered, positive air pressure. When the steam injector was used heat exchanger I was used for preheating, followed by steam injection to the UHT temperature, then flash evaporation to the preheat temperature followed by cooling in heat exchangers III and IV.

Various attributes of the processed milks were then evaluated during storage. This included: extent of whey protein denaturation [2, 3], influence of lactose on protein crosslinking [4, 5], influence of milk...
Denaturation of Whey Proteins

For milk processed through a UHT system, there was increased whey protein denaturation as the processing temperature was increased. Using indirect heating to 140°C produced about 60% denaturation. The amount of denaturation was also higher in concentrated milks than in skim milk but there was no difference in the pattern of whey protein denaturation. Most of the denatured whey proteins become associated with the casein micelles and so there is an increase in casein micelle size with additional protein material being observed to adhere to the casein micelle surfaces. This was especially obvious in 3x UF skim milk heated to 140°C which had a diffuse layer of material around the casein micelles. We also observed that when milk was UHT heated, some casein micelles aggregated, while the incidence of submicellar casein (or micelle fragments) was increased.

The shape of casein micelles was also altered depending on the intensity of heat treatment. After heating milk to UHT conditions, formation of so called spikes, hairs, tendrils and appendages on the micelles were observed. An open micellar structure was observed if osmium tetroxide staining was omitted during examination by electron microscopy. Osmium tetroxide is commonly used to impart heavy metal staining and improves contrast in electron micrographs. This staining, however, confers an artifactually compact appearance to the micelles. Probably, the open appearance of the micelle is more representative of its actual structure. Typically, the surface of micelles in UHT samples appeared rough as though having short tendrillar appendages.

Processing Temperature/Time

For people working in the UHT milk processing industry, it is recognized that small changes in processing parameters can affect product stability, especially in formulated products. Using skim milk concentrated by reverse osmosis, we have made some observations on the influence of UHT heating conditions on product stability. The most obvious is that product shelf life can be limited because of a variety of product defects including gelation, irreversible sedimentation, and product discoloration from browning.

Milks stored at 15°C and processed by steam injection gelled faster than milk processed by indirect plate heating. They also had more sedimentation and sedimentation increased with severity of heating (that is, higher temperatures or longer holding times) during steam injection. There was more sedimentation during storage at 35°C than at 15°C to the extent that at 35°C, sedimentation was the factor that limited shelf life. Even when stored at 15°C, the 2X milks that had the more severe steam injection heat treatments sedimented excessively.

As expected, browning was more intense for samples processed with more severe heat treatment such as higher temperatures, longer holding times, or indirect heating. Shelf life of indirectly heated 2X milk stored at 35°C was limited by browning.

Protein Crosslinking

In gelled UHT milk, the casein micelles of milk stored at 20°C or 4°C had tendrils connecting micelles to each other to form a three-dimensional network. In samples stored at 35°C (which includes those with the most browning), the casein micelles did not show any tendrils protruding from the surface of particles and there was no gelation. These tendrils were most likely a linear aggregate of several polypeptide chains comprising the βK-complex that had been released from the casein micelles. Their absence in samples stored at 35°C suggests that protein modification had occurred within the micelles to the extent that it prevented release of the βK-complex.

These tendrils were observed in samples with and without lactose, although no browning occurred if the reducing sugar was not present. Having lactose, no sugars, or sucrose present made no difference to the rate at which the UHT milks gelled. It was
thus concluded that age-gelation is not promoted by occurrence of the Maillard reaction. Rather, intramicellar protein-protein reactions, including those initiated by carbohydrate-protein browning reactions, provide protection against age-gelation by preventing dissociation of the βκ-complex from the micelles. The streaking often observed in SDS-PAGE of UHT milk can be a result of both types of protein modifications.

**Micelle Dissociation and Gelation**

Using immunogold labeling and transmission electron microscopy the gradual dissociation of proteins from the micelles in UHT concentrated UF milk was observed. At the beginning of storage, the β-lactoglobulin label was mainly associated with the surface of micelles. After four months of storage, there was labeling still associated with the micellar surfaces but the intermicellar matrix was also well labeled. At eight, ten and twelve months of storage, the bulk of the labeling was on the intermicellar matrix with very little on the micellar surfaces. This gradual transfer of labeling from the micelles to the intermicellar matrix suggested that the initial βκ-complex moved into the intermicellar serum during storage.

Labeling for κ-casein followed a similar trend. Initially the labeling was on the micelles. After six and eight months, there was increased labeling observed within the intermicellar matrix, mainly between adjacent micelles. The labeling appeared as linear patterns as well as clumps. There were few tendrillar connections between micelles through eight months of storage; these structures proliferated by ten months when the milk gelled. The labeling after ten months was very dispersed, but involved linkages between micelles. This trend was accentuated after twelve months in which there were many linear clusters between adjacent micelles.

For the first eight months of storage, labeling for β-casein and αs₁-casein was almost exclusively on the micelles. After ten months, the micelles were less heavily labeled, and there was increased labeling in the intermicellar matrix. Thus, some of these caseins also migrate from the micelles to the intermicellar spaces and become associated with the βκ-complex as gelation occurs.

**THE MECHANISM OF AGE-GELATION**

The mechanism by which age-gelation of UHT milk occurs involves release of βκ-complex from the casein micelles followed by subsequent aggregation of the βκ-complex, and formation of a three-dimensional network of crosslinked proteins. Release of the βκ-complex is observed as protuberances and tendrils on the micelle surface. Involvement of the casein micelles in age-gelation occurs through attached βκ-complex appendages and not via contact with the micelle surfaces.

Ultra-high temperature processing of milk denatures β-lactoglobulin, which forms complexes with micellar κ-casein. Apparently, formation of this βκ-complex changes the conformation of κ-casein and predisposes it to subsequent dissociation from the micellar moiety. This conformational change weakens the interactions between κ-casein and other proteins (probably αs₁-casein) in the casein micelle, so that it is no longer anchored as tightly to the micelle as native κ-casein. Then as the UHT milk is stored, the anchor is disrupted and κ-casein is released along with its attached β-lactoglobulin.

The βκ-complexes are quite large (up to 200 nm in length) and comprise multiple κ-casein and β-lactoglobulin molecules. Consequently, there are multiple anchor sites of attachment of the βκ-complex to the micelle and release of the complex from the micelles is not instantaneous. As anchor sites are broken, the complex will gradually be released and extend from the micelle surface as typically seen in micrographs. If only partial release occurs, then the micelle's effective diameter is increased and viscosity increases. Complete release of the βκ-complex reduces micelle diameter and viscosity decreases. Even by the time gelation occurs many of the βκ-complex molecules will still be physically associated with the surface of the micelles.

Age-gelation of UHT milk can be considered as a two-phase process. In the primary (or lag) phase, reactive units are formed by release of βκ-complex from micelles. This can be induced by any action (enzymic or non-enzymic) that weakens
bonds that anchor the complex (via κ-casein) to the micelle. The secondary (or aggregation) phase consists of the accumulation of βκ-complex in the milk serum between micelles. When the concentration of proteins in the serum reaches a critical level, gelation occurs. Those micelles that still have attached βκ-complex will also be incorporated into the network.

Many of the observed phenomena related to age-gelation of UHT milk can be explained based upon this theory of βκ-complex release from the casein micelles followed by formation of a βκ-complex gel network.

Heat Treatment Intensity
Increasing the heat intensity during UHT heating (by either increasing temperature or holding time) delays gelation because it increases the extent of chemical crosslinking within the micelles. The βκ-complex is more strongly bound to the micelle and its release from the micelle is delayed. Thus, retort sterilized milk is more stable than UHT milk. However, increased heat treatment tends to initiate more non-enzymatic browning reactions and product shelf life is limited by subsequent production of brown pigments.

Storage Temperature
Storing UHT milk at temperatures of >30°C delays gelation but shelf life is limited because of Maillard browning. Chemical crosslinking of proteins can occur via lactose-lysine interactions as well as other reactions between amino acid side groups without involvement of a reducing sugar. Such crosslinking prevents release of proteins (especially the βκ-complex) from the micelle. Lowering storage temperature to 4°C did not affect gelation even though β-casein dissociates from the micelles at low temperature because of reduced hydrophobic interactions. This suggests that the βκ-complex is predominantly held to the micelle by electrostatic forces (including calcium-mediated salt bridges) to αs1-casein. Even though proteolysis is accelerated at higher storage temperature, its effect on breaking βκ-complex anchor sites is mitigated by increased protein crosslinking covalently binding the βκ-complex to the micelles. Thus, extensive proteolysis can occur without age gelation taking place.

Milk Concentration
While UHT milk often remains stable without gelation for more than a year, concentrated milks gel much faster. Ultrafiltered milk may gel in less than 6 months depending on processing conditions. Its higher protein concentration increases the number of protein particles per unit volume of milk serum without significantly changing the concentration of lactose or soluble salts. Also, the micelles occupy a larger percentage of the total milk volume and so complete release of the βκ-complex is not required for contact between them. Thus, a smaller fraction of the βκ-complex need dissociate from the micelles during storage to reach the critical concentration required for. Furthermore, we have observed that the denatured whey proteins are less tightly bound to the casein micelles in concentrated milk and would be released more quickly.

Addition of phosphates
It has long been observed that adding orthophosphates to UHT hastens gelation while adding hexametaphosphate delays gelation. This can be explained based on the effect these salts have on the electrostatic interactions between the βκ-complex and the other proteins in the casein micelle. Adding orthophosphates (or other calcium complexing agents) would lower calcium ion activity and compete with ionized protein side groups that participate in calcium bridging. This would reduce the extent of ionic bonding between proteins, allowing the βκ-complex to more easily escape the micelle. In contrast, adding hexametaphosphate (especially at low levels such as 1 mM where it is most effective in retarding age-gelation) would allow bridging between ionized groups that would not otherwise form an ionic bond. This would hold the κ-casein more tightly to the micelle and delay release of the βκ-complex.

Proteolysis
Both proteolysis by plasmin and psychrotrophic bacterial proteinases have been implicated in accelerating age-gelation. While they have not been shown to directly act on the βκ-complex they can hydrolyze the proteins that anchor the complex to the micelles. Such hydrolysis would allow quicker release of βκ-complex
from the micelles. Plasmin more rapidly hydrolyzes β-casein than αs1-casein, while the bacterial proteases attack αs1-casein. If the βκ-complex is primarily anchored to αs1-casein then any hydrolysis of αs1-casein would promote gelation.

Adjusting pH

As the pH of milk is increased above its native level, it gels more rapidly after UHT processing. This is expected because at higher pH, although the denatured β-lactoglobulin still interacts with κ-casein, less of the resultant βκ-complex is attached to the casein micelles. At pH 6.85, age-gelation occurs in about half the time of pH 6.7 milk. At pH 7.3, there is very little micellar-attached βκ-complex and so the milk gels within the first few weeks of storage. An effect of lowering pH on age-gelation has not been observed because milk at pH < 6.4 typically heat precipitates during UHT processing.

CONCLUSION

Age-gelation of UHT milk can be considered as a consequence of the following steps:

**Primary Phase:**
1. UHT processing of milk denatures β-lactoglobulin.
2. Denatured β-lactoglobulin covalently bonds with κ-casein to form large polymeric βκ-complexes.
3. Bonding of β-lactoglobulin to κ-casein to form βκ-complex weakens ionic bonds that anchor κ-casein (via αs1-casein) to the micelles.
4. During storage of UHT milk, the βκ-complex is gradually released from the micelle as multiple anchor sites of κ-casein are broken.

**Secondary Phase:**
5. The βκ-complex accumulates in the serum phase as large protein aggregates that have been completely released from the micelles or as long tendrils that are still partially attached to micelles.
6. When a critical volume concentration of βκ-complex is attained, a gel network of crosslinked βκ-complex is formed with any attached casein micelles being incorporated into the network.
7. Crosslinking of the βκ-complex continues, and other proteins are incorporated into the network, until a semi-rigid gel is produced.

ACKNOWLEDGMENTS

Age-gelation of UHT milk has been studied extensively at Utah State University using concentrated milk. This research was initiated by Prof. Rodney Brown (through funding from USDA ARS) and also included Dr. Paul Savello (who installed and kept the UHT system operational) and the author. The author's students made contributions during their time at Utah State University: Bashir H. Yousif (MS), Venkatachalam Narayanaswamy (MS), Douglas W. Olson (MS), Mohamed A. Elhilaly (MS), and M. Christopher Alleyne (PhD) who all received support from the National Dairy Board (USA) through the Western Center for Dairy Protein Research and Technology. The author also acknowledges the experimental work conducted by Je Hong Ryue, Dr. Mrudula Kalpalathika, and Dr. Mohan Reddy. Dr. Miloslav Kalab and Dr. Nabil Youssef provided guidance on electron microscopy. The immunolabeled micrographs were produced by Dr. Alleyne and the stereo­micrograph by William McManus. The photographic plate was prepared by Gary Pedersen.

REFERENCES


APPENDIX

A round table discussion was held after the previous Ultra-High Temperature Processing of Milk Symposium, March 2-3, 1994 at Utah State University. A list of ideas for further research on UHT milk was developed. It is by no means complete, but perhaps it will help generate ideas for those who may desire to continue this research.

Possible UHT Experiments

• Fortify UHT milk with whey proteins.
• Add protease inhibitors after UHT heating.
• Change temperatures during storage (for example, 40° then 25° or 4°C or visa versa).
• Obtain psychrotrophic bacteria-free milk.
• Treat the milk with immobilized plasmin.
• Remove the glycosides from k-casein.
• Change the mineral content of the milk, especially phosphates.
• Remove some colloidal calcium phosphate.
• Adjust milk pH after UHT heating.
• UHT process severely heated (retorted) milk.
• Add formaldehyde (0.1-.02%) to milk to fix proteins.
• Add native β-lactoglobulin to milk after UHT processing.
• Add UHT processed whey proteins to milk and serum protein-free milk.
• Use a cool storage treatment before UHT processing.

Parameters that should be investigated include:

• Enzyme activity.
• Plasmin activity (plus plasminogen etc).
• Extent of proteolysis.
• Surface changes of casein micelles by electron microscopy.
• Voluminosity.
• Particle size.
• Aggregate characteristics.
• Changes in casein micelles.
• Composition of protein complexes.
• Dissociation of complexes from the micelles.
• Surface hydrophobicity.
• Soluble calcium and phosphate.
• Ionic calcium and phosphate.
• Conductivity.
• Colloidal calcium phosphate characteristics.
• Extent of whey protein denaturation during storage.
UHT Flavored Milks

Paul A. Savello, Ph.D.
Utah State University

Indirect UHT (Plate Exchange)

Preheat: 170°F
UHT: 285°F for 4 sec
1st Cool: ~130°F
Homog: 2000/500 psi
2nd Cool: 70°F

Samples stored at room temperature for 90 days.

Samples taste tested at days 0, 45, and 90 by small group within NFS department.

Questions to answer:

- Difference between direct and indirect heat exchange?
- Difference between adding flavor before or after UHT?
- Flavor changes over storage time at room temperature?
- Concentrated flavored milk changes over storage time at room temperature?

Direct UHT (Steam Injection)

Preheat: 170°F
UHT: 285°F for 4 sec
Flash Cook: ~165°F
Homog: 2000/500 psi
2nd Cool: 70°F

Samples stored at room temperature for 90 days.

Samples taste tested at days 0, 45, and 90 by small group within NFS department.

Ingredients:

- 2% milk
- Orange flavor
- Root beer flavor
- Sugar

Flavors added at 1x, 2x, and 3x levels
Orange-Flavored Milk

Indirect

Before (IB)  After (IA)

1x  2x  3x  1x  2x  3x

Day 0  Day 45  Day 90

DIB  22  28  18
LH  39  33  33
DIB  22  28  18
DIA  28  34  27
LH  39  33  33
LIA  30  32  35
DIA  28  34  27
LIA  30  32  35

Orange-Flavored Milk

2x Day 0  Day 45  Day 90

DIB  26  34  34
LB  33  33  31
DIB  26  34  34
DIA  34  36  32
LH  33  35  31
DIA  34  36  32
LIA  34  44  36

Orange-Flavored Milk

3x Day 0  Day 45  Day 90

DIB  34  36  45
LB  45  41  37
DIB  34  36  45
DIA  37  43  29
LH  45  41  37
LIA  35  41  37
DIA  37  43  29
LIA  35  41  37

Root Beer-Flavored Milk

1x Day 0  Day 45  Day 90

DIB  18  23  30
LB  44  40  34
DIB  18  23  30
DIA  37  33  30
LH  44  40  34
DIA  37  33  30
LIA  45  39  32
DIA  37  33  30

Root Beer-Flavored Milk

2x Day 0  Day 45  Day 90

DIB  27  39  30
LB  31  42  39
DIB  27  39  30
DIA  43  52  41
LH  31  42  39
LIA  44  49  50
DIA  43  52  41
LIA  44  49  50
### Root Beer-Flavored Milk

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### Orange-Flavored Milk

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### RO-concentrated and UHT-processed Flavored Milks

1. 2x milk RO-concentrated to 2x level
2. Concentrated and unconcentrated milks UHT processed by direct or indirect heat exchange
3. Flavors added either before or after UHT processing
4. Samples stored at room temperature for 45 days
5. 2x flavored milk concentrate reconstituted to 1x before taste panel
Heat Treatments

The purpose of an ultra-high heat treatment is to impart commercial sterility to product for extended room temperature shelf stability. Sterility is attained by applying sufficient heat to the product to inactivate the desired number of bacterial spores. This heat induced lethality can be expressed as $F_0$, the equivalent number of minutes the product is exposed to 250°F. Common values used commercially are $F_0$'s of 6-10.

The mathematical expression for $F_0$ is the accumulated

$$\text{# minutes of heat exposure at } T^\circ\text{F times } 10^{(T-250)/z}$$

where $T$ is the sterilization temperature and $z$ is 18°F for spore log reduction. The $z$ term is the number of degrees necessary to achieve a 10 fold reduction in spore counts. It is graphically expressed as the slope of the Thermal Death Time curve which plots the minimum time required for a given number log reductions of spores at different temperatures. A plot of this semi-log linear relationship indicates far less time is required to achieve the desired spore log reduction as the temperature is increased (Figure 1).

Figure 1. A typical Thermal Death Time curve for a microbial population with a slope of 18°F.
A similar relationship exists for nutrient degradation except the z values are considerably higher as listed in Table I (Sadler, 1987).

Table I. Z Values for Various Vitamins and Nutrient Interactions

<table>
<thead>
<tr>
<th>Component</th>
<th>z value (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin</td>
<td>45</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>50</td>
</tr>
<tr>
<td>Nicotinic acid</td>
<td>45.5</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>56</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>50</td>
</tr>
<tr>
<td>B12</td>
<td>50</td>
</tr>
<tr>
<td>Folic acid</td>
<td>72</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>72</td>
</tr>
<tr>
<td>Maillard Browning</td>
<td>45</td>
</tr>
<tr>
<td>Lysine</td>
<td>38</td>
</tr>
</tbody>
</table>

Using thiamin as an example with a z value of 45°F, the vitamin degradation line indicates two phenomenon when compared to the line representing spore log reductions (Figure 2).

Figure 2. Comparing the implications of vitamin and microbial destruction at various temperatures.

The graph illustrates at temperatures below 250°F, vitamin degradation occurs before spore log reduction whereas at temperatures above 250°F, the spores are inactivated at a faster rate than vitamin degradation. This differential increases as the temperatures of sterilization increase and the subsequent time requirements decrease. This is the fundamental advantage ultra-high temperature (UHT) short time treatments (e.g. 290-300°F for only a few seconds) for the sterilization of milk based products; good vitamin retention levels are attained.
The next graph (Figure 3) plots the equivalent time required to attain an Fo of ~28 using an indirect UHT process and the amount time associated with degradation of thiamin. The time for thiamin is quite low indicating little degradation has occurred.

![Graph showing equivalent time vs thermal processor time](image)

Figure 3. Comparing the equivalent amount of time for bacterial destruction to thiamin degradation during an indirect UHT process. Reference: R. Gygax, Ross Products Division

The following compares three different pasteurization heat treatments to ranges commonly used for UHT and retort sterilization (Kessler, 1989):

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Temp (F)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurization</td>
<td>144 - 149</td>
<td>30 minutes</td>
</tr>
<tr>
<td></td>
<td>160 - 167</td>
<td>14 - 40 seconds</td>
</tr>
<tr>
<td></td>
<td>185 - 194</td>
<td>2 - 10 seconds</td>
</tr>
<tr>
<td>UHT sterilization</td>
<td>275 - 302</td>
<td>20 - 2 seconds</td>
</tr>
<tr>
<td>Retort sterilization</td>
<td>228 - 248</td>
<td>40 - 20 minutes</td>
</tr>
</tbody>
</table>

Pasteurization is most commonly conducted in the 160-167°F range and imparts little heat effect but the product does not benefit from having room temperature shelf stability. UHT followed by aseptic filling offers an attractive compromise in terms of very quickly establishing commercial sterility before much product and nutrient degradation occurs. Retort sterilization obviously in the most severe and occurs after the unsterile product is filled into hermetically sealed containers. The temperature and time ranges listed above may be a bit outdated. Retorts can be operated at higher temperatures for much lower cook times.

Figure 4 considers the time required to achieve an Fₐ of 10 under various sterilization conditions. The first example is when the product achieves a retort temperature of 250°F. The actual cook time would be ~8.5-9 minutes since some lethality is generated during the come up and cool down phases. If the retort can be increased in temperature to 256°F, the cook time requirements
are reduced to ~4.5 minutes. Conversely, if the retort is held at lower temperatures of 240°F, the cook time is extended to over 35 minutes. Hence, the temperatures and subsequent times used during retort or conventional sterilization processes may differ widely. Different nutrient losses might occur depending upon the retort conditions.

![Graph showing different cook times at various temperatures](image)

**Figure 4.** The different cook times required at different cook temperatures to achieve an F₀ of 10.

To provide a comparison, the time/temperature profile of a typical, indirect UHT treatment which delivers an F₀ of 10 to the product is included in Figure 5. As you can see, there is a dramatic reduction in the time required to sterilize product via UHT.

![Graph comparing UHT process to retorts](image)

**Figure 5.** An indirect UHT process compared to the various retort processes for equivalent degree of lethality.

There are also differences in the effect of direct vs. indirect UHT heating. Direct heating is achieved by steam injection or steam infusion followed by flash cooling. The direct steam elevates the product to the desired sterilization temperature immediately as well as provides ~10% dilution of the product during the UHT treatment (Proceedings, 1979). Both situations
cause less degradation of nutrients compared to indirect heating which is attained via the use of plate or tubular heat exchangers. In this case, there is some come up and cool down required which induces additional heat degradation to the product.

The following information deals only with nutrient degradation which occurs over time on samples stored at ambient temperature conditions. Some data on the additional nutrient losses which occur at elevated temperatures exist in the literature. However, most of the information lists physical and organoleptic degradation. The higher storage temperatures, i.e. 35°C, tend to induce greater browning via the Maillard reaction and noticeable amounts of enzymatic activity can occur from heat stable, residual proteases and lipases. The products become unacceptable due to excessive browning, gelation, and/or off-flavors associated with the release of free fatty acids (Alkanhal et al., 1994).

Vitamin Degradation

Vitamin B₁ (thiamin) is the vitamin that is solely affected by heat. Second order reaction kinetics models have been developed to predict thiamin thermal degradation (Kessler and Fink, 1986) at various time/temperature conditions.

A number of other vitamins exhibit losses due to the combination of temperature and oxygen: vitamins C (ascorbic acid), B₆ (pyridoxal and pyridoxamine), B₁₂ (cobalamin), folic acid and, to a lesser extent, niacin and pantothenic acid. In general, the literature reports the following cross comparisons based on a percentage of the vitamins that degrade (Table II).

Table II. Effect of Heat Treatments on Loss of Vitamins in Milk

<table>
<thead>
<tr>
<th>Heat Treatment</th>
<th>Vitamin C</th>
<th>Thiamin</th>
<th>Vitamin B₆</th>
<th>Vitamin B₁₂</th>
<th>Folic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurization</td>
<td>(25)ᵇ</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>UHT</td>
<td>&lt;30</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Sterilization</td>
<td>30-100</td>
<td>20-50</td>
<td>15-50</td>
<td>20-100</td>
<td>30-50</td>
</tr>
</tbody>
</table>

ᵇLoss due to handling and treatment

Reference: Scott, 1989
Table II illustrates little vitamin degradation occurs with pasteurization. The incremental vitamin loss associated with UHT is less than retort sterilization.

Table III expands the comparison of vitamin loss from milk either pasteurized or UHT treated. UHT milk is more susceptible to shelf loss because it is held at a higher (ambient vs. refrigeration) temperature for much longer time periods. Except for thiamin, the vitamins will degrade at a faster rate in the presence of oxygen. Conversely, limited degradation occurs if the oxygen content can be minimized. Vitamin C is degraded first in the presence of oxygen and will protect the other vitamins from being oxidized. Elevated temperature storage will increase the rate of degradation.

Table III. The Effect of Pasteurization, UHT, and Storage on the Vitamin Levels and Stability in Milk

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>raw milk (mg/kg)</th>
<th>pasteurization</th>
<th>UHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>heat storage</td>
<td>heat storage</td>
</tr>
<tr>
<td>C</td>
<td>21</td>
<td>0-10 25-45</td>
<td>15-25 100</td>
</tr>
<tr>
<td>Folicin</td>
<td>0.05</td>
<td>0-10 0</td>
<td>10-20 varies</td>
</tr>
<tr>
<td>Folateb</td>
<td>0.08</td>
<td>20 na</td>
<td>40 na</td>
</tr>
<tr>
<td>B1</td>
<td>0.44</td>
<td>&lt;10 ?</td>
<td>&lt;20 heat</td>
</tr>
<tr>
<td>B2</td>
<td>1.75</td>
<td>0 light</td>
<td>0 light</td>
</tr>
<tr>
<td>B12</td>
<td>0.004</td>
<td>&lt;10 0</td>
<td>0-30 100</td>
</tr>
<tr>
<td>B6</td>
<td>0.64</td>
<td>&lt;10 0</td>
<td>~10 steady</td>
</tr>
<tr>
<td>Niacin</td>
<td>0.94</td>
<td>0 0</td>
<td>&lt;10 20a</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>3.5</td>
<td>0 0</td>
<td>&lt;10 30a</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.031</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>A &amp; B carotene</td>
<td>0.5</td>
<td>0 light</td>
<td>0 yes</td>
</tr>
<tr>
<td>D,E,K</td>
<td>--</td>
<td>-- --</td>
<td>-- --</td>
</tr>
</tbody>
</table>

Note: After six weeks
b Wigertz and Jägerstad, 1993.

Reference: Andersson et al., 1995

The information in Table III poses the question: to what extent are the vitamins in milk contributing to a person's dietary needs as expressed as a percentage of daily value (DV)?

Table IV lists the nutrient levels in milk based on an 8 oz. serving size. The last two columns indicate the maximum heat/O₂ related degradation of the vitamins is only 3-5% of the DV except...
for B\textsubscript{12} which was degraded by 10\% of its DV. Therefore, the overall impact of UHT on the relative vitamin content in milk has little nutritional implications.

Table IV. The Amount of Vitamin Loss in Milk Due to UHT Treatment Compared to Daily Values

<table>
<thead>
<tr>
<th>Vitamin, wt.</th>
<th>raw milk\textsuperscript{a} (wt/8 oz.)</th>
<th>%DV</th>
<th>UHT Loss (%)\textsuperscript{a}</th>
<th>Max. Loss (wt/serving)</th>
<th>Reference DV\textsuperscript{b} (wt/serving)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, mg</td>
<td>5.5</td>
<td>14</td>
<td>15 - 25</td>
<td>1.4</td>
<td>40</td>
</tr>
<tr>
<td>Folicin, mg</td>
<td>0.013</td>
<td>7</td>
<td>10 - 20</td>
<td>0.003</td>
<td>0.2</td>
</tr>
<tr>
<td>B\textsubscript{1}, mg</td>
<td>0.11</td>
<td>16</td>
<td>&lt;20</td>
<td>0.02</td>
<td>0.7</td>
</tr>
<tr>
<td>B\textsubscript{12}, mcg</td>
<td>1</td>
<td>33</td>
<td>0 - 30</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>B\textsubscript{6}, mg</td>
<td>0.17</td>
<td>24</td>
<td>~10</td>
<td>0.02</td>
<td>0.7</td>
</tr>
<tr>
<td>Niacin, mg</td>
<td>0.24</td>
<td>3</td>
<td>&lt;10</td>
<td>0.02</td>
<td>9</td>
</tr>
<tr>
<td>Pantothenic acid, mg</td>
<td>0.91</td>
<td>18</td>
<td>&lt;10</td>
<td>0.09</td>
<td>5</td>
</tr>
<tr>
<td>Riboflavin, mg</td>
<td>0.46</td>
<td>57</td>
<td>--</td>
<td>--</td>
<td>0.8</td>
</tr>
<tr>
<td>Biotin, mg</td>
<td>0.008</td>
<td>5</td>
<td>--</td>
<td>--</td>
<td>0.15</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Andersson et al., 1995
\textsuperscript{b} For toddlers

Commercial UHT sterilized shelf stable milks and refrigerated pasteurized milks limit the information declared on their labels (Table V). Gossner's and Hershey's UHT sterilized, shelf stable flavored milks and common pasteurized milks only include vitamins A, C, and D at the following %DV values:

Table V. Vitamin Declarations of DV Content on Several Commercial Retail Milks

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Gossner's</th>
<th>Hershey's</th>
<th>Past. Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>A\textsuperscript{1}</td>
<td>15</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>D\textsuperscript{1}</td>
<td>25</td>
<td>10</td>
<td>25</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Fortified vitamins.
The milks do not list themselves as excellent sources of riboflavin, $B_{12}$, and $B_6$. The reason may be due to the significant role that oxygen plays in vitamin degradation over time.

**Role of oxygen**

As mentioned previously, oxygen is the degrading catalyst for the shelf stability of ascorbic acid, folic acid, $B_{12}$, $B_6$, and vitamin A. If the oxygen level can be minimized, then limited degradation occurs (Tables VI and VII).

**Table VI. The Role of Oxygen in the Degradation of Ascorbic and Folic Acid**

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Oxygen (ppm)</th>
<th>Storage (days)</th>
<th>% Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascorbic acid</td>
<td>0.1</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>14</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>Folic acid</td>
<td>0.1</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

*Reference: Porter and Thompson, 1972*

The UHT temperatures themselves do not affect vitamin A (McCarthy *et al.*, 1985, pp. 2045-2051) but vitamin A also degrades over time due to oxygen (Table VII). The presence of fat has been shown to have a protective effect (*ibid.*, pp. 2052-2059).

**Table VII. The Effect of Time and Fat Content on the Stability of Vitamin A in UHT Treated Milk**

<table>
<thead>
<tr>
<th>% Fat:</th>
<th>% Decrease in Vitamin A$^1$ in UHT$^2$ Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 13 days</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>83</td>
</tr>
<tr>
<td>2.92</td>
<td>79</td>
</tr>
<tr>
<td>6.16</td>
<td>68</td>
</tr>
<tr>
<td>9.70</td>
<td>58</td>
</tr>
<tr>
<td>After 21 days</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>83</td>
</tr>
<tr>
<td>85</td>
<td>70</td>
</tr>
<tr>
<td>62</td>
<td></td>
</tr>
</tbody>
</table>

$^1$Retinyl palmitate

$^2$Indirect UHT heating.

*Reference: Lau *et al.*, 1986, p. 2057

Table VII illustrates two points: 1) the progressively protective nature of the fat and 2) the
decrease of vitamin A is much less after the first 13 days.

It is important to minimize the amount of occluded oxygen in the product during and after aseptic filling and to minimize the amount of oxygen permeating through the package over shelf life. Several mechanisms have value in reducing the amount of air in the product: deaerate prior to UHT treatment, use direct UHT heating followed by flash cooling, and blanket the product in the aseptic surge tank and/or after filling with an inert gas such as nitrogen or carbon dioxide. The product can also be purged of oxygen by bubbling nitrogen into the product during filling before the package is sealed (USA patent # 4,935,255).

Several package variations are commercially available. Although use of metal cans or glass bottles are ideal, much progress has been made in the oxygen barrier properties of plastics. Polyvinylidene chloride (PVDC) copolymers, better known as Saran, have good oxygen barrier properties particularly at high humidity levels. Ethylene-vinyl alcohol (EVOH) copolymers have better barrier properties at low humidity but loses them under high humidity conditions. Both are being used in plastic, multi-laminate containers to provide barrier properties against the migration of gasses such as oxygen, nitrogen, and carbon dioxide and moisture (The Wiley Encyclopedia of Packaging Technology).

We have found that even packages lined with aluminum foil allow some oxygen migration which can become a significant factor over shelf life. For example, assuming the package has a permeation rate of 0.011 cc O₂/package/day, over the span of six months or 180 days, 1.98 cc's of O₂ will theoretically enter the product. Assuming 19.43 mg of ascorbic acid reacts with 1.2513 cc of O₂, in the six months time period, 30.7 mg of ascorbic acid/package will be oxidized. In a practical sense, not all of the entering oxygen will react with the ascorbic acid and different product matrixes might cause the degradation of ascorbic acid to behave differently. None-the-less, the effect of oxygen migration through the package should be evaluated to determine the degree that shelf degradation of oxygen sensitive vitamins occurs.

As noted above, milk is not a uniform contributor of all of the vitamins. Some companies have found value in fortifying milk beverages and promoting them as nutritional supplements. Ross Products Division, Abbott Laboratories, for one, has a long history in providing consumers with retorted, vitamin fortified, milk based nutritional beverages. Lately, we have also been gaining experience with UHT sterilized and aseptically filled products. In some instances, we have a different experience with nutrient degradation as what has been presented thus far. One explanation is the B₁₂ and folic acid in milk are bound to whey proteins which may influence their bioavailability after protein denaturation occurs. B₆ occurs naturally as pyridoxal and pyridoxamine but it is added normally as pyridoxine.

Commercial Experience

Ross markets products that contain vitamin levels at ~20-30% of DV per serving. Thiamin is the only vitamin that appears to be affected only by heat. Since vitamins A and C are degraded by
the combination of heat and oxygen, effort is extended to minimize the oxygen level in the
product during processing and filling and in the container. Overall, the the milligram amounts
are similar to those already presented but percent degradations are typically lower since these
vitamins are added at higher rates than found inherent in the milk.

The model used at Ross for thiamin degradation considers a $D_{250}$ value of 165 and a $z$ value of
45°F. The model allows us to predict losses under various time/temperature regimes (Figure 6).

Figure 6. The Predicted Nutrient Degradation of Thiamin
and Vitamin C During Indirect UHT Heating
Reference: R. Gygax, Ross Products Division

Riboflavin ($B_2$) is another one of particular interest since it is degraded by light and follows a
consistent first order reaction kinetics profile based on light exposure. One of the key questions
for Quality Assurance groups is what degree of light exposure is appropriate to reproduce a worst
case, yet reasonable model to use to determine riboflavin fortification rates. For example, what
should the standard light intensity, positioning, and duration be? Since three general packaging
scenarios are possible: can, cup, or bottle figuration, should the light be directly overhead or at
some angle to the container. Only the bottle would have a shoulder that would cause the product
to be exposed to light while setting on the shelf with overhead light. For cans and cups, the light
should be positioned at the side of the containers.

Figure 7 compares the theoretical rate of riboflavin degradation when exposed to constant light
exposure to the actual data that was obtained with UHT product aseptically filled into opaque
plastic containers. Although opaque, the containers did allow for some light transmission. The
model provided excellent correlation to the actual results. This enabled us to calculate a safe and
effective fortification rate that would insure label claim is met through the intended shelf life and
light exposure conditions.
One reference indicated riboflavin loss during storage under refrigeration (Munoz et al., 1994). Losses in the range of 16 to 23.4% were reported in opened containers stored in the dark at 8°C for six days. Loss was attributed to the packaging material, the amount of actual product exposed to light on the surface, and the penetration of light into the interior of the product. The authors encourage limiting the time of use duration once the container is opened.

Vitamins A, C, B₁ and possibly B₁₂ and some low amounts of folic acid and pantothenic acid exhibit losses over shelf life. We have not seen any losses of B₆ (pyridoxine).

When we compare the vitamin recovery values in UHT treated products to retort sterilization, the UHT process is less damaging to the vitamins. Since there can be substantial product matrix effects, the actual loss of these vitamins cannot always be predicted. The products must be tested and evaluated over shelf life to develop accurate degradation patterns.

**Protein**

The whey proteins are partially denatured with UHT and totally denatured with retort sterilization. The denaturation of the whey onto the casein micelles affords a lower curd tension which might have some value for increasing gastric emptying time for infants.

Although 4-7% lysine bioavailability is lost due to the Maillard browning reaction during UHT, little loss in overall protein nutritive value occurs. The by-products of the browning reaction have been determined to not be mutagenic (Berg et al., 1990).
Cow milk immunoglobulin IgG has been studied for its potential as an immunological supplement to infant formulae and other milk products. Milks with higher levels of IgG may help in reducing the effects of enteropathogenic and enterotoxigenic bacteria and viruses which cause diarrhea. Pasteurization reduces the IgG level inherent in raw milk by ~33%; UHT and retorting denatures and inactivates IgG (Li-Chan et al., 1995). As this area of research continues, alternate methods of sterilization will have to be considered to retain the immunological properties of these proteins.

Lactoferrin occurs at very low levels in cow milk but represents ~20% of the proteins in human milk. Its role in infant development has great interest and has been associated with having bacteriostatic effects, promoting growth of intestinal cells and iron absorption, and in suppressing lipid peroxidation. The following describes its thermal stability (Kawakami et al., 1992):

<table>
<thead>
<tr>
<th>Heat</th>
<th>Time</th>
<th>Lactoferrin</th>
</tr>
</thead>
<tbody>
<tr>
<td>144°F</td>
<td>30 minutes</td>
<td>most destroyed</td>
</tr>
<tr>
<td>302°F</td>
<td>4 seconds</td>
<td>24% destroyed</td>
</tr>
<tr>
<td>250°F</td>
<td>10 minutes</td>
<td>73% destroyed</td>
</tr>
</tbody>
</table>

Since lactoferrin has been demonstrated to be stable over time at neutral pH, the authors suggest that it should be sterilized via non-thermal means and then added aseptically to the milk.

Lastly, lysinoalanine is created at levels of 170-570 mg/kg during conventional retorting. Little has been found in UHT treated milk (Scott, 1989).

**Carbohydrates**

Browning occurs with the Maillard condensation of lactose and amino end groups of the proteins. The reaction is not extensive enough to reduce the biological level of the lactose as a source of energy. The reaction kinetics have been developed for UHT treated milks. The information, when graphed on semi-log paper, illustrates that UHT treated milks' color are lighter than conventionally retorted milks and similar to pasteurized milk (Kessler and Fink, 1986).

One compound that is formed during the UHT and retort treatments is lactulose (Table VIII). Lactulose formation occurs when the glucose moiety is isomerized to fructose as an enediol intermediate via the Lobry de Bruyn-Alberda van Ekenstein transformation. The reaction is catalyzed by phosphate and citrate ions and slowed by calcium ions. Proteins are not involved in its formation but higher levels can retard the amount formed (Andrews and Prasad, 1987). Lactulose is not digested in the small intestine, rather it enters the colon and is fermented. Higher amounts of ingested lactulose can cause diarrhea. Lesser amounts have a laxative effect and are reported to have bifidogenic properties.
The following table gives a good representation of the amounts of lactulose formed via the different heating scenarios (Hurrell et al., 1989). The 3.9 gm/l formed in milk was caused via retort sterilization at 248°F for 20 minutes (Rossi and Pompei, 1991).

Table VIII. The Development of Lactulose in Milk and Infant Formula Due to Various Heat Treatments

<table>
<thead>
<tr>
<th></th>
<th>Lactulose (gm/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pasteur</td>
</tr>
<tr>
<td>Milk</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant formula</td>
<td>na</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indirect UHT heating causes a higher amount of lactulose (Geier and Klostermeyer, 1983). It is believed that less amounts are formed during direct UHT heating primarily because of the dilution phenomenon that occurs.

Table IX illustrates the amount of lactulose formed via two different UHT temperatures and various hold times. The amount formed via typical UHT treatments is less than what is reported for retort sterilization.

Table IX. Influence of Various Indirect UHT Treatments on the formation of Lactulose in Milk

<table>
<thead>
<tr>
<th>UHT,°F:</th>
<th>288</th>
<th>299</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lactulose</td>
<td>Lactulose</td>
</tr>
<tr>
<td>Hold Time (sec.)</td>
<td>Fo°</td>
<td>(gm/l)</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>0.07</td>
</tr>
<tr>
<td>7.5</td>
<td>15</td>
<td>0.12</td>
</tr>
<tr>
<td>15.9</td>
<td>33</td>
<td>0.23</td>
</tr>
<tr>
<td>31.7</td>
<td>65</td>
<td>0.69</td>
</tr>
<tr>
<td>60</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>128</td>
<td>262</td>
<td>1.69</td>
</tr>
</tbody>
</table>

°Calculated with a z value of 18.

Extracted from Hewedy et al. 1994
Minerals

UHT encourages the precipitation of calcium onto the micelle and phosphate groups. This has not been shown to have any effect on in-vivo calcium absorption properties (Scott, 1989).

Fat

UHT has no effect on fat in milk products. If some of the heat resistant lipases from Pseudomonas organisms are present then the release of free fatty acids could occur over time. These cause off-flavors but would not be a source of nutritional concerns.

Much nutritional interest is being focused on the value of adding marine oils and/or arachidonic, decosahexaenoic (DHA), and eicosapentaenoic (EPA) acids to our diets. These are long chain, poly-unsaturated fatty acids highly susceptible to lipid oxidation. I am not aware of any literature relating their stability to UHT treatment affects.

Nutriceuticals

The whole area of nutriceuticals is receiving widespread attention. One can only speculate on the extent they will be added to foods in the future. These compounds have been classified into four main categories (Kevin, 1995 where the following information was sourced from "Eating Well" magazine; Christopher Beecher).

1. Terpenoids: carotenoids, limonoids, lycopene, monoterpenes, plant sterols, and triterpenoids.

2. Thiols: allylic sulfides, gamma-glutamyl allylic cysteines, and isothiocyanates.


4. Miscellaneous: fiber, indoles, linolenic acid, phthalides, and polyacetylenes.

Although I'm not aware of any published work on how UHT affects the stability of these compounds, one can surmise the oxidative ones would be prone to degradation similar to the oxygen sensitive vitamins. Some of these could very well be the important compounds for the future and since milk is such a wonderful medium as a food, there could be interest in adding them to milk based drinks, soups, sauces, and/or desserts.

Direct Dosing of Heat Labile Nutrients

Direct dosing is a current technology available to the UHT low acid food industry. Its use involves additional risk in the maintenance of an asepsis environment and perhaps because of the
risk, direct dosing has not achieved wide spread use. The basic concept is to first UHT sterilize
the milk product and store it in an aseptic surge tank. The next step is to sterilize the heat
sensitive material via filter, electronic, or some other means as a separate operation. While
maintaining asepsis, the material is added to the surge tank and mixed with the milk until
homogeneity is attained.

As mentioned previously, IgG is heat sensitive and degrades during the UHT sterilization
treatment. Work has been conducted to demonstrate IgG can be sterilized via membrane filter
sterilization and then added aseptically to a sterile milk product (Fukumoto et al., 1994).

Lactoferrin is also heat sensitive as discussed. Kawakami et al. (1992) recommended
pasteurizing lactoferrin separately using electrical conductivity and then mixing it aseptically
with the sterilized milk.

Concluding Comments

UHT thermal sterilization of milk based foods does not extensively degrade its nutrients. As
long as contact with oxygen and temperature exposure conditions are strictly controlled, the
milk's nutritional content should be stable allowing for long term shelf stability at room
temperature. UHT milks compete with the organoleptic freshness of pasteurized milk which
tends to limit their wide spread use. UHT milk should have good advantages to those products,
particularly the vitamin supplemented, nutritional milk beverages, that have historically been
sterilized via longer time, lower temperature retorting processes.
References


Proceedings, (1979) "International Conference on UHT Processing and Aseptic Packaging of Milk and Milk Products," Sponsored by Department Food Science NCSU and Dairy Research Inc.


Novel compositions and methods are disclosed for low-fat and skim milk products which have an increased creamy mouthfeel, whiter color, and taste sensations similar to milk with a high fat content. The textured milk products involve skim milk and lowfat milk being treated with a milk coagulant to partially coagulate and aggregate proteins in the milk. The enzyme-treated milks are heat-processed to denature the coagulating enzyme. The finished milk products are then cooled and stored at an appropriate refrigeration temperature.
SKIM MILK

PASTEURIZE (OPTIONAL)

COOLING

INOCULATION

INCUBATION

HEAT TREATMENT (PASTEURIZATION OR ULTRAPASTEURIZATION)

COOLING

REFRIGERATED STORAGE

FIG. 1
2% MILK
SKIM-I UNTREATED
60°C. 800-200 psi
-5.70 ± .04 49.8 ± .4
-8.19 ± .07

IA
-4.46 ± .01 57.2 ± .4
IB
-4.15 ± .04
IC
-4.05 ± .13
SKIM-2 UNTREATED
60°C. 2000-500 psi
-8.21 ± .06 51.2 ± .6

2A
-3.79 ± .01 58.4 ± .3
2B
-3.73 ± .02
2C
-3.83 ± .07 59.9 ± .5

FIG. 2
SAMPLE NUMBER

2% MILK
SKIM-3 UNTREATED
77°C. 800-200 psf
3A
3B
3C
SKIM-4 UNTREATED
77°C. 2000-500 psf
4A
4B
4C

-20 -10 0 10 20 30 40 50 60 70 80

\[ b^* \]

\[ L^* \]

56.6 ± .7
51.3 ± .8
59.2 ± .3
59.5 ± .3
60.4 ± .7
52.2 ± .8
59.9 ± .3
60.0 ± .3
60.5 ± .6

FIG. 3
FIG. 4

SAMPLE NUMBER

2% MILK

SKIM-5 UNTREATED
93.3°C, 800-200 psi

5A

5B

5C

-5.70 ± .04

-8.73 ± .12

-5.34 ± .01

-4.96 ± .01

-4.70 ± .04

56.6 ± .7

52.6 ± .8

60.3 ± .3

60.7 ± .3

61.5 ± .5
SAMPLE NUMBER

WHOLE MILK

MILK-1 1% UNTREATED
60°C. 2000-500 psi

IA

-2.47 ± 0.15

IB

-6.31 ± 0.07

IC

-2.10 ± 0.08

MILK-2 2% UNTREATED
60°C. 2000-500 psi

2A

-1.96 ± 0.03

2B

-2.15 ± 0.11

2C

-4.57 ± 0.13

2A

-0.16 ± 0.04

2B

-0.48 ± 0.03

2C

-1.85 ± 0.04

FIG. 5
FIG. 6

SAMPLE NUMBER

WHOLE MILK

MILK-3 1% UNTREATED
77°C. 2000-500 psi

MILK-4 2% UNTREATED
77°C. 2000-500 psi

\[ \begin{array}{c|c|c}
\text{SAMPLE NUMBER} & \text{b*} & \text{L*} \\
\hline
\text{WHOLE MILK} & -2.47 \pm 0.15 & 80.6 \pm 0.4 \\
\text{MILK-3 1% UNTREATED} & -5.85 \pm 0.14 & 70.1 \pm 0.3 \\
77°C. 2000-500 psi & -2.05 \pm 0.02 & 73.7 \pm 0.5 \\
3A & -2.12 \pm 0.12 & 74.1 \pm 1.3 \\
3B & -1.76 \pm 0.14 & 75.2 \pm 1.8 \\
3C & -3.97 \pm 0.17 & 76.6 \pm 1.5 \\
\text{MILK-4 2% UNTREATED} & -0.83 \pm 0.05 & 76.0 \pm 0.3 \\
77°C. 2000-500 psi & -1.21 \pm 0.09 & 77.6 \pm 0.6 \\
4A & -1.15 \pm 0.02 & 77.2 \pm 0.2 \\
4B & -1.21 \pm 0.09 & 77.6 \pm 0.6 \\
4C & -1.15 \pm 0.02 & 77.2 \pm 0.2 \\
\end{array} \]
FIG. 7

SAMPLE NUMBER

WHOLE MILK

MILK-5 1% UNTREATED
93.3°C. 2000-500 psi

MILK-6 2% UNTREATED
93.3°C. 2000-500 psi

-2.47 ± 0.15

-6.14 ± 0.09

-2.05 ± 0.04

-2.36 ± 0.08

-2.52 ± 0.04

-4.46 ± 0.03

-2.07 ± 0.06

-1.82 ± 0.09

-1.83 ± 0.13

80.6 ± 0.4

70.8 ± 0.3

73.9 ± 1.0

74.4 ± 0.8

73.3 ± 0.3

75.6 ± 0.2

76.3 ± 0.5

75.0 ± 0.2

75.2 ± 1.3
FIG. 8

SAMPLE TYPE  □ b * (AVERAGE)  □ L * (AVERAGE)

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>b * (Average)</th>
<th>L * (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skim Milk</td>
<td>-8.44 ± .10</td>
<td>65.7 ± .7</td>
</tr>
<tr>
<td>Treated Skim Milk</td>
<td>-2.92 ± .60</td>
<td>72.4 ± .7</td>
</tr>
<tr>
<td>1% Milk</td>
<td>-6.10 ± .20</td>
<td>70.4 ± .4</td>
</tr>
<tr>
<td>Treated 1% Milk</td>
<td>-2.12 ± .20</td>
<td>73.9 ± .9</td>
</tr>
<tr>
<td>2% Milk</td>
<td>-4.33 ± .30</td>
<td>75.4 ± 1.3</td>
</tr>
<tr>
<td>Treated 2% Milk</td>
<td>-1.38 ± .60</td>
<td>75.8 ± 1.8</td>
</tr>
<tr>
<td>Whole Milk</td>
<td>-2.47 ± .15</td>
<td>80.6 ± .4</td>
</tr>
</tbody>
</table>
COMPOSITIONS AND METHODS FOR MANUFACTURING A SKIM OR LOWFAT MILK PRODUCT WITH INCREASED CREAMINESS, COLOR, MOUTHFEEL, AND TASTE SENSATIONS SIMILAR TO MILK WITH A HIGHER FAT CONTENT

BACKGROUND

1. The Field of the Invention
The present invention relates to compositions and methods of manufacture of an improved skim or lowfat milk product. In particular, the preferred embodiment of the invention relates to compositions and methods of manufacture of a textured type of skim or lowfat milk which is produced by treating skim or lowfat milk with a milk coagulant to partially coagulate and aggregate proteins in the milk. One of the most important processing steps is heating of the milk in order to denature the coagulating enzyme. The finished milk product is then cooled to and stored at an appropriate refrigeration temperature. The final product not only has an increased creamy mouthfeel, but also is characterized by a white color and taste sensations similar to milk with a higher fat content.

2. The Background Art
Milk is a unique product obtained by the secretion of the mammary glands of mammals and is intended for nutrition of the young. Milk provides those nutrients on which many living organisms depend for continued health and growth. The consumption of milk in the United States has become an important aspect of human health. Moreover, because most individuals like the taste of milk, its presence in the marketplace is demanded. Unfortunately, milk products are generally high in fat content. Americans are becoming increasingly selective about the milk products they consume because of the health problem in later life often associated with the consumption of large amounts of fat. The presence of large amounts of fats in the human body can lead to the deposit of the fats in the arteries. Arterial fat deposits can restrict the circulation of blood which can cause strokes and heart attacks.

At the same time that the public has requested healthier alternatives to presently available milk products, the public has been unwilling to give up flavor or quality in taste of milk products having a high fat content. Generally, even if one milk product is healthier than another milk product, many individuals will eventually return to the milk product which is of a greater quality in terms of taste and flavor. If one type of milk product contains less fat than another milk product, while maintaining acceptable taste, consumers will generally prefer the lower fat-containing product. Indeed, milk products which provide healthy alternatives to the public are eagerly being sought.

Traditionally, the processing of milk results in a change in the composition of the milk. One of the most important processing steps is heating of the milk in order to control the presence of microorganisms. Generally, as the temperature of the milk is increased, microorganisms present in the milk will become deactivated and heat killed.

Heat treatment may be applied to impart other desirable properties. In some products, changes in flavor, color, or viscosity caused by heating may be desired. Heating prior to sterilization may increase the stability of milk proteins to coagulation by subsequent high heat treatments.

The change in flavor from heat treatment of milk proceeds to a "cooked" flavor as the milk temperature increases. This is due to free sulfhydryl groups formed at temperatures above 60°C. The milk then changes to a sterilized milk flavor as the temperature of the milk increases. This is due to the formation of lactones and methylketones from fats.

Still another important processing step is the separation of the milk to yield skim milk and cream. Skim milk has a very low fat content, less than about 0.05%, and this is the milk most health-conscious individuals consume. Nevertheless, skim milk is appropriately berated because of its weak taste and watery mouthfeel. By mixing skim milk and cream, milk may be standardized to a desired fat content to produce the milk products commonly known to most consumers as "1%," "2%," and "whole milk."

The separation of milk to yield skim milk, and even lowfat milk such as 1%, and cream results in the loss of most of the texture or viscosity experienced by the consumption of whole milk. Individuals have submitted that skim milk has a "watery" mouthfeel (i.e., no consistency) due to the absence of fat in the milk (milksfat) in the fluid. Also, the weak flavor and watery color of skim milk is unappealing both to one's taste buds and aesthetic appreciation. Therefore, conventionally prepared and processed skim milk is considered undesirable to the consumer in taste and flavor. Many consumers find the lowfat, 1% or 2% milks also to be unappealing.

Some individuals have attempted to provide a nonfat milk product without the watery texture and taste due to the absence of milksfat in the fluid. Such attempts have involved the addition of nonfat solids into the milk product to provide for some type of texture. The addition of nonfat solids, however, has not met with widespread consumer approval.

Nonfat dry milk powder has been added to fluid skim milk in order to increase the total milk solids of the product. In essence, the nonfat milk solids added in a powder form are similar to the milk solids found in the fluid skim milk. The relative percentages of the constituents of nonfat dry milk powder are in the same relative percentage range as the same constituents in fluid milk.

By adding nonfat dry milk powder to fluid skim milk total protein content, total lactose content, total ash (mineral) content, and total micronutrient content, (e.g., vitamins) all increase to produce a skim milk product with increased total milk solids but with the same relative percentages of each milk constituent (based on dry matter). This process does not lead to consumers being able to perceive an enhanced creaminess or improved mouthfeel sensations because all the milk constituents are in their native (unaltered) state, which does not affect mouthfeel or taste sensations on the tongue.

Other attempts have involved the introduction of fat substitutes into the dairy products. The addition of such fat substitutes gives the impression that fat has been added to the milk product. One commercialized fat substitute product known in the art, produced by such a process, is commonly referred to as SIMPLESSE®, manufactured by The NutraSweet Corporation. The fat substitute SIMPLESSE® involves the microparticulation of whey or egg proteins. These proteins are heated, stressed, and restructured, resulting in protein structures that are globalized.
Although a food product produced according to the foregoing process provides a food product which does fool the tongue of consumers without the presence of fat, the process is not without its disadvantages. In particular, the converted proteins presented by the process can only be placed in cold food or dairy products such as ice cream. If placed in heated products, the converted proteins revert to an altered state and do not provide the texture desired for in the milk product. The restrictive nature of these temperature-sensitive products is immediately apparent. Although cold milk products such as ice cream are popular, the use of milk as an ingredient in cooked foods is considerable. A milk product which reverts to an untextured and tasteless composition when commonly placed in a heated condition is disadvantageous.

Further disadvantages of food products prepared by introduction of fat substitutes include the significantly increased price to the finished food product, the possible need for warning statements to prevent warming of the food product, and the fact that fat substitutes are food additives that require FDA approval and specific labeling requirements. Additionally, the fat substitutes contain caloric value (protein-based fat substitutes contain 4 calories per gram—as does normal protein in foods) which increases the total calories of the finished food product.

In light of the foregoing, it is clear that all of the problems present in the lowfat and particularly skim milk area have not been solved. A market is available for a textured skim milk or lowfat milk which solves these additional problems not remedied by currently known skim or lowfat milks. A need, therefore, exists in the art for compositions and methods for making a skim or lowfat milk product which is textured so that individuals will believe they are drinking milk with a fat content greater than normal skim or lowfat milks.

A need also exists in the art for compositions of methods for making a skim or lowfat milk product which fools the tongue of an individual without adding unwanted fats or fat substitutes to the milk product. Additionally, a need exists in the art for compositions of methods for making a skim or lowfat milk product having greater consumer acceptability than normal skim or lowfat milk. This texture and sensory product wherein individuals receive the health benefits from the consumption of milk without a sacrifice due to the presence of fats.

Still further, a need exists in the art for compositions of methods for making a skim or lowfat milk product which is not temperature sensitive so that it can be used as an ingredient in cooking.

A need also exists in the art for compositions of methods for making a skim or lowfat milk product wherein individuals receive the health benefits from the consumption of milk without a sacrifice due to the presence of fats.

A further need exists in the art for compositions of methods for making a skim or lowfat milk product wherein the caloric value is not increased and taste is not diminished.

BRIEF SUMMARY AND OBJECTS OF THE INVENTION

The present invention seeks to resolve problems incident to the consumption of skim and lowfat milk. More specifically, the compositions and methods of this invention constitute an important advance in the milk processing art by providing a textured type of milk product having a perceived increased viscosity which is produced by treating skim or lowfat milk with an enzyme to partially coagulate and aggregate proteins already in the milk. The treated milk is then heat-processed to pasteurize or ultra-pasteurize the product to denature the coagulating enzyme. The finished milk product is then cooled to and stored at an appropriate refrigeration temperature.

The "textured skim milk" invention prepared by the foregoing treatment offers the health-conscious consumer the advantage of its being a nonfat milk product with considerably creamier texture and taste comparable to a milk product with significantly greater amounts of milkfat present.

One object of the present invention is to provide compositions of and methods for making a skim or lowfat milk product which is textured so that individuals will believe they are drinking milk with a fat content greater than normal skim or lowfat milk, due to the increased creaminess, mouthfeel and color.

Still another object of the present invention is to provide compositions of and methods for making a skim or lowfat milk product which is not temperature sensitive and so can be used in cooking.

A further object of the present invention is to provide composition and methods for making a skim or lowfat milk product wherein individuals receive the health benefits from the consumption of milk without a sacrifice due to the presence of fats.

Yet another object of the present invention is to provide compositions of and methods for making a skim or lowfat milk product which has the color and appearance of a milk having a higher fat content.

Another object of the present invention is to provide compositions of and methods for making a skim or lowfat milk product which does not have increased caloric value and which does not decrease flavor.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims.

To achieve the foregoing objects, and in accordance with the invention as embodied and broadly described herein, is a milk product having substantially the same fat content as skim milk. Because the milk product has substantially the same fat content of skim milk, it can be understood that the fat content of the milk product is quite low. The milk product includes not only pure milk, but also products which comprise the milk of the present invention.

The milk product provides a texture and a sensory experience that is unmistakably similar to 2% milk or in some cases, whole milk. This texture and sensory experience circumvent the watery taste and texture defects
commonly experienced by consumers when drinking skim milk. The texture and sensory experience are present without regard to the temperature of milk product.

The textured milk product of the present invention is produced by the methods disclosed herein. Preferably, the methods for manufacturing the textured milk product comprises treating cold skim or lowfat milk with a coagulating enzyme to partially coagulate and aggregate casein micelles in the milk. It is preferred that a rennet be used as the coagulating enzyme and many types of rennet are available for this use. For example, rennet can be obtained from calves, microorganisms, and plants. The preferred type of rennet is chymosin.

**BRIEF DESCRIPTION OF THE DRAWINGS**

In order to more fully understand the manner in which the above-recited and other advantages and objects of the invention are obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope, the invention will be described with additional specificity and detail through the use of the accompanying drawings in which:

FIG. 1 is a flow chart indicating processing steps which comprise the methods of manufacturing the textured skim or lowfat milk product.

FIG. 2 is a graph illustrating L* and b* values for experiments performed in Example 5.

FIG. 3 is a graph illustrating L* and b* values for experiments performed in Example 6.

FIG. 4 is a graph illustrating L* and b* values for experiments performed in Example 7.

FIG. 5 is a graph illustrating L* and b* values for experiments performed in Example 8.

FIG. 6 is a graph illustrating L* and b* values for experiments performed in Example 9.

FIG. 7 is a graph illustrating L* and b* values for experiments performed in Example 10.

FIG. 8 is a graph illustrating average L* and b* values for experiments performed in Examples 5 to 10.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The present invention is directed to novel compositions of and methods for making a more textured and tasty skim milk product. The skim or lowfat milk product of the present invention avoids the watery mouthfeel of known skim or lowfat milks caused by the absence of, or smaller amount of milkfat in the fluid. The skim or lowfat milk product provides flavor and taste sensations that are accepted by consumers. The present invention, where necessary, can be best understood by reference to the drawings, wherein like parts are designated with like numerals throughout.

Although the present invention is best understood by reference to a more textured skim milk beverage product, it should be understood that the present invention is not so limited. Instead, a wide variety of milk products such as the different types of milks, and milk products which comprise milk such as cheeses, puddings, ice cream, and the like are intended to be covered by the present invention. What is important is applying the principles of the present invention to a milk product to provide a textured quality of increased creaminess and mouthfeel similar to milk products having higher amounts of fat. For example, the methods of the present invention can be used for 1% and 2% milks as well as for skim milks. It can be appreciated, however, that the greatest difference will be observed with the milks with lower or no fats.

The understanding of the structure of milk is provided by the following sections A and B. It is believed that the principles and unique features of the present invention can be better understood and discussed with a working knowledge of the materials which comprise the present invention.

A. The Components of Milk

Milk, containing protein, fat, lactose, vitamins, and minerals, together with natural enzymes and those derived from microorganisms within the milk, can be regarded as a relatively complete food. It has a high nutritional value, and it is also an excellent medium for microbial growth.

Lactose is the distinctive sugar of milk. Other carbohydrates are present only in traces. Lactose is a reducing disaccharide composed of glucose and galactose, and is also the principal carbon source for most of the microorganisms that grow in milk. Lactose gives milk a slightly sweet taste.

Milkfat consists of numerous different lipids. More than 98% of milkfat is made up of triglycerides. Cholesterol, diglycerides, free fatty acids, phospholipids, and cerebrosides are also present. The component of fatty acids of milk lipids exhibit a remarkably wide range of 4-20 carbon atoms and 0-4 double bonds.

Milkfat present in milk provides a better mouthfeel and taste because the fat is in a globular form and is sufficiently "slick." This gives the sensation of creaminess, thicker body, or increased mouthfeel. When fat is removed from milk, the milk solids that remain (proteins, lactose, ash, micronutrients) do not have the globular form or provide a "slick" surface to tell the tongue that the product is richer and creamier.

The minerals in milk are mainly inorganic salts. Some inorganic matter is bound covalently, such as phosphate groups in proteins. When milk is ashed to determine "salt content," ash does not truly represent milk salts because organic salts are destroyed by ashing and some nonsalt components (e.g., sulfur from amino acids) contribute to the ash. Milk contains numerous other elements in trace quantities. For example, salts of organic acids, such as citrate, occur in fresh milk.

Milk also contains several kinds of milk proteins, often classified as caseins, which are a group of phospho-containing, milk-specific proteins that precipitate upon acidification to pH 4.6 and are necessary for the coagulation and aggregation featured by the present invention. Caseins represent about 80% of the total milk proteins. Sometimes "protein content" is calculated merely by multiplying total nitrogen by a constant relative to milk, proteins, and milk products. Nevertheless, their common property of low solubility at pH 4.6 (at least for bovine milk) serves as a basis for a rather convenient operational definition. At this pH, all of the caseins, except some of the proteolytic derivatives, precipitate.

Compositionally, the hallmark of the caseins is ester-bound phosphate. All of the casein polypeptide chains have at least one such group per molecule.
One of the most common types of casein, and important to the present invention, is the k-casein molecule. About one-third of the k-casein molecules are carbohydrate-free and contain only one phosphate group. It is believed that k-casein, as isolated from milk, consists of a mixture of polymers held together by intermolecular disulfide bonds.

k-Casein is rapidly hydrolyzed by the enzyme chymosin, and by other proteases, yielding an N-terminal fragment called para-k-casein, which contains two cysteine residues, and a C-terminal fragment of 64 residues called the macropieceptide. The macropieceptide contains all of the carbohydrate and phosphate groups, as well as any genetic substitutions. It should be noted that this hydrolysis reaction, as will be discussed in greater detail at a later point, is the basis of the coagulating and aggregating step of the present invention.

Whey or serum proteins also are present in milk, and typically are found in the liquid left after the coagulated and aggregated caseins are removed from the milk. These proteins represent a rather diverse group including α-lactalbumin, β-lactoglobulin, bovine (blood) serum albumin, immunoglobulins, and small molecular weight peptides derived by proteolysis of some of the caseins. All of the proteins named above have been isolated, and have at least partially been characterized. In addition, milk serum contains a number of so-called minor proteins and a number of enzymes. Other proteins and enzymes are located in the membrane of the fat globules; they amount to about 0.35 grams per kilogram of milk.

Milk has many miscellaneous components. For example, all vitamins are present. Further, as analytical techniques improve, more components are being identified. The understanding of the structure of milk is provided in this specification because it is believed that the principles and unique features of the present invention can be better understood and discussed with a working knowledge of the materials which comprise the present invention.

B. The Production of Milk: Skim and Lowfat Milk Compared to Whole Milk

Raw milk is obtained from the secretion of mammary glands by mammals. Typically, raw milk is not the milk product which most individuals consume. Raw milk is first processed in dairy plants through a number of steps.

One step of the process of milk production is pasteurization. Low-temperature, long-time pasteurization (e.g., 30 minutes at 63°C) and high-temperature, short-time pasteurization (e.g., 15 seconds at 72°C) are milk treatments that kill most microorganisms and inactivate some enzymes, but do not cause many other changes. Higher temperature pasteurization (e.g., 1.0 second at 89°C, although the conditions vary widely in the art) is more severe; all vegetative microorganisms are killed, most enzymes are inactivated, part of the whey proteins can become denatured, and the -SH groups can become exposed.

Complete sterilization (e.g., 20 minutes at 118°C) is meant to kill all microorganisms, including spores; inactivate all enzymes; cause numerous chemical changes, such as browning reactions; and form formations; and ultra-high temperature ("UHT") heating (e.g., at or above 138°C for a few seconds) is meant to commercially sterilize milk while minimizing chemical changes, even though some enzymes are not inactivated fully.

Another step in the production of milk typically involves the use of a cream separator. The cream separator is a flow-through centrifuge which is used to separate the milk into an essentially fat-free portion (skim milk) and a fat-rich portion (cream).

Cream consists of a concentration of the fat in milk, wherein the fat mainly exists as globules protected by a membrane. As such, cream can have a variety of compositions and is normally defined according to fat content or function. The physico-chemical properties of cream are very much influenced by the state of dispersion of the milkfat globules and the globule membrane which surrounds them.

As an alternative to centrifugally separating the milk, the milk may also be separated by relying on the density difference between the milkfat in the globules and the aqueous phase in which they are dispersed. If milk is allowed to stand, fat rises, and the familiar process of "creaming" is observed with a fat-rich fraction collecting at the surface above the skim milk.

It is known that by mixing skim milk and cream, milk may be standardized to a desired fat content to produce the milk products which are commonly referred to as "1%," "2%," and "whole milk." After milk is standardized, the fat globules of milk may be broken up into very small particles (fat globules) by forcing them through special valves under high pressure (i.e., homogenization). Homogenization of milk reduces the creaming process such that the fat globules do not accumulate at the surface of the milk. All sterilized milks or, more generally, all long-life liquid milk products, are homogenized in practice.

C. Texturizing Milk Products

According to the present invention, the textured skim or lowfat milk composition is produced by treating milk with a coagulant to aggregate the proteins in the milk. Preferably, skim milk is treated with a coagulant to aggregate the proteins in the skim milk such that the skim milk becomes characterized by a texture. According to one embodiment of the present invention, the textured milk product is produced by treating skim milk with rennet to aggregate the casein in the milk. 1% and 2% milks may also be treated within the scope of the present invention although the greatest effect of the present invention can be seen with skim milk. The term "lowfat milk" refers to 1% and 2% milks.

Casein exists in milk in complex micelles which consist of casein molecules, calcium, inorganic phosphate and citrate. The micelles are roughly spherical particles, mostly 0.02 to 0.30 μm in diameter. The casein micelles also contain inorganic matter, mainly calcium phosphate, in a concentration of about 8 grams per 100 grams casein. The particles are voluminous, holding more water than casein. Finally, they contain small quantities of some other proteins, such as the milk enzymes, lipase and plasmin, and part of the proteosepeptone.

It has been found that the introduction of rennet to a skim or lowfat milk leads to the aggregation of the micelles. The rennet enzyme specifically cleaves one of the bonds in k-casein, releasing a glycomacropeptide. This action destabilizes the casein micelles such that they begin to coagulate and aggregate.

The most used preparation is calf rennet. However, although calf rennet is the preferred type of coagulating enzyme, it should be understood that many different proteolytic enzymes are able to lead to the aggregation of the micelles within the scope of the present inven-
tion. The different types of coagulants which are rou-
tinely used to aggregate the proteins in the skim milk
are quite diverse. For example, various different proteo-
lytic enzymes are available such as microbial rennets
(from Mucor miehei, Mucor pusillus, Endothia parasitica,
Bacillus spp., Aspergillus, spp.), vegetable (plant) ren-
nets, and other proteolytic enzymes known to those
skilled in the art. What is important is that any enzyme
can be employed which is capable of coagulating milk
by acting on caseins without destroying the milk's suit-
ability for human consumption. For the sake of simplic-
ity, however, calf rennet will be referred to most often as
the coagulating enzyme.

The active principle of calf rennet is the endopepti-
dase chymosin. Chymosin, having a molecular weight
30,700, is readily soluble in water. Chymosin hydro-
lyzes protein molecules into large peptides. Chymosin
(as well as many other endopeptidases) splits particu-
larly the Phe-Met bond of the k-casein. In the preferred
embodiment of the present invention, preferably, in the
range from about 20% to about 60% of the k-casein in
the textured milk product is split before heating. It is
known that at least 60% of the k-casein must be split in
order for aggregation to occur. However while the milk
is being heated, more of the k-casein is split. Therefore,
only although only 20% of the k-casein may be split before
heating, the splitting continues during heating so that
the amount of k-casein split eventually reaches 60%,
and aggregation begins.

The splitting of the k-casein by the chymosin can be
a relatively quick reaction. Small peptides containing
the same bond also are split, though the reaction is
much slower than on k-casein; the rate increases as the
peptide is a larger portion of the k-casein molecule.
As indicated earlier, k-casein is split into para-k-
-casein and a caseinomacropeptide. (The latter is thus
identical to the whey proteose, at least when only chy-
mosin acts for a short time at milk pH.) The two poly-
peptides have very different properties. The para-k-
casein is insoluble in milk serum and in the absence of
Ca++ but it can be kept in dispersion by the other
caseins. The caseinomacropeptide is very soluble, and
does not associate; it is present in whey in an extended
conformation, almost as a random coil. The caseino-
macropeptide is heterogeneous because of the variation
in glucose content.

Although the aggregation of the casein micelles is an
important step in the production of the textured milk
product, it must be understood that the aggregation
should not be allowed to progress to the stage of gel
formation, as is experienced with the production of
cheeses. Cheese production involves the formation of
a network by the para-k-casein micelle aggregates which
have an irregular and elongated shape. As soon as a
three-dimensional network forms throughout the milk,
it becomes a gel or, to use a common term, a “curd”.

Even after formation of the gel network, many more
bonds between micelles can be formed in principle,
because a much more compact packing of the micelles is
possible. When this occurs, liquid is expelled from the
gel, a process called “syneresis”. Moisture content of the
curds after syneresis depends primarily on temperature,
ph, pressure gradients applied, and fat content. In prac-
tice, syneresis usually is stopped at the desired level
by lowering the temperature.

In the present invention, syneresis does not occur.
Moreover, a three-dimensional network does not form
throughout the milk to form a gel or curd. Instead, the
flocculating paracasein micelles are only allowed to
form the small aggregates, and it is the presence of these
small aggregates which provide the textured quality to
the treated skim or lowfat milk product.

Various factors affect the production of the textured
milk product. Some of these factors include: (1) the
temperature of the skim or lowfat milk; (2) the amount
of enzyme initially present in the skim or lowfat milk;
(3) the time the enzyme is allowed to act on the caseins
before the enzyme is deactivated; (4) and the amount of
milk used.

With regard to the temperature of the skim or lowfat
milk, a heat treatment of greater intensity than low
pasteurization causes an increase in rennet activity.
Using decreased temperature causes a decrease in ren-
ett activity. An increase in rennet activity reduces the
incubation period, i.e., the time with which a milk sam-
ple, inoculated with rennet, is required to stand before a
sufficiently high temperature must be delivered to deac-
tivate the rennet. It should be remembered, however,
that if the heat treatment is too severe, the rennet is
denatured and rennet activity is discontinued.

With regard to the amount of the enzyme, a higher
amount of enzyme introduced into the milk sample
causes a rate increase in the aggregation occurring in
the milk sample. This reduces the necessary incuba-
tion period. Conversely, a lower amount of enzyme intro-
duced into the milk sample causes a decrease in the
aggregation and thereby increases the necessary incuba-
tion period.

The longer the period of time the enzyme is allowed
to react with the caseins in the milk sample, the greater
the aggregation of the caseins in the milk sample to
arrive at a textured milk product. The less time the
enzyme is allowed to react with the casein in the milk
sample, the less aggregation occurs.

Further, the greater the milk-to-enzyme ratio, the
longer it takes for the enzymes to react with all of the,
caseins present in the milk sample. The smaller the
milk-to-enzyme ratio, a shorter time period is necessary
for reaction of the enzymes with the caseins.

It can be seen that the factors affecting the process
are all interrelated and can be altered in response to
alterations of each other factor. It is a simply a matter of
routine experimentation by one with ordinary skill in
the art to discover the various possible combinations.

D. Textured Milk Processing System

The complete milk processing system of the present
invention, wherein skim or lowfat milk is textured, is
outlined in FIG. 1. The milk processing system com-
prises a series of pipes and vats through which the milk
of the present invention is transported. The milk pro-
cessing system also comprises other apparatus known to
those skilled in the art to process the milk product of the
present invention.

According to the preferred embodiment of the pres-
et invention a quantity of milk is initially cooled if
needed, to about 40° F. (about 4° C.). (Before the en-
zyme unculation, pasteurizing, ultrapasteurizing and
homogenizing the milk can optionally be performed if
desired.) After the milk is cooled, the milk is inoculated
with the coagulating enzyme. The milk, and the coagu-
inating enzyme used to inoculate the milk, will vary in
quantity depending upon the design choice of the per-
son manufacturing the textured milk product. In the
preferred embodiment, the textured milk product is
comprised of about 90 grams of rennet per 45 kilograms
of milk.
The temperature of the milk at the time of inoculation is preferably about 40°F (about 4°C). The temperature of the milk during the period of inoculation and incubation is in the range from about 35°F (about 2°C) to about 50°F (10°C) when the reaction time is in the range from about 30 to 60 minutes. Alternatively, the temperature of the milk during the period of inoculation and incubation is in the range from about 35°F (about 2°C) to about 75°F (24°C) when the reaction time is in the range from about 10 to 90 minutes. The temperature of the milk during the period of inoculation may also be in the range from about 35°F (about 2°C) to about 104°F (40°C) when the reaction time is in the range from about 5 to 90 minutes.

It must be noted that in the present invention, the factors of time, temperature and concentration share an important relationship, wherein the range of one factor is dependent upon the range of the other two factors. Therefore, many different combinations of the three factors can be successfully used.

For example, if a higher level of enzyme is used and the temperature is held constant, then the necessary reaction time will be shorter. If a lower level of enzyme is used and the temperature is held constant, then the necessary reaction time will be longer.

Similarly, if the level of enzyme is kept constant and the temperature is raised, the reaction time will decrease. If the level of enzyme is kept constant and the temperature lowered, the reaction time will increase.

Further, if the level of enzyme and the reaction time are both held constant, then the temperature of the reaction can be varied. While many combinations can be used to effect the process of the present invention, the various combinations can easily be discovered by simple experimentation by those with ordinary skill in the dairy field.

The inoculation step of the present invention may further be comprised of the step of mixing the milk with the calf rennet such that the calf rennet is evenly dispersed throughout the quantity of milk. Dispersing the calf rennet throughout the quantity of milk prevents the aggregation of proteins in limited areas so that much of the skim milk continues to exhibit a watery mouthfeel to a consumer. The step of mixing may comprise blending, or stirring, the calf rennet throughout the skim or low-fat milk.

The inoculated milk is then incubated, that is, allowed to stand for a period of time. During this period of time, the calf rennet reacts with the casein in the milk to cause k-casein hydrolysis, leading to casein aggregation. As discussed previously, the aggregation of the casein by the calf rennet should not continue to such a degree that a gel is formed from the milk.

The time that the inoculated milk is allowed to stand varies depending upon the design choice of the manufacturer of the textured milk product. Preferably, the inoculated milk is allowed to stand for about 30 to about 60 minutes at a temperature of about 35°F (about 2°C) to about 50°F (10°C). In another embodiment, the inoculated milk is allowed to stand in the range from about 10 to about 90 minutes at a temperature range from about 35°F (about 2°C) to about 75°F (24°C). In still another embodiment, the inoculated milk is allowed to stand in the range from about 5 to about 90 minutes in a temperature range of about 35°F (about 2°C) to about 104°F (40°C). Again, the time the milk is allowed to stand varies with the related factors. An appropriate incubation time with the appropriate temperature can be determined by simple and routine experimentation.

In the preferred embodiment of the present invention, the inoculated milk, after it is allowed to stand for a period of time to hydrolyse and aggregate, is heated or i.e. pasteurized. The step of pasteurization is performed for a variety of reasons.

One reason for pasteurizing milk is to minimize possible health hazards arising from pathogenic microorganisms associated with milk. In the present invention, the milk is heat-treated to cause the pasteurizing effect. Pasteurization results in minimal chemical, physical, and organoleptic changes in the milk.

Another reason for pasteurizing milk, and which is an important step in the present invention, is to halt the reaction of the calf rennet with the casein in the milk. The increased temperature of the milk, represented by the pasteurization process, denatures and inactivates the calf rennet. The inactivated calf rennet is prevented from causing further aggregation of the casein in the milk, which, if allowed to continue, would form the gel which would lead to the production of cheese.

Pasteurization can be defined in different ways, based on the relationship between temperature and time. For example, high temperature-short time ("HTST") pasteurization is approximately 72°C for about 16 seconds. Milk can also be pasteurized at about 62°C if held at that temperature for about 30 minutes. With the present invention, pasteurization at 72°C for about 16 seconds is preferred, although pasteurization at 63°C for about 30 minutes can also be used. The necessary times and temperatures are those that create conditions necessary to destroy the enzyme after the enzyme is finished. Any temperature above 72°C (for about 16 seconds) up to about 142°C (for about six seconds) will create these conditions.

As indicated previously, a high milk-to-enzyme ratio will considerably slow the aggregation of the casein in the milk product. Therefore, it can be understood that instead of pasteurizing the inoculated milk to halt the aggregation of casein by the enzyme, one may introduce a large quantity of non-inoculated milk into the inoculated milk to substantially halt the aggregation of casein by the enzyme since there will be a high milk-to-enzyme ratio. Such a procedure, which essentially involves diluting the concentration of the enzyme in the milk, may be necessary when heating of the milk cannot be immediately accomplished.

The method of preparing the textured skim or lowfat milk product within the scope of the present invention also includes the step of storing the pasteurized milk until such time as the textured milk product is purchased by a consumer. In one embodiment of the present invention, the pasteurized milk is placed in a holding tank. In another embodiment of the present invention, the pasteurized milk is concentrated into a powdered form in order to store the textured milk product. The powdered milk product can be reconstituted by the addition of water.

The method of storing the textured milk product most often comprises the step of cooling the pasteurized milk to an appropriate refrigeration temperature. The reduction in the temperature of the milk product decreases the growth rate of any microorganisms not killed or deactivated by the pasteurization step. Most milk products are cooled to a temperature in the range from about 35°F (about 2°C) to about 40°F (about 4°C).
E. Physical Characteristics of the Textured Milk Product

The textured skim or lowfat milk product can be characterized by various physical traits. As indicated previously, microscopic examination of the textured skim milk indicates aggregates of casein which are elongated and irregularly shaped. Nevertheless, the aggregates of casein have been found to be a variety of additional shapes and sizes which may be known to those skilled in the art.

Typically, the aggregates of casein may have a width of about 0.5-10 micrometers and a length of about 0.5-10 micrometers. Most of the aggregates will usually be in the range from about 1-3 micrometers.

As the skim or low fat milk is textured, a color change occurs which can be measured. This color change can indicate the change that occurs in the textured skim or lowfat milk.

A reflectance colorimeter measures the light that reflects from a food sample. The reflected light is detected and is expressed as a three (3) part color measurement. The color ranges are: L* which measures between black (zero value) to white (100 value); a* which measures between green (negative 80 value) to red (positive 100 value); b* which measures between blue (negative 80 value) to yellow (positive 70 value). The color of textured skim milk and milk with a fat content are most critically evaluated using the L*, a* and b* values.

The textured milk product can be characterized by the increased white and decreased bluish colors of the textured milk product. The L* value of the textured milk product is preferably in the range from about 55 to 65, indicating an increased whiteness to the textured milk product. Untreated skim milk (no enzyme treatment) usually has an L* value of about 45 to 50, indicating less whiteness to the normal skim milk. Milk with a fat content (for example, 2% milk) has an L* value of approximately 65 to 75, indicating significant whiteness value.

The b* value of the textured milk product using skim milk is preferably in the range from about -5 (negative 5) to about -2 (negative 2), indicating a decreased bluish color to the textured milk product. Untreated skim milk (no enzyme treatment) usually has a b* value from about -10 (negative 10) to about -8 (negative 8) indicating more bluish hue to the normal skim milk. Milk with a fat content (for example, 2% milk) has a b* value of approximately -7 (negative 7) to -4 (negative 4), indicating less bluish hue to the fat-containing milk.

EXAMPLES

The use of the methods for producing a textured milk product within the scope of the present invention will be further clarified by a consideration of the following examples, which are intended to be purely exemplary of the use of the invention and should not be viewed as a limitation on any claimed embodiment.

EXAMPLE 1

Sensory evaluation tests by milk consumer taste panels were conducted to determine the perceived creaminess mouthfeel between the milk of the textured skim milk product and 2% milk. These tests were also compared in sensory tests to normal skim milk, i.e. nonenzyme treated. The comparison test was performed by placing three pairs of two test milk samples in each pair in front of test subjects. The two test milk samples were paired as: normal skim milk vs. textured skim milk; normal skim milk vs. normal 2% milk; and textured skim milk vs. normal 2% milk.

The test subjects were asked to evaluate the test milk samples in each pair and indicate on the questionnaire, which test milk sample of the pair had the creamier mouthfeel. Seventy percent (70%) of respondents indicated the textured skim milk product had a creamier mouthfeel when compared to normal skim milk. Sixty-three percent (63%) of respondents indicated the normal 2% milk had a creamier mouthfeel when compared to normal skim milk. Seventy-three percent (73%) of respondents indicated the textured skim milk product had a creamier mouthfeel when compared to normal 2% milk.

The results of the test indicated that milk consumers are unlikely to be able to differentiate between the textured skim milk product of the present invention and normal 2% milk in terms of the body and mouthfeel of the milk product. Almost always, a milk consumer is able to differentiate between skim milk and 2% milk when compared side-by-side in a taste comparison due to the difference in milkfat content. Despite the lower milkfat content of the textured skim milk product, the data indicate that its mouthfeel was perceived as creamier than either normal skim milk or normal 2% milk.

EXAMPLE 2

Six gallons (51.6 pounds or 23.4 kilograms) of skim milk, having a fat content of approximately 0.3%, was obtained at a temperature of about 40°F. (about 4° C.). To the skim milk, about 4.6 grams of single-strength calf rennet (diluted 1:40 in cold water) was introduced. The composition was then mixed by stirring.

After approximately 18 to 20 minutes of enzyme action, the inoculated skim milk was heat treated. The enzyme-treated skim milk was preheated to 164° F. (about 73° C.) and then ultra-high temperature treated at 285° F. (about 141° C.) and held for 4 seconds. The heat treatment of the inoculated skim milk substantially inactivated the calf rennet in the skim milk.

The pasteurized skim milk was then placed under refrigerator conditions where it was stored until consumption. The temperature of the holding tank was about 40°F. (about 4° C.). Consumption of the processed skim milk revealed that the milk tasted similar to 2% milk in spite of the fact that the skim milk contained substantially less milkfat than the 2% milk.

It must be noted that all milk samples must be pasteurized at some time during the process, even if the milk is eventually UHT processed. Within the scope of the present invention, generally skim milk is pasteurized and then cooled prior to inoculation with the appropriate enzyme level. The inoculated milk is allowed to react with the enzyme at reduced temperature (e.g. about 4° C.). The inoculated and textured skim milk is then heat-treated (preferably pasteurized) again in order to inactivate the enzyme. The second heat treatment can also be a UHT treatment.

It is also feasible to UHT process the milk prior to enzyme inoculation. The UHT-treated milk is cooled and allowed to react with the enzyme at 40°F. (about 4° C.). The textured skim milk is then pasteurized to inactivate the enzyme.

EXAMPLE 3

A textured milk product is produced according to the procedure of Example 2, except that 1% milk is pro-
cessed according to the methods of the present invention to arrive at a more textured milk product instead of skim milk. This example is important to show that different standards of milk may be characterized by greater texture and improved quality of taste in spite of low milkfat content. Therefore, 1% milk may taste like 2% milk or even whole milk.

EXAMPLE 4

A textured milk product is produced according to the procedure of Example 2, except that 2% milk is processed according to the methods of the present invention to arrive at a more textured milk product instead of skim milk. This example is important to further show that different standards of milk may be characterized by greater texture and improved quality of taste in spite of low milkfat content. Therefore, 2% milk may taste like whole milk.

EXAMPLES 5–10

The following examples illustrate experiments which were conducted to determine the color change(s) occurring in the textured skim milk of the present invention. The color of untreated skim milk was compared to the colors of treated skim milk, 1% milk, and 2% milk. Reference should be made to the Figures when necessary. The numbers at the top (or bottom) of each bar in the Figures indicate average value ± standard deviation.

EXAMPLE 5

Untreated samples

one hundred gallons of milk (860 pounds) of skim milk (approximate fat content of 0.4%) was obtained, preheated to 140°F (60°C) and held for 25 seconds. Sample 1 ("Skim-1") was homogenized at 800 psi in the first stage and 200 psi in the second stage. Sample 2 ("Skim-2") was homogenized at 2,000 psi in the first stage and 500 psi in the second stage. The samples were cooled to approximately 45°F (7°C) by plate heat exchange immediately following the heat and homogenization treatments. These samples 1 and 2 (FIG. 2) represent the pre-enzyme, preheat treatment ("untreated") samples.

Treated samples

Calf rennet (77.4 ml diluted 1:40 in cold water) was then added to the 860 pounds of skim milk at approximately 45°F (7°C) for one hour.

The enzyme-treated skim milk was then heated to 170°F (77°C) and held for 25 seconds to inactivate the enzyme. Three (3) sets of samples were generated. Samples 1A and 2A were not homogenized following the 77°C heat treatment. Samples 1B and 2B were homogenized at 800 psi in the first stage and 200 psi in the second stage. Samples 1C and 2C were homogenized at 2,000 psi in the first stage and 500 psi in the second stage. All samples were cooled to approximately 45°F (7°C) by plate heat exchange immediately following the heat and homogenization treatments. The samples were refrigerated at 7°C.

Color measurements were performed on an OMNISPECTR™ Reflectance Colorimeter manufactured by Wescor, Inc., Logan, Utah. The L* value, which measures between black (zero value) to white (100 value), and the b* value, which measures between blue (negative 80 value) to yellow (positive 70 value), were measured. The resulting data are illustrated in FIG. 2. FIG. 2 illustrates the L* and b* values of the samples 1A, 1B, and 1C, and 2A, 2B, and 2C as compared with untreated skim milk samples ("Skim-1" and "Skim-2") and 2% milk.

It can be seen from reference to FIG. 2 that the untreated skim milk samples (those not receiving any enzyme treatment) have a reduced whiteness value. These samples received the preheat treatment and homogenization pressure treatment without any enzyme addition.

Samples 1A, 1B, 1C, 2A, 2B, and 2C all showed an increase in the whiteness value (a higher L* value) as a result of the enzyme treatment. In all samples, the enzyme treatment and combined heat/homogenization treatments resulted in L* values higher than the 2% milk sample.

As seen from reference to FIG. 2, the untreated skim milk samples ("Skim-1" and "Skim-2"), have a lower b* value (i.e., a higher blue value—the more negative the number the more blue hue to the food sample).

Samples 1A, 1B, 1C, 2A, 2B, and 2C all showed a decrease in the blue value as a result of the enzyme treatment. In all samples, the enzyme treatment and combined heat/homogenization treatments resulted in less negative b values than the 2% milk sample.

EXAMPLE 6

Experiments were performed using similar processes as described in Example 5. The untreated samples ("Skim-3" and "Skim-4") were processed similarly to "Skim-1" and "Skim-2" in Example 5 except the pre-enzyme, preheat temperature was 170°F (77°C). Treated samples 3A, 3B, and 3C were processed similarly to samples 1A, 1B, and 1C except the pre-enzyme, preheat temperature was 170°F (77°C). Treated samples 4A, 4B, and 4C were processed similarly to samples 2A, 2B, and 2C except the pre-enzyme, preheat temperatures was 170°F (77°C).

The results of the experiments are illustrated in FIG. 4. Enzyme treatment of the skim milks (samples 3A, 3B, and 3C and 4A, 4B, and 4C) caused the L* value to increase and the b* value to become less negative compared with the untreated skim milks ("Skim-3" and "Skim-4") and the 2% milk.

EXAMPLE 7

Experiments were performed using similar processes as described in Example 5. The untreated sample ("Skim-5") was processed similarly to "Skim-1" in Example 5 except the pre-enzyme, preheat temperature was 200°F (about 93°C). Treated samples 5A, 5B, and 5C were processed similarly to samples 1A, 1B, and 1C except the pre-enzyme, preheat temperature was 200°F (about 93°C).

The results of the experiments are illustrated in FIG. 4. Enzyme treatment of the skim milk (samples 5A, 5B, and 5C) caused the L* value to increase and the b* value to become less negative compared with the untreated skim milks ("Skim-5") and the 2% milk.

EXAMPLE 8

Experiments were performed using the same basic processes as described in Example 5, except that 1% and 2% milks were treated. Comparison of experimental results were made with untreated 1% milk sample ("Milk-1") and untreated 2% milk sample ("Milk-2") and whole milk.

Untreated Samples:
One hundred gallons (860 pounds) of 1% and 2% milks were obtained, preheated to 140°F (60°C) and held for 25 seconds. Sample 1 ("Milk-1") was homogenized at 2,000 psi in the first stage and 500 psi in the second stage. Sample 2 ("Milk-2") was homogenized at 2,000 psi in the first stage and 500 psi in the second stage. The samples were cooled to approximately 45°F (7°C) by plate heat exchange immediately following the heat and homogenization treatments. These samples 1 and 2 (FIG. 5) represent the pre-enzyme, preheat treatment ("untreated") samples.

Treated samples:

calf rennet (77.4 ml diluted 1:40 in cold water) was then added to the 860 pounds of 1% and 2% milks at approximately 45°F (7°C) for one hour.

The enzyme-treated milks were then heated to 170°F (77°C) and held for 25 seconds to inactivate the enzyme. Three (3) sets of samples were generated. Samples 1A and 2A were not homogenized following the 170°F (77°C) heat treatment. Samples 1B and 2B were homogenized at 800 psi in the first stage and 200 psi in the second stage. Samples 1C and 2C were homogenized at 2000 psi in the first stage and 500 psi in the second stage. All samples were cooled to approximately 45°F (7°C) by plate heat exchange immediately following the heat and homogenization treatments. The samples were refrigerated at 45°F (7°C).

Color measurements were performed by reflectance colorimetry. The L* value, which measures between black (zero value) to white (100 value), and the b* value, which measures between blue (negative value) to yellow (positive 70 value), were measured. The resulting data are illustrated in FIG. 5. FIG. 5 illustrated the L* and b* values of the samples 1A, 1B, and 1C, and 2A, 2B, and 2C as compared with untreated 1% milk sample ("Milk-1") and untreated 2% milk sample ("Milk-2") and whole milk.

It can be seen from reference to FIG. 5 that the untreated 1% and 2% milk samples (those not receiving any enzyme treatment) have a reduced whiteness value compared with the respective enzyme-treated samples. Samples 1A, 1B, 1C, 2A, 2B, and 2C all showed an increase in the whiteness value (a higher L* value) as a result of the it enzyme treatment. In all samples, the enzyme treatment and combined heat/homogenization treatments resulted in L* values higher than their untreated counterpart milk sample.

As seen from reference to FIG. 5, the untreated 1% milk sample ("Milk-1") and untreated 2% milk sample ("Milk-2") had a lower b* value (i.e., a higher blue value—the more negative the number, the more blue to the food sample).

Samples 1A, 1B, 1C, 2A, 2B, and 2C all showed a decrease in the blue value as a result of the enzyme treatment. In all samples, the enzyme treatment and combined heat/homogenization treatments resulted in less negative b* values than the untreated counterpart milk sample and compared with the whole milk.

EXAMPLE 9

Experiments were performed using similar processes as described in Example 8. The untreated 1% and 2% milk samples ("Milk-3" and "Milk-4", respectively) were processed similarly to "Milk-1" and "Milk-2" in Example 8 except the pre-enzyme, preheat temperature was 170°F (77°C). Treated samples 3A, 3B, and 3C were processed similarly to samples 1A, 1B, and 1C in Example 8 except the pre-enzyme, preheat temperature was 170°F (77°C). Treated samples 4A, 4B, and 4C were processed similarly to samples 2A, 2B, and 2C in Example 8 except the pre-enzyme, preheat temperature was 170°F (77°C).

The results of the experiments are illustrated in FIG. 6. Enzyme treatment of the 1% milk samples (samples 3A, 3B, and 3C) and of the 2% milk (4A, 4B, and 4C) caused the L* value to increase compared with the untreated counterpart milk sample and the b* value to become less negative compared with the untreated counterpart milks ("Milk-3" and "Milk-4") and compared with the whole milk.

EXAMPLE 10

Experiments were performed using similar processes as described in Example 8. The untreated 1% and 2% milk sample ("Milk-5" and "Milk-6") were processed similarly as to "Milk-1" and "Milk-2" in Example 8 except that the pre-enzyme, preheat temperature was 200°F (about 93°C). Treated samples 5A, 5B, and 5C were processed similarly to samples 1A, 1B, and 1C in Example 8 except the pre-enzyme, preheat temperature was 200°F (about 93°C). Treated samples 6A, 6B, and 6C were processed similarly to samples 2A, 2B, and 2C in Example 8 except that the pre-enzyme, preheat temperature was 200°F (about 93°C).

The results of the experiments are illustrated in FIG. 7. Enzyme treatment of the 1% milks (samples 5A, 5B, and 5C) and of the 2% milk (6A, 6B, and 6C) caused the L* value to increase compared with the untreated counterpart milk sample and the b* value to become less negative compared with the untreated counterpart milks ("Milk-5" and "Milk-6") and compared with whole milk.

It can be seen from these experiments that enzyme treatment caused a change in color of the milks by decreasing the blueness and, for the most part, increasing the whiteness. This change in color affects the enjoyment of the skim and lowfat milks because the milks after treatment appear more like milk with higher fat content.

SUMMARY

From the foregoing, it will be appreciated that the present invention provides compositions of and methods for making a skim and lowfat milk products wherein the skim and lowfat milk is textured so that individuals will believe they are drinking milk with a fat content greater than normal skim or lowfat milk, and colored so that the milk does not appear so blue and unappetizing.

The present invention also provides compositions of and methods for making a skim or lowfat milk product which fools the tongue of an individual without providing unwanted fats and without destroying taste.

The present invention further provides compositions of and methods for making a skim or lowfat milk product which is not temperature sensitive.

Still further, the present invention provides compositions of and methods for making a skim or lowfat milk product which has greater consumer acceptability due to its increased creaminess, color and mouthfeel as compared with untreated skim and lowfat milks.

Additionally, the present invention provides compositions of and methods for making a skim or lowfat milk product wherein individuals receive the health benefits from the consumption of nonfat or lowfat milk without sacrificing the enjoyment of milks with higher fat contents.
The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed and desired to be secured by United States Patent is:

1. A method for manufacturing a skim milk product, the method comprising the steps of:
   (a) inoculating skim milk with a coagulating enzyme to cleave a portion of the casein in the skim milk so as to destabilize the casein;
   (b) incubating the inoculated skim milk for a period of time sufficient to allow the destabilized casein in the skim milk to form aggregates of destabilized casein so as to produce a skim milk product having a mouthfeel similar to milk having milk-fat content; and
   (c) heat treating the inoculated skim milk to inactivate substantially all of the coagulating enzyme.

2. The method for manufacturing a skim milk product as defined in claim 1, further comprising the step of pre-heat treating the skim milk before the step of inoculating the skim milk with the coagulating enzyme.

3. The method for manufacturing a skim milk product as defined in claim 1, wherein the method further comprises the step of storing the skim milk product so as to prevent the skim milk product from spoiling.

4. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk at a temperature in the range from about 35°F to about 50°F

5. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk at a temperature in the range from about 35°F to about 75°F.

6. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk at a temperature in the range from about 35°F to about 104°F.

7. A method for manufacturing a skim milk product as defined in claim 4, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk for a period in the range from about 30 to about 60 minutes.

8. A method for manufacturing a skim milk product as defined in claim 5, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk for a period in the range from about 10 to about 90 minutes.

9. A method for manufacturing a skim milk product as defined in claim 6, wherein the step of incubating the inoculated skim milk comprises the step of incubating the inoculated skim milk for a period in the range from about 5 to about 90 minutes.

10. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of incubating the skim milk with a coagulating enzyme comprises the step of incubating the skim milk with calf rennet.

11. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of inoculating the skim milk with a coagulating enzyme comprises the step of inoculating the skim milk with a microbial rennet.

12. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of incubating the inoculated skim milk comprises the step of incubating the skim milk with a coagulating enzyme comprising the step of inoculating the skim milk with a plant rennet.

13. A method for manufacturing a skim milk product as defined in claim 1, wherein the step of heat treating the inoculated skim milk product comprises the step of ultra-heat pasteurizing the inoculated skim milk to halt the reaction of the coagulating enzyme with the casein in the milk.

14. A method for manufacturing a skim milk product as defined in claim 1, wherein the incubation time period is adjusted in accordance with the chosen temperature so as to produce a desired quantity of aggregates of destabilized casein.

15. A method for manufacturing a lowfat milk product, the method comprising the steps of:
   (a) inoculating a lowfat milk with a coagulating enzyme to cleave a portion of casein in the lowfat milk so as to destabilize the casein;
   (b) incubating the inoculated lowfat milk for a period of time sufficient to allow the destabilized casein in the lowfat milk to form aggregates of destabilized casein so as to produce a lowfat milk product having a mouthfeel similar to milk having a higher milk-fat content; and
   (c) heat treating the inoculated lowfat milk to inactivate substantially all of the coagulating enzyme.

16. The method for manufacturing a lowfat milk product as defined in claim 15, further comprising the step of pre-heat treating the lowfat milk before the step of inoculating the lowfat milk with the coagulating enzyme.

17. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of incubating the inoculated lowfat milk comprises the step of incubating the inoculated lowfat milk at a temperature in the range from about 35°F to about 50°F.

18. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of incubating the inoculated lowfat milk comprises the step of incubating the inoculated lowfat milk at a temperature in the range from about 35°F to about 75°F.

19. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of incubating the inoculated lowfat milk comprises the step of incubating the inoculated lowfat milk at a temperature in the range from about 35°F to about 104°F.

20. A method for manufacturing a lowfat milk product as defined in claim 17, wherein the step of heat treating the inoculated lowfat milk comprises the step of heat treating the inoculated lowfat milk at a period in the range from about 30 minutes to about 60 minutes.

21. A method for manufacturing a lowfat milk product as defined in claim 18, wherein the step of incubating the inoculated lowfat milk comprises the step of incubating the lowfat milk for a period in the range from about 10 minutes to about 90 minutes.

22. A method for manufacturing a lowfat milk product as defined in claim 19, wherein the step of incubating the inoculated lowfat milk comprises the step of incubating the lowfat milk for a period in the range from about 5 minutes to about 90 minutes.

23. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the method further comprises the step of storing the lowfat milk product
until consumption so as to prevent spoiling of the lowfat milk product.

24. A method for manufacturing a lowfat milk product as defined in claim 23, wherein the step of storing the lowfat milk product comprises the step of storing the lowfat milk product in a refrigerated holding tank.

25. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of inoculating the lowfat milk with a coagulating enzyme comprises the step of inoculating the lowfat milk with a calf rennet.

26. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of inoculating the lowfat milk with a coagulating enzyme comprises the step of inoculating the lowfat milk with a microbial rennet.

27. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of inoculating the lowfat milk with a coagulating enzyme comprises the step of inoculating the lowfat milk with a plant rennet.

28. A method for manufacturing a lowfat milk product as defined in claim 15, wherein the step of heat treating the inoculated lowfat milk comprises the step of ultra-heat pasteurizing the inoculated lowfat milk to halt the reaction of the coagulating enzyme with the casein in the lowfat milk.

29. A method for manufacturing a lowfat milk product as defined in claim 15 wherein the incubation time period is adjusted in accordance with the chosen temperature so as to produce a desired quantity of aggregates of destabilized casein.

30. A processed skim milk comprising: skim milk treated with a coagulating enzyme so as to form aggregates of a portion of the casein in the skim milk, the processed skim milk having a resulting texture such that the mouthfeel of the processed skim milk is similar to the mouthfeel of milk having a higher milk-fat content, the processed skim milk being characterized by the absence of a casein aggregate gel network, and the coagulating enzyme being deactivated after aggregation of a portion of the casein in the skim milk wherein said deactivation occurs prior to the formation of a gel from the casein aggregates.

31. A processed skim milk product as defined in claim 30, wherein the coagulating enzyme comprises a proteolytic enzyme.

32. A processed skim milk product as defined in claim 30, wherein the coagulating enzyme comprises a rennet.

33. A processed skim milk product as defined in claim 32, wherein the coagulating enzyme comprises a calf rennet.

34. A processed skim milk product as defined in claim 32, wherein the coagulating enzyme comprises a microbial rennet.

35. A processed skim milk product as defined in claim 34, wherein the microbial rennet comprises Mucor miehei.

36. A processed skim milk product as defined in claim 34, wherein the microbial rennet comprises Mucor pusillus.

37. A processed skim milk product as defined in claim 34, wherein the microbial rennet comprises Endothia parasitica.

38. A processed skim milk product as defined in claim 34, wherein the microbial rennet comprises Bacillus spp.

39. A processed skim milk product as defined in claim 34, wherein the microbial rennet comprises Aspergillus spp.

40. A processed skim milk product as defined in claim 32, wherein the rennet comprises a plant rennet.

41. A processed skim milk product as defined in claim 30, wherein the coagulating enzyme is comprised of about 90 grams of rennet per 45 kilograms of skim milk.

42. A processed skim milk product as defined in claim 32, wherein the rennet is added to the skim milk at a temperature in the range from about 35°F to about 104°F.

43. A processed skim milk product as defined in claim 42, wherein the rennet is allowed to react with the casein in the skim milk for a time period in the range from about 5 to about 90 minutes.

44. A processed skim milk product as defined in claim 30, wherein the coagulating enzyme acts on the k-casein in the milk.

45. A processed skim milk product as defined in claim 30, wherein the milk product maintains a mouthfeel similar to milk with a higher fat content during subsequent storage and use at temperatures ranging from normal refrigeration to normal cooking temperatures.

46. A processed skim milk product as defined in claim 30, wherein the casein aggregates in the milk product have a length in the range from about 0.5 to about 10 micrometers and a width in the range from about 0.5 to about 10 micrometers.

47. A processed skim milk product as defined in claim 30, wherein the processed milk product has a whiteness value in the range from about 55 to 65 L* units.

48. A processed skim milk product as defined in claim 30, wherein the processed milk product has a blueness value in the range from about -5 to about -2 b* units.

49. A processed lowfat milk product comprising: lowfat milk treated with a coagulating enzyme so as to form aggregates of a portion of the casein in the milk, the processed lowfat milk product having a resulting texture such that the mouthfeel of the processed lowfat milk product is similar to the mouthfeel of milk having a higher milk-fat content, the processed lowfat milk product being characterized by the absence of a casein aggregate gel network, and the coagulating enzyme being deactivated after aggregation of a portion of the casein in the lowfat milk wherein said deactivation occurs prior to the formation of a gel from the casein aggregates.

50. A processed lowfat milk product as defined in claim 49, wherein the coagulating enzyme comprises a rennet.

51. A processed lowfat milk product as defined in claim 50, wherein the coagulating enzyme comprises a calf rennet.

52. A processed lowfat milk product as defined in claim 50, wherein the coagulating enzyme comprises a microbial rennet.

53. A processed lowfat milk product as defined in claim 52, wherein the microbial rennet comprises Mucor miehei.

54. A processed lowfat milk product as defined in claim 52, wherein the microbial rennet comprises Mucor pusillus.

55. A processed lowfat milk product as defined in claim 52, wherein the microbial rennet comprises Endothia parasitica.
56. A processed lowfat milk product as defined in claim 52, wherein the microbial rennet comprises Bacillus spp.

57. A processed lowfat milk product as defined in claim 52, wherein the microbial rennet comprises Aspergillus spp.

58. A processed lowfat milk product as defined in claim 50, wherein the rennet comprises a plant rennet.

59. A processed lowfat milk product as defined in claim 49, wherein the coagulating enzyme is comprised of about 90 grams of rennet per 45 kilograms of lowfat milk.

60. A processed lowfat milk product as defined in claim 49, wherein the coagulating enzyme is added to the milk at a temperature in the range from about 35° F. to about 104° F.

61. A processed lowfat milk product as defined in claim 60, wherein the coagulating enzyme is allowed to react with the casein in the milk for a time period in the range from about 5 to about 90 minutes.

62. A processed lowfat milk product as defined in claim 49, wherein the coagulating enzyme acts on the k-casein in the milk.

63. A processed lowfat milk product as defined in claim 49, wherein the milk product maintains a mouthfeel similar to milk with a higher fat content during subsequent storage and use at temperatures ranging from normal refrigeration to normal cooking temperatures.

64. A processed lowfat milk product as defined in claim 49, wherein the casein aggregates in the milk product have a length in the range from about 0.5 to about 10 micrometers and a width in the range from about 0.5 to about 10 micrometers.

65. A processed lowfat milk product as defined in claim 49, wherein the processed milk product has a whiteness value in the range from about 70 to about 80 L* units.

66. A process lowfat milk product as defined in claim 49, wherein the processed milk product has a blueness value in the range from about —3.0 to about 0.0 b* units.

67. A skim milk product manufactured by the following process:
(a) inoculating skim milk with a coagulating enzyme to cleave a portion of the casein in the skim milk so as to destabilize the casein;
(b) incubating the inoculated skim milk for a period of time sufficient to allow the destabilized casein in the skim milk to form aggregates of destabilized casein so as to produce a skim milk product having a mouthfeel similar to milk having a higher milk-fat content; and
(c) heat treating the inoculated skim milk so as to inactivate substantially all of the coagulating enzyme.

68. A lowfat milk product manufactured by the following process:
(a) inoculating lowfat milk with a coagulating enzyme to cleave a portion of the casein in the lowfat milk so as to destabilize the casein;
(b) incubating the inoculated lowfat milk for a period of time sufficient to allow the destabilized casein in the milk to form aggregates of destabilized casein so as to produce a skim milk product having a mouthfeel similar to milk having a higher milk-fat content; and
(c) heat treating the inoculated lowfat milk so as to inactivate substantially all of the coagulating enzyme.

69. A textured milk product comprising aggregates of casein micelles, said textured milk product providing a subjective sensation of creaminess similar to milk with a higher fat content.

70. A textured milk product as defined in claim 69 wherein the aggregates of casein micelles are contained in skim milk.

71. A textured milk product as defined in claim 69 wherein the aggregates of casein micelles are contained in lowfat milk.

72. A textured milk product as defined in claim 69 wherein the creamy sensation is maintained during subsequent storage and use at temperatures ranging from normal refrigeration to normal cooking temperatures.

73. A method for manufacturing a textured milk product, the method comprising the steps of:
(a) inoculating milk with a coagulating enzyme to cleave a portion of the casein in the milk so as to destabilize the casein;
(b) incubating the inoculated milk with a coagulating enzyme to cleave a portion of the casein in the milk so as to destabilize the casein;
(c) heat treating the inoculated lowfat milk so as to inactivate substantially all of the coagulating enzyme.

74. The method for manufacturing a textured milk product as defined in claim 73 wherein the inoculated milk comprises skim milk.

75. The method for manufacturing a textured milk product as defined in claim 73 wherein the inoculated milk comprises lowfat milk.

76. The method for manufacturing a textured milk product as defined in claim 73 wherein the step of substantially halting the enzyme reaction comprises the addition of a large quantity of non-inoculated milk.

77. The method for manufacturing a textured milk product as defined in claim 73 wherein the step of substantially halting the enzyme reaction comprises heating.

78. The method for manufacturing a textured milk product as defined in claim 77 wherein the heating proceeds to a temperature in the range of from about 72° C. to about 142° C.

79. The method for manufacturing a textured milk product as defined in claim 78 wherein the temperature is maintained for a period of from about 6 seconds to about 16 seconds.

80. The method for manufacturing a textured milk product as defined in claim 77 wherein the heating proceeds to a temperature of about 63° C.

81. The method for manufacturing a textured milk product as defined in claim 80 wherein the temperature is maintained for a period of about 30 minutes.
New Product Development

Presented at U.H.T. Symposium 3/19/96
by Paul Scharfman, Specialty Cheese Co., Inc.

Slide: La VacaRica brand product line

For those of you who don’t read newspapers like the "Cheese Reporter" at breakfast every morning, let me briefly explain what our little company does. We have three small cheese plants in Wisconsin where we manufacture and package cheese for niche markets. We produce and sell La VacaRica brand cheese and cream products for Hispanic ethnic groups whose heritage is Mexican, Cuban, Puerto Rican, Salvadoran, and Dominican. Yes, each Hispanic ethnicity has its own product line.

Slide: The Rich Cow brand product line

We also make the Rich Cow brand Middle Eastern cheese and cream products that are targeted to people who trace their ethnic roots to the countries of India, Iran, Pakistan, Syria, the Gulf States, Lebanon, Egypt, and Armenia. And, since Israel is part of the Middle East, we make a variety of Kosher cheeses including--are you listening Shimon Peres--a kosher Syrian cheese.

Slide: Just the Cheese Brand Product Line

Our most recent new product line is truly unique--and is still in limited test market. We have invented a new snack food that is made solely of cheese yet is crunchy and delicious! To make these "Cheese Chips" we simply season and oven-roast 100% natural Wisconsin cheese. As the cheese dries, its flavor is concentrated so consumers get great cheese taste in a crunchy, calcium rich snack. And, since our patent-pending roasting process preserves all of cheese’s natural nutrients, each one ounce serving of our new Just the Cheese brand of Oven Roasted Natural Cheese Snacks has more calcium than a glass of milk! The two ounce packages come in four varieties: White Cheddar, Garlic ’n Herb, Jalapeno, and Onion.

My objective today is to describe the New Product Development Process that I use both in my company and in my New Product Development Consulting business. I will offer you an overview of this process and take examples from the development of my company’s new product lines.

Slide: New Product Development takes Time

To begin, our New Product Development Process starts with several assumptions. The first is that New Product Development takes time. The more time you allow, the better chance you will have a truly unique, hi-
potential new product line. The less time you offer, the more likely you are to come out with a simple knock-off of someone else's idea, or a poor execution of a new idea. By way of example, I was asked last week by an ice cream manufacturer to do consulting work with them to develop new products for their summer sales. I told him that would be no problem—for the summer of 1997! As you can guess, that was not what they wanted to hear.

Slide: Simple Line Extension in 6 months
Complicated Line Extension in 12 months
New Product Line in 24 months

As a rule of thumb, we figure it takes us 6 months from conception to marketplace introduction of a simple line extension such as putting Jalapenos into our Quesadilla cheese. It takes us about a year to introduce a line extension which poses difficult production challenges or is truly new to the consumer. For instance, in late 1994 we recognized that consumers of Caribbean extraction had a traditional behavior that used our leading cheese: they consumed Queso Blanco cheese and tropical fruits such as Guava or Mango as dessert. It took us a year to capitalize on this insight and offer our new and unique Queso Blanco con Frutas—white cheese with pineapple and Mango.

For a truly new line of products we plan on a two year time period from initial idea generation to full scale product launch. As an example, it took us almost 18 months to get into our current test market with our new line of Just the Cheese brand Oven Roasted Cheese Snacks. I figure we will not be able to expand the line for at least a year.

Slide: Amoeba

The second assumption we make at our company and in our New Product Consulting work is that new product success comes to a firm the way an amoeba grows. Amoebas slowly extend from their current base. They do not leap into totally new areas. So too, successful new products rarely come from companies that leap into totally new technologies or businesses. You are more likely to succeed if you absorb the market opportunities close to your core competencies than those further away.

Slide: New Products add value to the marketplace. They are not copycats.

The final assumption we make in developing new products is that our new products must add value to the marketplace. To do so they must be either truly unique or our company has to offer a meaningfully better execution than is currently available. Copycat products, to us, are not acceptable as outcomes of our New Product Development Process. As you will see, before we introduced our La VacaRica brand of Hispanic cheeses we
proved to ourselves that they were significantly superior products and packages compared to any other brand's items.

Slide: The New Product Development Process starts with a Team

With these assumptions stated, let's work our way through the Development Process itself. To start, a company needs to assemble a team of people who come from a wide variety of backgrounds and believe in the importance of the New Product Project. The Team needs to be given its authority by the most senior person in the company. In all of my consulting work, for instance, I insist that the General Manager of the client firm actually be part of the Team so he or she can constantly affirm the priority the project has over the daily "firefighting" that the Team members face.

Slide: Assemble a Diverse Team

Who else should be on your new product development team? The team will need to have enough people on it so that all aspects of the new business can be addressed: "R&D", advertising/marketing, sales, production, quality assurance, finance, and legal/regulatory, at least. If your company does not have all these experts on staff, you will need to hire the missing resources as consultants. You should be aware that the cost of doing so is generally less than you would expect: some universities have research staff who are able and anxious to help as "R&D" experts, I bet your company's salespeople and brokers will be glad to help, and your many label suppliers will donate their time or work for a modest fee, and I have had great success involving other suppliers and even food safety regulators in our Development Teams.

Slide: Know what you are good at. Compare yourself to your competition.

To successfully introduce a new product, your company has to be better at its manufacture and marketing than the competition. So, the first task for the Development Team is to assess both the abilities of your firm and those of your competition. The Team needs to understand what the Company is good at, and where its competitors are better.

Every company has some strengths and some weaknesses. Too often the Management of a small to medium size firm feels dismayed when evaluating their company. As a small business owner, I know that I am constantly reminded of my firm's weaknesses--and rarely of its strengths. Yet every firm must have some distinct strengths or it would not still be in business.

We find that a good way to start a situation assessment is with a brief "competitive review". Your Team can do this by visiting their local supermarkets and Specialty stores and looking for products that compete
with your existing products. Your Team should call your customers and brokers to ask for competitive samples and to ask why they think your products are valuable in their competitive market. To store clerks and business associates alike your Team members should ask similar questions, "We make such and such product. What do you see as our competition? How do you perceive our product compared to our competition?"

Look at your competitions' product lines and business practices. Why are you successful when you compete with them? Are your strengths in customer relations? If so, then new product development will focus on either expanding your business with your existing customers or finding similar customers. Are the firm's strengths in a unique or difficult-to-imitate product? If so, the new product development process will focus on expanding the product line using this proprietary process. Many firms make very good product with very good customer service but compete on price because their product is a commodity. Such firms need to develop a new product that fits with their existing plant and personnel but is more differentiated. In the cheese industry, many small cheddar and mozzarella makers fit this description. They are ideal candidates for new product development for niche-market cheeses. The question for such firms is how to develop a new niche-market product--no one benefits by duplicating another firm's niche cheese.

Let me show you a summary of the self-assessment I did when I was considering buying what is now my company. At that time I was not sure I wanted to go through with the acquisition and if I did I was not sure what role new product development would play in the the new enterprise.

Slide: 9/91 Company Assessment

As you can see the firm I was considering buying had significant weaknesses. It would have little cash after an acquisition, and it had poor new product and sales capabilities. These weaknesses were compensated for by strengths in several cheesemaking areas and a competitive opportunity in the Hispanic market. Based on this summary assessment, my team felt we should move forward into the Hispanic cheese business after the acquisition by developing new products that would move the new company away from its traditional base in the manufacture of Colby and Muenster type cheeses.

Slide: Develop a wide range of new product ideas that are feasible for you

My plan was to make the acquisition contingent upon developing a successful new Hispanic cheese concept. I figured that the firm could build on its cheesemaking strengths in Cuban Queso if I could bring it solid new Hispanic cheese product concepts.
To do so I first did a thorough study of our major customers' operations since I clearly understood that the best source of new product ideas is from existing customers.

Slide: The best source of new product ideas is from existing customers

I found that the customers were brimming with ideas for me to implement should I acquire the firm. In fact, our company enjoyed 35% volume growth in its first year after the acquisition, of which at least a third was simple execution of ideas these major customers suggested before I had made the acquisition.

My initial customer visits were also followed by a formal brainstorming exercise for further new product idea generation using the customers ideas as one set of stimuli. These "concept creation" sessions involved both team members, members of industry associations, and industry "experts". It was based on these ideas and our earlier competitive assessment that we developed the core ideas behind our La VacaRica brand.

Slide: Pick a mega-trend and ride it. John Naisbitt says, "trends are like horses: they are easier to ride in the direction they are already going".

After your team has an understanding of your company's core competencies and competitive strengths it is time to create new product ideas that build on your strengths.

New product development involves making bets. It is a gamble. Your odds will be much better if your risk is tied to a growing trend in society. Look at a list of predictions about our society and ask yourself what each prediction means for your product category. What needs will become more important if the predictions come true? In my case, I did a leveraged buyout based on the mega-trends around ethnic growth and consumer fragmentation.

Slide: Mega-Trends

Here are some trends that should spark ideas for new products.

- Global economy
- Home and Hearth
- Cultural nationalism
- Europization
- Rise of the Pacific Rim
- Convenience
- Women as leaders
- Empty nesters
- We'll live longer
- Growth in the Southwest
Slide: Brainstorm ideas with your team that you think your firm could produce.

The next step in the Development Process is to gather your development team for several hours. Pin up a list of trends that you believe in and a summary of your Situation Analysis. Ask the group to come up with fifty new product ideas that are consistent with the trends. Then ask the group to eliminate those ideas that your firm could not produce even if it had the money to change some equipment.

Let me tell you how this process has worked for me. In 1994, I asked that the State of Wisconsin grant the Wisconsin Specialty Cheese Institute funds to do new product development for its small cheesemaking members. Over the six months after the funds were granted, I led this project until the new product concepts were developed and turned over to our members.

To initiate the Process, I first pulled together a Development Team, and did an assessment of our members' competitive situation. In order to brainstorm new product ideas, we assembled a group of 22 people for one and a half days at a local hotel. The participants included food editors from national magazines, chefs from famous white table cloth establishments, housewives, industry experts, a banker, several regulators, and some manufacturers. We divided into three groups and each group received a presentation on future trends plus a summary of our Team's competitive assessment. We then set to work creating. By the afternoon of the second day of work we had created some 200 new product ideas that we felt were both feasible for our State's small cheesemakers and had strong sales potential.

One of those ideas evolved into our Just the Cheese brand of Oven Roasted Cheese Snacks, as I will describe.

Slide: Ask your team to take your list of ideas and put them in priority order according to which ones have the best mix of these elements:
-- you can do it
-- your competition can't do it as well
-- you think there is a market for it
Then, go get some consumer feedback on your ideas.

After our massive brainstorming session, my core Team settled in for the work of sorting, combining and prioritizing our new product ideas. We did this prioritizing based on three criteria. We wanted to focus on ideas that our State's small cheesemakers could manufacture, those that their competition could not do as well, and ideas for which we felt there would be
a solid demand. Based on this activity our Team found we had roughly fifty new product concepts. Some of these concepts were targeted to families, some to senior citizens, some to teens, some to casual theme restaurants, some to white table cloth restaurants, and there were other new product ideas that were targeted to groups that I can no longer remember. Since we knew that our next step would be talking to our potential target groups, and we figured we could not afford to talk to so many different groups of people, we narrowed our list of new product ideas to those that were targeted to three groups. This narrowed our list of new product concepts to 35.

If your Development Team ranked highest some new product ideas for empty nesters, some for teenagers, and some for Norwegians, then go ask a handful of each to give you their opinions of your ideas. You don’t need a professional researcher at this point. Just go and ask what your potential customers think. Use your friends and acquaintances. Listen carefully to what they say. Don’t disagree. Do ask them specific questions about how they would use the product. Your objective at this stage is not to decide if your new product idea is good or bad. Your objective is to improve your ideas so they might become saleable. The key question, therefore, is not "do you like my idea?" but, rather, "would you use this product often? And, if not, what could we do to improve it?"

Slide: Go back to the drawing board. Create revised, "Positioning Statements".

To communicate your ideas to your potential customers you must give them the "guts" of the idea. They need to know what the product is, what benefit it delivers and why they should believe the benefit is best delivered by your product, not that of your competion. This is called "positioning" a new product in a consumer’s mind.

To develop positionings for your Team’s new product ideas you should force your Team to put their ideas into a one paragraph positioning description that can be understood by a six-year old. Each idea’s positioning should answer the following questions:

--who will use it
--what will they use it instead of (that is, what will it compete with)
--why will they use it
--why should users believe your product will deliver that benefit

Slide: A "positioning" must answer these questions:

To (target group) ABC brand of (what it will compete with) is the brand that offers you (benefit) because the product is (reason for believing benefit).

For instance, and I’m sorry about this example, a competitor to UHT milk might be a local dairyman who wants to bottle his own milk. For him a
new product concept could be as simple as, "Introducing Joe's Logan Dairy fresh milk for your family. Our milk tastes better since it is made locally so it is fresher."

Slide: "Introducing Joe's Logan Dairy fresh milk for your family. Our milk tastes better since it is made locally so it is fresher."

In this example, a simple two sentence description of the new product idea gives a member of the target group all he or she needs to know to give you their opinion of the idea. They can answer questions like, "would you buy it", "do you believe the brand can deliver the benefit", "do you find the benefit important", and so on.

As we developed the ideas for new Hispanic cheese product lines five years ago we felt we had five solid ideas that would be meaningful to Hispanic consumers and could be technically insulated from our competition. Here are the core positionings we had in mid-1991.

Slide: Our alternate concepts for a Hispanic cheese line.

As you can see, we needed to investigate a range of positioning ideas.

Slide: Use a "focused group discussion" to ask your potential customers their opinions.

For those of you who don't know, a "focus group" is simply a small group discussion focused on a single subject. I imagine you have all heard how focus groups have been used to help elect politicians -and to predict the O.J. jury. For our purposes, of course, we want to focus the group's discussion on our new product ideas.

To do a focus group, one uses a skilled moderator and between five to ten members of your target group. At this stage in the Development Process, we usually start the group discussion by asking the respondents to talk about our new product's competition and what they wish was available in the marketplace that is not available now. Then we show them our ideas. We ask whether they would use the product and how it compares to competition. And we, ask how they would improve it.

In the case of our Just the Cheese brand Oven Roasted Cheese Snacks, such groups were absolutely crucial. As I mentioned, the idea for this product line came out of brainstorming done for the Wisconsin Specialty Cheese Institute.

Slide: INTRODUCING "CHEESE COOKIES"

Here is the initial new product idea we showed consumers in late 1994. As you can see, this idea was originally a cookie-type concept targeted
toward upscale consumers. In our first focus groups we learned that we had missed the mark.

Slide: Ask Consumers to Improve the Concepts until you have some ideas that are greeted with enthusiasm by consumers.

The consumers in those early focus groups told us how to improve the concept. Rather than give up on the idea, we revised it. The consumers helped us to see that the core idea was "cheese and crackers without the crackers", not a desert product. So, we changed the concept to what you see here.

Slide: INTRODUCING "ROASTED CHEESE CHIPS"

When we took this revised concept to further focus groups, we started to get some keen enthusiasm for the concept from both mainstream consumers and restaurant chefs. We had created a "concept" that would sell!

Slide: When you have identified an exciting product idea, take the time to determine what are the crucial "consumer words" that drive interest in the idea. Identify what phrases you need to emphasize as you sell the idea.

Whenever we feel we have a strong new product idea, our Development Team begins the process of assembling a complete selling package. A selling package, by the way, does not include namby-pamby marketing experts who wear pink ties. Oh! Why look at that!

We create many alternate phrases that we think capture the core "consumer promise". For our Just the Cheese brand, here is the list of some of the consumer promises that we created after we had identified the core selling idea we just saw.

Slide: Just the Cheese brand Benefit Study

You can see the range of consumer promises that we investigated. Some focus on taste as a benefit, others on health, others on convenience, and so on. The lesson here is that even though we thought we had identified the basic new product idea, we spent the time to improve the idea and be sure we knew how to communicate it.

When we were at this stage in the development of our La VacaRica brand of Hispanic cheeses, we felt the nuances of communication in Spanish were critically important so we conducted several focus groups to explore several phrases.

Slide: Communication of La VacaRica brand positionings
For instance, we wanted to know whether the connotation of "rich taste" was that the product tasted good or whether it was "rich, snooty and unapproachable".

Slide: La Riqueza de Lechepura TM

We spent a good deal of time exploring these issues among the different ethnic subgroups within the Hispanic population. As the groups progressed we were increasingly led to believe that "rich taste" was the high ground of taste imagery for Hispanic cheese users. Over the course of our focus groups, we learned that "whole milk" connoted "good milk" to our target audience. These people told us that "skim milk" was "leche descremada" which translates literally to "milk without the cream" but means "milk without the goodness". They felt that whole milk cheese would have more flavor than skim milk cheese. Consequently, we adapted the phrase you see--which is our trademarked slogan now. It translates, roughly, to mean, "the goodness of whole, pure milk". It is the reason why Hispanic consumers believe our cheese tastes better than the competition.

Slide: When you feel you understand your new product idea and how best to communicate it to the target group, spend the money to test it thoroughly.

A "Concept Test" is simply a test administered to at least 100 people to see if your new product concept communicates what you think it does, and whether many of your targeted audience would buy it. The bigger the risk in developing a new product, the more people you want to test it on. I refer to these tests as "electrified hurdles" since concepts which fail in their concept testing must either be reworked or abandoned. It is not worth expending product development resources on new product concepts until you are certain of their appeal.

Slide: Design a Questionnaire

The Team should put together a simple questionnaire to evaluate the merit of their concepts among their target groups. The format of the questionnaire is to first, thank the respondent for being willing to answer the questions. Second, show the respondent the concept.

Slide: If this product was available in stores in your area.....

Third, ask the respondent how likely they would be to purchase the new product. The question you see on the slide is the classic first question in most concept tests. We always ask it first so as not to bias the answer with thoughts raised by further questioning.

Slide: Below are a list of benefits some people feel this product offers....
Fourth, we ask questions to determine what the respondent understood to be the meaning of the concept. This slide shows an example of such a communications testing question. It is amazing how often a concept is understood by consumers in a manner very different from that intended by the Development Team that wrote it.

Finally, ask the respondent a few questions to verify that he/she was in the target group. These questions usually include standard demographic information.

Slide: Create some prototypes of product, package and label. Refine them based on your consumers' reactions in the same way you revised and improved your concept.

If your concept has been well accepted by its target group, it is time to move on to prototype development. We used focus groups to help us develop the package and graphics for our La VacaRica brand.

Slide: First graphic design La VacaRica brand

Here you can see our initial graphic design. The brand name we were using was that used in the early stages of our development effort.

Slide: Second graphic design La VacaRica brand

While some consumer marketers think that doing research on packaging is akin to doing research on the color of your tie, we found our research very helpful in resolving our packaging graphics issues.

Slide: Design of cow with horns

For example, the cow with horns you see here is authentic for most Latin dairy herds but our consumers simply did not like the horns. We got rid of them.

Slide: La VacaRica brand in zip bag

This package was the final winner in our consumer focus groups. Unfortunately, the research we later did among supermarket buyers nixed the zip bag because their store personnel could not easily shelve the product. It would either fall over or take up too much room on the shelves.

Slide: Final package front

Here is the final step in our graphic development work. I'm sure you will agree it is quite an improvement over the cactus design we started with!

Slide: Determine what items should be in the product line
We field a set of questions in our concept tests that help us sort through which cheese varieties consumers most prefer. In the Hispanic market, this is particularly important due to the wide range of varieties each ethnicity and nationality prefers.

Slide: Flavor screen

As you can see, we asked Hispanic consumers around the country their preferences for cheese types to be included in our La VacaRica brand product line. We found differences from city to city that enabled us to better target our product line as we introduced the line.

Slide: Product Development should be based on your target group's preferences, not your own.

To develop our La VacaRica brand cheeses to be the best tasting products on the market, we asked Hispanic consumers to tell us how our prototypes tasted. We spent many weeks going from benchtop to consumer and back. Each item in our line had to be optimized.

Slide: La VacaRica brand product test format for focus groups

As we learn which attributes of the product are important to our consumers, we develop a grid for them to respond to the products we ask them to taste. In the example on this slide, you can see how we could first ask consumers to evaluate a competitive product on the attributes of crumbliness, whiteness, and so on. After they had completely evaluated the competitive product, we could ask them to do the same for our prototype products. This allowed us to determine our target for each physical attribute of our cheeses.

As I am sure our later speakers will discuss, this sort of consumer-based product development pays off with high performance products.

Slide: La VacaRica brand taste test results

We were able to develop Hispanic cheeses that are the best tasting in the marketplace. In late 1991, we spent $35,000 to ask 200 Hispanic consumers to taste each of our cheeses and compare them to their leading competitors. You can see we succeeded.

Slide: Go sell your product, but only a little bit at a time. Remember Murphy's Law. Listen carefully to reactions from the marketplace.

We literally used color xeroxes, cut them out and pasted them on clear packages of our cheese in order to sell our first customers. We sold about 100 pounds that way, and we learned a lot. I was not willing to invest in
finished labels until I saw the product attain sales in several stores. And, by the way, I'm glad I waited to print labels since we had to revise our labels based on some feedback from our distributor.

In the case of our Just the Cheese brand, we are staying in test market rather than expand broadly because we feel we have so much to learn. In fact, we plan several significant changes to the packaging of the product based on our learning in test market.

Overall, I would caution a Development Team to be careful not to go too quickly into broad distribution. Your production capabilities will be doing something new. The marketplace will be reacting to something new. Give yourself a chance to walk before you run.

Slide: You can do anything but you can't do everything

After inventing a new product, I find it very difficult to let other people take the lead in selling it. But my job, and that of most people on a Development Team, is elsewhere. The salespeople, and brokers are the pro's. At this point in the Development Process you must let go and move on.

Slide: An in-store product demonstration

This is a shot of my wife and daughter doing the first demo on our La VacaRica brand cheese. After the brand was launched, we continued to learn and modify the line. I continue to do occasional demos myself so I can stay in touch with the response of consumers to our products. And, I keep learning. In that sense, the New Product Development process never stops.

Slide: "All you need in life is...."

Maybe I'm like Mark Twain. I tend to see the world through the distorting lens of ignorance: I always assume that the New Product Development Process will end with its most important phase. We celebrate!

Slide: Celebrate!
PATRICIA A. FEHLING

OWNER/FOOD SCIENTIST, FEHLING & ASSOCIATES

Patricia Fehling graduated from the University of California at Davis with a degree in Food Science & Technology and was employed at Ogden Food Products for 17 years prior to opening her own research firm. She was Director of Research and Product Development at Ogden Foods whose divisions included Progresso Quality Foods, Las Palmas Mexican Foods, Hain Pure Foods and Tillie Lewis Foods.

Fehling & Associates is a food research and product development consulting firm. It was founded in 1984 by Patricia Fehling who has had 26 years of experience in the food industry conducting research, product development, technical services, as well as marketing assistance as related to the client’s new products.

Patricia Fehling has taught product development seminars at the University of California at Davis, has appeared on several television programs representing the food industry and is actively involved with the Institute of Food Technologists. She has been a past Chairman for the Northern California IFT, and has held several committee memberships.

She is a member of National Food Processors Association, American Association of Cereal Chemists, Research and Development Associates for Military Food and Packaging systems and Society for Packaging and Handling Engineers.
PRODUCT DEVELOPMENT PROCESS

PRODUCT CONCEPT

THE TEAM:

Food Scientist
Quality Control
Process Engineers
Production
Marketing
Purchasing
Management
FOOD SCIENTIST:

Ingredients

Formula and Specifications

Manufacturing/Equipment

Microbiological Concerns

Process

Cost Parameters

Container

Legal/Label - Regulatory Issues

Stability/Shelf Life
UHT PRODUCT DEVELOPMENT

CONSIDERATIONS FOR SAFE, QUALITY, AND CONSISTENT PRODUCTS

INGREDIENTS

PREPROCESSING PROCEDURES

PUMPS/HOMOGENIZERS

BATCH SIZES

HEAT EXCHANGERS

PROCESS TIME TEMPERATURE AND FLOW RATE

FILLING MACHINES

CONTAINER/PACKAGE

SHELF LIFE

SOME OF THE ABOVE CAN BE NEGOTIATED
INTERACTIONS:

PHYSICAL

INGREDIENTS

CHEMICAL

EQUIPMENT

HOW DO THEY INTERACT?

MICROBIOLOGICAL

PROCESS

ORGANOLEPTIC

CONTAINER

NUTRITION

SHELF LIFE
INGREDIENTS - ALL SHOULD HAVE A DEFINED FUNCTION

- VISCOSITY
- pH
- SOLIDS CONTRIBUTION
- FLAVOR
- COLOR
- PARTICLE CONTRIBUTION
- SHELF LIFE EXTENSION
- NUTRITION
WHAT ARE INGREDIENTS:

WATER

PROTEIN

LIPIDS

CARBOHYDRATES

ENZYMES

ALL CAUSE CHEMICAL AND PHYSICAL CHANGES

SEQUENCE OF INGREDIENT ADDITION TO REMEMBER:

STARCHES

HYDROCOLLOIDS

ACIDS

PHOSPHATES

PROTEINS

WATER
INGREDIENTS:

DAIRY PRODUCTS

FLAVORS

HYDROCOLLOIDS

STARCHES

EMULSIFIERS

PHOSPHATES

FRUITS

SUGARS

COCOA POWDER

ACIDS
PREPROCESSING PROCEDURES CRITICAL TO THE FORMULATION:
ORDER OF INGREDIENT ADDITION
PROTECTION OF THE PROTEINS
MIXING SYSTEMS - RPMs
HOLDING TIMES AND TEMPERATURES

PUMPING SYSTEMS:
HOMOGENIZERS
BACK PRESSURES
BALANCING THE SYSTEM PRESSURES

HEAT EXCHANGER TYPES AND PROCESS AFFECT ON THE FORMULATION:
VISCOSITY - EMULSIONS
COLOR
FLAVOR
PROTEINS
SCALE UP CONCERNS

A. Scale up for any product is a matter of predicting the performance of a "Larger System Based on the Operating Parameters of Smaller System."

B. Define - Document - Plan - Anticipate

C. Be Aware of:

- Water
- Agitation - Type and Amount
- Air
- Time
- Temperature
- Shear
1. Introduction

Slide 1.

An overview of aseptic packaging options and market opportunities for dairy products

Charles H. Watkins
Director of Marketing
Robert Bosch Corporation

The aseptic industry has grown considerably over the last 60 years. It is now possible to package an extensive variety of products with this technology, offering to the consumer high product quality, shelf stability and packaging convenience, and to the producer new product possibilities, reduced packaging costs, tighter process control and streamlined operations.

Slide 2.

Fresh dairy products; milk, cheese dip, sour cream, cream, etc.

Within the dairy sector, the product segments potentially addressed by aseptics are quite varied from a marketing standpoint, and each has its own opportunities and unique challenges. Overall, establishing a shelf-stable dairy market with the consumer has been a difficult road. Mainline dairy products are quick to evidence the heat treatment necessary for shelf-stability, and the consumer has a ready standard of comparison in the fresh products supplied by our excellent refrigerated distribution system. The chilled quality of refrigerated product is a flavor attribute in itself, and also, rightly or wrongly, a measure of presumed product healthfulness to the consumer. Ask yourself if you've ever shied away from a dairy dip at a party, treating it as suspect simply because it was warm.
Nevertheless, for certain aseptic products, the market is well established, and while not growing significantly does support profitable ongoing business. For others, aseptics has been a highly successful packaging medium, developing entirely new markets with significant, and continuing, growth curves.

Finally, there are some products for which aseptic equipment and process capabilities exist, but the products themselves have not been pursued in the U.S.

In this product-oriented presentation, I'll overview the major aseptic dairy product categories in the retail and institutional markets, giving current status and the range of packaging options available today. For interest I've included a number of product examples from outside the U.S., but it should be remembered that many are produced on equipment which has not achieved FDA approval for production here. In some cases, alternative FDA approved equipment is available; in others not.

For context I'd like to start with some brief historical background relating to the use of retort canning for dairy products, which is still a very viable packaging alternative.

Slide 3.

Dole machine drawing

Aseptic packaging had its start with dairy products in the 1930's, driven by the desire to obtain improved shelf-stable product quality over what could be achieved in the still retorts available at that time.

The Dole canning process was developed in 1948, and provided the first workable packaging method to complement high-temperature-short-time treatment and cooling of product in continuous flow heat exchangers. Containers and lids were sterilized with superheated steam and filled and sealed in a high temperature environment.

Initially commercialized with milk and soup in 1952, the Dole process vied with the agitated retorts which became prevalent in the 1950's for canning of thin viscosity dairy products. This competition continues today. For more viscous products such as pudding and cheese sauce, which suffer unacceptable coagulation and carmelization in conventional post- sterilization processing, the Dole is really the only viable canning alternative. I understand there was one FMC Orbitort running cheese sauce, but this is no longer in operation.
But post-sterilization canning remains a viable packaging technology for a number of diary products. These are principally smaller volume fluid and thin viscous applications where there is a packaging requirement for retort, where flavoring is used, where natural flavor attributes are less important or where product formulations can be adjusted to mitigate the effects of heat treatment. In an agitated retort, the thin viscous nature of these types of products reduces process times and facilitates re-homogenization, yielding acceptable, if characteristic, product quality.

As examples, the Yoo-Hoo beverage has been packaged in glass bottles, which would not withstand the dole process. Also in aluminum cans which need to be pressurized with nitrogen for shipping strength. Dole has not commercialized the introduction of sterile liquid nitrogen in its high temperature filling environment, though I understand this is being worked on.

Evaporated milk is a retort product. It's traditionally been used in recipes, as coffee creamer, and for emergency rations and its characteristic flavor is accepted in its market. Flavored dietary products have been retorted in the past without consumer objection. Infant formula, which with all its fortifications was not expected to taste like a natural dairy product anyway. and some creamed soups.

Dietary and sports drinks including Nestle Sweet Success

Dole is making new inroads in these thin-viscous product categories in recent years here and in Europe, particularly in the developing dietary and meal substitute market segments. Reasons include increases in machine output, reduced costs over large scale retorts, and pursuit of improved flavor profiles by producers as they attempt to capture market share. Slim Fast and the Nestle Sweet Success product is packed on Dole. Dole systems fill 4-16 oz containers at speeds up to 30,000 containers per hour.

Tetra Yoo-Hoo, Hershey

With the development of hydrogen peroxide sterilization of plastic packaging in Europe in the '60s, and approval of peroxide's use by the FDA in 1981, the American consumer was offered a greatly expanded range of packaging options for shelf-stable dairy products. Non-thermal sterilization brought out the true strength of aseptic technology, marrying high product quality with consumer-convenient packaging.
Plain milk and Yoo-Hoo were the first low-acid aseptic products in flexible packaging, introduced to the retail marketplace in 1982 and followed closely by Hershey with their flavored milk. Many different milk, flavored milk and some yogurt based beverages have been introduced shelf-stable over the years, with varying success, always in brick packaging.

Slide 7.

European and Japanese Tetra milk

Tetra shelf-stable milk is in fact the most common low-acid aseptic product worldwide and I hear of product examples in Africa, Asia, Europe, South America, and Indonesia. Japanese and French 1 liter packages are shown here.

Brick pack containers have typically been produced in fill volumes ranging between 125 ml up to 1 liter at output rates around 6000 containers per hour.

Slide 8.

Parmalat 1 liter milk, flavored milk, smaller sizes

With the widely publicized national roll out of the Parmalat product line, 1994 was an important year for shelf-stable dairy products in the U.S. incorporating a unique reclosable pour spout in the 1 liter CombiBlock package, it is hoped Parmalat's aggressive promotional campaign may finally get the U.S. consumer accustomed to shelf-stable ambient temperature dairy products.

Slide 9.

CombiBlock 64 oz milk

Aseptic brick pack containers larger than 1 liter are now a reality with the installation this year of a half-gallon CombiBlock container at Johanna Farms in New Jersey. Commercial production awaits completion of the FDA filing process.

Slide 10.

Elopak gable top cartons

Elopak hopes to commercialize this year in the U.S. the first fully aseptic gable-top carton for low-acid products. This package is currently being used for both high and low-acid
shelf-stable products in Europe and a U.S. installation is being sought to complete the FDA filing process. Elopak uses a 7 layer paperboard/foil/plastic structure and eliminates product contact with the cut material edge in the interior of the carton. Output is 8,100 cartons per hour.

Slide 11.

European plastic bottled milk

Aseptic plastic bottled milk has not been introduced in the U.S. and is in general far less common in the world market than brick pack. Examples are found in the Caribbean and a limited number of European countries - notably France, Germany, and the U.K.

Shown here are .5, 1, and 1.5 liter milk containers in HDPE. Also a German yogurt-fruit drink.

Equipment used to produce these bottles reportedly runs up to 12,000 containers per hour, but the sterilsants used to my knowledge have not been approved by the FDA for aseptic production in the U.S. Individual suppliers should be contacted for current status.

Slide 12.

European glass bottled milk

Environmental recycling has been a strong drive in Europe resulting in this German 1 liter milk bottle in glass which is true return/reuse.

If there ever were interest in this type of product in the U.S. the lack of suitable high-speed FDA approved equipment would likely be an impediment. There is one FDA approved low-acid bottle machine in production here, but at 100 bottles per minute output, it is not economic for the commodity milk market segment.

Slide 13.

E-concept pouch

In terms of alternative packaging formats, refrigerated non-aseptic pouched milk is common in Canada with over 60% of the market. Pouch milk is also prominent in Switzerland, South America, Mexico and India, and to a limited extent in at least one eastern block country Hungary. Most pouch milk is refrigerated, but there is some aseptic.
In Europe, pouched milk is expected to become increasingly common, driven by environmental concerns, and there are new installations under construction.

One developmental project is underway in Germany, called the E-concept pouch, shown here. Material and equipment suppliers have formed a consortium with a dairy to produce 1 liter aseptic milk pouches as an alternative to the brick-pack. Introduction is expected late this year.

Slide 14.

Creamer display packs; Ultra, Presto, Morningstar

In terms of other fluid milk products, an important developing market category is aseptic coffee creamers. This product was introduced to the U.S. in 1988 by Ultra Products, though until recently the majority of the available production was dedicated to McDonald's. With additional equipment installations in the last two years, and the 1994 entry of the strongly-branded international-delight flavored coffee creamers, the market for shelf-stable creamers in the U.S. is finally taking off.

The potential market for aseptic creamers is enormous. Approximately 411 million cups of coffee are consumed daily in the United States, and 54% use a whitener of some sort. The current production of single serve liquid whiteners is estimated at 18 billion cups with some 1.5 billion already shelf-stable.

Shelf stable creamers are gaining popularity because they can be distributed at ambient temperatures and because they eliminate concerns over temperature abuse both in distribution and final presentation to the consumer.

Aseptic creamers are already found in the institutional sector, including airlines and restaurants, convenience stores, and warehouse clubs. The office coffee-service sector is a particularly large opportunity as aseptics is the only way a coffee-service vendor can provide a natural product in the non-refrigerated vendor distribution system.

The retail supermarket may also become an important outlet. Flavored coffee creamers in gable-top cartons distributed in the dairy case grew 5-fold in the 1989-1993 period, reaching $194 million dollars total category sales last year.

Aseptic coffee creamers are produced at speeds up to 100,800 creamers per hour on thermoform/fill/seal systems. In addition, a pre-formed cup machine for coffee creamers was FDA approved in 1995.
Slide 15.

Japanese creamers in pouches

Several packaging and marketing approaches have not yet been introduced in the U.S. in Japan, 5 ml shelf stable creamers are distributed retail in pouches.

Slide 16.

European multi-packs

In Europe, the majority of single-serve creamers are aseptic. These European multi-packs are very popular and are commonly available in supermarkets. Multi-packs are often downstream flow-wrapped in oriented polypropylene to reduce moisture loss and permit use of monolayer polystyrene rather than more expensive barrier cup materials.

Slide 17.

Creamer lidding - flowers

Collectable lidding materials have become an important marketing tool in Europe. One Swiss dairy has found these significantly increase sales and has greatly expanded the number of new series produced, reaching in 1994 alone some 44 new multi-pack lidding series with over 3,600 pictures.

I thought I'd show you a cross section of the kinds of things that are possible - in this case a typical wildflower series.

Slide 18.

Creamer lidding - birds

Birds

Slide 19.

Creamer lidding - whales

Whales
Slide 20.
Creamer lidding - vehicles
Historic transportation

Slide 21.
Creamer lidding - farm implements
Historic farm implements

Slide 22.
Creamer lidding - landmarks
Landmarks and events. This entire series is devoted to the famous Lucern bridge, which burned down in 1993.

Slide 23.
Creamer lidding - motorcycles
The best of Americana, Harley Davidson.

Slide 24.
Creamer lidding - Volkswagen
A collection of Volkswagen nostalgia for children of the 60's.

Slide 25.
Creamer lidding - entertainers
Popular entertainers
Slide 26.

Creamer lidding - cartoon

Well known cartoon characters. The Swiss dairy has found children actually promote creamer use by their parents.

Slide 27.

Creamer lidding - dinosaurs

And I suspect have even shifted adult consumption to portion sizes through collectable lid films targeted at this audience.

No end to the possibilities, and a real marketing opportunity for coffee creamers.

Slide 28.

European creamer cans

To finish the coffee creamer segment, I've included one slide of the popular European aseptic creamer-cans. With the exception of the smaller pitcher-shaped package on the right, these pre-formed, in many cases reclosable, plastic containers are filled inverted on a cup machine and contain 200 ml of coffee cream. An opening pour-spout is molded into the cup.

No U.S. equivalent exists.

Slide 29.

Domestic pudding; HW, Del Monte, Pathmark

Another major aseptic dairy product category in the U.S. is shelf-stable ready-to-eat puddings. These were originally produced in Dole cans, and although some Dole production continues for nutritional pudding products, packaging has largely shifted to plastic cups.

Puddings were in fact the first dairy product to arrive shelf-stable in plastic cups in the U.S., initially with Conofast, quickly followed by thermoform systems in the early 1980's, taking advantage of peroxide sterilization approval.
Introduced as single flavor puddings, this important category has vied with the refrigerated case for product enhancements. Today, layered puddings and variety packs are available shelf-stable, increasing the important novelty aspect of this product category. The products are also ideally suited to non-refrigerated club-stores, and have developed well in this increasingly important distribution channel.

New aseptic thermoform/fill/seal equipment is capable of producing these type of packages at over 55,000 containers per hour. More generally, available equipment can generate a wide array of package designs spanning cups, tubs and trays and barrier polypropylene thermoforming at draw ratios up to 1.5 is now feasible.

Slide 30.

European pudding products - fruit based

If you look to Europe, which to my knowledge is the only other market currently having shelf-stable desserts in flexible packaging, you find a much wider variety of products and container sizes than in the U.S.

Fruit-based puddings are common there, important product line extensions to the dessert category. Fruit is either mixed in the pudding, or layered as a compote on the top or bottom. Technically, either is possible, depending only on the filler configuration of the packaging machine.

Slide 31.

European pudding products - dual compartment

Dual compartment dessert products are also found shelf-stable in Europe. One compartment holds the dairy based dessert, the other is filled with either an aseptic fruit compote, or granola filled non-aseptically in the downstream.

In 1995 these types of dual compartment cups were introduced to the U.S. in the refrigerated yogurt category, a possible harbinger of things to come shelf-stable.

Slide 32.

European pudding products - general upscale, novelty

In general, the use of shelf-stable products as desserts rather than snacks is far more developed in Europe. Product containers are frequently molded with flutes or geometric shapes; the product is separated intact from the package, inverted and served, often with a creme sauce.
Novelty and niche markets are also more developed; the flan products pictured in the center have molded cartoon characters which entice children when inverted on the dessert plate.

Slide 33.

Del Monte yogurt cans

Shelf-stable yogurt is another product category not found in the U.S. There has historically been very limited work with aseptic yogurts here, no doubt stemming from marketing pessimism, as shelf-stable distribution requires the destruction of live cultures.

Del Monte introduced an aseptic yogurt in 4 oz Dole cans in 1987, withdrawing it in 1991. Given consumer familiarity with plastic yogurt cups in the refrigerated case, it is unclear what role the metal can played in the lack of product popularity.

Understandably, yogurt producers insist the presence of live cultures is mandatory, but I would not dismiss the possibility of a successful shelf-stable yogurt so quickly and believe this would be a natural compliment to puddings and gelatins.

The code of federal regulations does permit shelf-stable yogurt, as long as it is labeled "heat treated after culturing".

Slide 34.

Growth in U.S. yogurt consumption

While still low by European standards, U.S. per-capita consumption of yogurts has grown steadily. The category has moved well beyond its early "health-food" mantle, and is now viewed more generally as a "healthy-food". As such, the presence of live cultures may not be as important as is commonly believed, and a shelf-stable product might attract a new group of consumers wanting a perceived alternative to the relatively confectionery puddings and gelatins, live cultures or not.

Slide 35.

Dannon delights dual compartment, Prailey's, Kraft yogurt

Several new refrigerated product introductions in 1995 in fact indicate the line between yogurts and desserts in these single-serve products is already starting to blur. The dual compartment Dannon product line includes Bavarian Cream and cheesecake yogurts. Kraft and Praileys have introduced products which mix gelatin and yogurt.
European shelf-stable yogurts

The yogurt producers might in fact welcome the development of a shelf-stable brother as it would undoubtedly increase interest in the overall category.

As we see here, shelf-stable yogurt is an established product in some countries in Europe. Its development in the U.S. is fundamentally a marketing challenge.

Frito cheese dip

Other cultured products ideally suited to aseptics include sour cream and cheese dips. Cottage cheese has never been introduced aseptically to my knowledge, would likely run afoul of the FDA due to particulates, and in any case may not stand up well to pumped processing. Aseptic sour cream has been available for food service in 1 liter Tetra.

As I mentioned in my opening comments, moving these mainline dairy products to the non-refrigerated shelf has always faced a considerable marketing hurdle due to their lack of refrigeration.

A number of aseptic cheese dips have nevertheless been introduced retail over the years, meeting with varying success, and a small shelf-stable presence has been maintained.

Ruffles cheese dip

The presentation of dips in the non-refrigerated snacks aisle makes eminent sense.

Hoffman nacho cheese dip kit

And the emergence of the Hispanic niche market has rekindled interest in this type of product. Shown here is a nachos kit with shelf-stable cheese sauce. The ambient temperature cheese has inherent logic to the consumer who will likely microwave it anyway.
Overall, the shelf-stable dairy product category would benefit from greater consumer exposure and education on aseptic packaging. Here as well, Parmalat's aggressive promotion of shelf-milk may prove to be an important milestone in shifting consumer perceptions in this regard.

Slide 40.

Sauces, condiments, glass, powdered, etc.

Most sauces, salad dressings, and condiments are shelf-stable and are either high-acid hot filled, or dry powdered consumer-mix products. Aseptic packaging is not necessary.

There have been a few low-acid cream sauces over the years in brick-pack.

Slide 41.

High and low-acid pasta sauces

Pasta sauces are one category that is fragmented and would clearly benefit from aseptic packaging. The high-acid sauces on the left are shelf-stable, typically in glass; the higher quality cheese low-acid sauces on the right must be refrigerated.

One can envision a product line of aseptic shelf-stable high and low-acid sauces, packaged in single-serve microwaveable plastic containers offering the consumer both convenience and high product quality.

Slide 42.

European cream sauces

Low-acid cream sauces are commonly packaged aseptically in Europe. We see here a range of products in brick-pack and single-serve plastic packages which are intended for vegetable and meat dishes, desserts, etc.

Slide 43.

Aerosol whipped-creams

Finishing up with mainline dairy products, whipped cream is another product suitable for aseptic packaging, but not found in the U.S. Our choices for pre-packaged products here are limited to the frozen products in tubs, such as Cool-Whip, or the refrigerated canned aerosols such as Reddi-Whip.
Aseptic aerosol whipped creams, shown here, are commonly available in Europe and the U.K., though the equipment used to package this product is not FDA approved.

Slide 44.

Nabisco egg beaters

I thought I'd show you a quick slide of one egg product in the retail marketplace which is packaged aseptically. The product is not truly aseptic and must be refrigerated because eggs can't be brought to UHT temperatures without coagulating. The product is therefore only pasteurized, but is filled on an aseptic cup machine, assuring very high packaging sterility.

Pasteurized eggs have also been available in the institutional market in 1 liter aseptic brick packs and larger bulk pouches.

Slide 45.

Infant formula/nutritionals canned, formula, sw.success, slim

Completing the retail market are the nutritional products. As mentioned previously, nutritional products such as infant formula have traditionally been retorted. Aseptic Dole cans are increasingly being used for improved flavor in the developing dietary and meal replacements markets. There is one nutritional product in aseptic plastic cups and I understand there was one product in retort plastic bottles introduced in 1993.

This product category is ideally suited to aseptics, which offers the possibility of modern consumer-convenient plastic packaging, both in thermoformed seal/peal containers, and for larger volumes, reclosable plastic bottles. Also, the tighter process control and short thermal treatment possible with UHT is more protective of nutritionally balanced products.

Aseptic packaging of nutritionals is likely to become increasingly important with new product formulations arising from bio-tech, the development of nutraceuticals, and the increasing use of home health care products in the future.

Slide 46.

European Milupa, Tetra cereal, nutritional

In Europe there's a wider variety of nutritional products packed aseptically. We see here several European aseptic products; a milk/cereal gruel for infants in 90 ml glass jars,
several brick-pack milk/grain products, and a nutritionally enhanced milk-based infant formula.

There are a number of other aseptic nutritional products on the market in Europe, primarily in glass bottles and jars in the 90-500 ml range. There are also several aseptic Dole can installations, but the larger retort market is almost exclusively in glass, not cans as in the U.S.

In general there is increasing interest in aseptic packaging for nutritional products in Europe, particularly single-serve in plastic cups.

Slide 47.

Institutional - ultra bulk creamer case

The final market area I wanted to touch on is the institutional market. this has been a major outlet for aseptic packaging, driven by the non-refrigerated distribution systems of this sector. Aseptic coffee creamers had their start here with the 400 count case a typical conveyance. Pudding cups, the juice box, shelf-milk, brick-pack pasteurized eggs are all found outside the normal retail channels.

Slide 48.

#10 pudding and cheese sauce

Pudding and cheese sauce in #10 cans is a key institutional dairy market segment with seven producers accounting for approximately 50 million containers per year on Dole systems. Most installed lines run at 30 containers per minute with newest models reaching speeds of 70.

Slide 49.

Aseptic cheese pouches

Aseptic v/f/f's pouch packaging was an important development in the 1980's, finally offering an aseptic alternative to the #10 can for dairy products. producer advantages from this packaging medium include a 50% reduction in container cost, elimination of empty can storage and handling, reduced shipping weight, and increased pallet density. Important user benefits accrue as well. Elimination of worker safety issues in handling and opening steel cans, improved product recovery, and a 95% reduction in solid waste weight and volume have been major attractions to the fast food industry, the #10 pouch's primary market.
Cappuccino pouch

Other dairy related products packaged in pouches for the institutional market include cappuccino and related milk flavored beverages.

Ice-cream mix pouch and milk shake, ice cream and frozen yogurt mixes.

Single tube v/f/f/s pouch machines typically run in the range of 23-30 pouches per minute and can use a variety of foil and non-foil barrier structures. Machines are sized for fill volumes of 1-5 liters, and while smaller volumes are in theory possible with machine modifications, a market for these smaller pouches has never developed.

Pre-sterilized fitmented pouch machines are available from several manufacturers, in this case a Scholle twin head filler. This type of equipment is designed for large volume pouches.

On up to 300 gallon tote bins. Output rates are more a function of the maximum UHT flow rate than machine speed, though the 30 second steam sterilization cycle of the fitment makes these fillers impractical for small volumes.

There is one middle-range aseptic pouch filler, the fitmented pouch machine from Liqui-box, which runs at 12 pouches per minute.

There is in fact very little use of large volume aseptic pouches for dairy products. I'm told Amboy Division of Dean Foods is the only producer of bulk cheese sauce, filled into 55
gallon drums with a Fran Rica filler. The product is used for frozen meal cheese toppings, snack foods and so forth.

Slide 55.

Aseptic = new market opportunities

In closing, the thought I'd like to leave you with is that aseptic technology is fundamentally about new market opportunities; the ability to bring new high-quality, value-added products into consumer convenient packaging, often using alternative means of distribution and storage. The technology has made possible entirely new and highly successful product categories, permitting dairy producers to re-invigorate and bring increased margins to what in many cases have become commodity products.

Market opportunities extend into exports as well. Centralized European aseptic producers are shipping dairy products all over Western Europe and the Eastern block. In the U.S. there is some export of dairy creamers but by and large the export market has not been developed and is a key opportunity for the dairy industry.

Aseptics has a proven track record, solid process science, and an experienced supplier base; a great technology with a bright future.

Thank you.
Milk Quality for UHT Processing

Bart Weimer
Utah State University

2nd Biennial UHT Symposium
Utah State University

1996
**Raw Milk Microbiology**

The dominate microflora of normal raw and processed milk is psychrotrophic bacteria (Phillips, 1986; Table 1). Psychrotrophic organisms are defined as, “microorganisms that can grow at 7°C or less, irrespective of their optimal growth temperature” (Collins, 1981). Several methods for inhibiting or killing these contaminating bacteria in milk at the farm have been used, but widespread use of these methods is found in America for various reasons (Gombas, 1987; Lee and Kim, 1985; Ordonez and Burgos, 1976; Searle and McAtthey, 1989; Stead, 1987). UHT processing is very effective in controlling residual bacterial contamination levels of finished products. Excluding post-processing contamination, several factors dictate the microbiota of the final product:

- **The total number and type of organism in the raw milk.** A higher concentration of cells in the raw milk will lead to more surviving organisms after thermal processing as defined by thermal death kinetics (Burton, 1988).

- **The organism ability to survive processing (thermal death kinetics).** Heat is the most common choice for processing milk, however bacteria have a wide range of tolerances to temperature; for example some psychrophiles are not able to grow at room temperatures, while some thermophiles survive and grow on the edges of boiling thermal pools. Some organisms – most notably members of the Bacillaceae – have adapted to survive extreme temperatures by producing dormant spores which are the most heat tolerant forms of microorganism known (Moran, 1990; Shehata, 1977; Yildiz, 1989).

- **The organism ability to grow during storage in the final product.** Storage temperature of the processed product will further select for organisms best able to grow. Many of the contaminating microbes have optimum growth temperatures near room temperature (25°C or 75°F), however psychrotrophs will also grow at refrigeration temperatures (4°C or 40°F).
Table 1. Treatments developed to reduce the initial microbiota in milk.

<table>
<thead>
<tr>
<th>Method</th>
<th>Treatment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermization</td>
<td>Heat treatment 64–68°C for 10–15 s (at the farm)</td>
<td>Used in Netherlands at the farm</td>
</tr>
<tr>
<td>Lactic Acid Bacteria*</td>
<td>Addition of spp. of <em>Lactobacillus, Pediococcus</em></td>
<td>Production of peroxide activates lactoperoxidase system.</td>
</tr>
<tr>
<td>Preservatives*</td>
<td>CO₂</td>
<td>Inexpensive, and effective especially against <em>Pseudomonas</em>.</td>
</tr>
<tr>
<td></td>
<td>Nisin</td>
<td>Inhibits cell growth, and delays spore germination.</td>
</tr>
<tr>
<td></td>
<td>Other chemical preservatives</td>
<td>Effective but illegal in the US.</td>
</tr>
</tbody>
</table>

*Must list as an additive in America.

Psychrotrophic organisms capable of surviving pasteurization are usually members of the families *Bacillaceae*, *Pseudomonaceae*, and *Achromobacteriaceae* and are thought to be responsible for reduced shelf life in milk products (Table 2). Making use of this fact the Mosley test has been used to predict milk shelf life based on the total plate count of raw milk (Richardson, 1985). However, Bishop and White (1985) noted that the predicted shelf life found in the Mosley test does not correlate to the actual shelf life. These observations suggest that factors other than total microbial load are involved in milk spoilage. Additional factors that may play a role in reducing the shelf life that are not accounted for in the Mosley test include heat stable microbial metabolites such as spores and enzymes.
Table 2. Bacteria commonly found in milk (Foster et al., 1983).

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactobacteriaceae</td>
<td><em>Streptococcus</em></td>
</tr>
<tr>
<td></td>
<td><em>Lactococcus</em></td>
</tr>
<tr>
<td></td>
<td><em>Leuconostoc</em></td>
</tr>
<tr>
<td></td>
<td><em>Lactobacillus</em></td>
</tr>
<tr>
<td></td>
<td><em>Microbacterium</em></td>
</tr>
<tr>
<td></td>
<td><em>Propionibacterium</em></td>
</tr>
<tr>
<td>Micrococcaceae</td>
<td><em>Micrococcus</em></td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td><em>Escherichia</em></td>
</tr>
<tr>
<td></td>
<td><em>Aerobacter</em></td>
</tr>
<tr>
<td></td>
<td><em>Proteus</em></td>
</tr>
<tr>
<td></td>
<td><em>Salmonella</em></td>
</tr>
<tr>
<td></td>
<td><em>Citrobacter</em></td>
</tr>
<tr>
<td></td>
<td><em>Klebsiella</em></td>
</tr>
<tr>
<td>Pseudomonadaceae</td>
<td><em>Pseudomonas</em></td>
</tr>
<tr>
<td>Bacillaceae</td>
<td><em>Bacillus</em></td>
</tr>
<tr>
<td></td>
<td><em>Clostridium</em></td>
</tr>
<tr>
<td>Achromobacteriaceae</td>
<td><em>Alcaligenes</em></td>
</tr>
<tr>
<td></td>
<td><em>Achromobacter</em></td>
</tr>
<tr>
<td></td>
<td><em>Flavobacterium</em></td>
</tr>
<tr>
<td>Bacteriaceae</td>
<td><em>Brevibacterium</em></td>
</tr>
<tr>
<td>Corynebacteriaceae</td>
<td><em>Corynebacteria</em></td>
</tr>
<tr>
<td>Parvobacteriaceae</td>
<td><em>Brucilla</em></td>
</tr>
</tbody>
</table>

Processed milk may not contain living or vegetative organisms but may still have a limited shelf life due to viable spores of *Bacillus* species or heat stable enzymes produced by many types of Gram negative bacteria during growth in the raw milk, especially from *Pseudomonas* species (Table 3; McKellar and Cholette, 1986).

The Queensland Food Research Institute — Australia, characterized 205 lipolytic strains of various bacteria isolated from 36 raw milk samples (Shelley, 1987) and found
psychrotrophic bacteria *P. fluorescens* and *P. fragi* accounted for 63.9% and 31.2% of the bacteria isolated from raw milk.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Psychrotrophic (cfu/ml)</th>
<th>Non-psychrotrophic (cfu/ml)</th>
<th>UHT tolerant products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram negative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acinetobacter / Moraxella</td>
<td>1</td>
<td>3</td>
<td>Protease</td>
</tr>
<tr>
<td><em>Aeromonas</em></td>
<td>15</td>
<td>6</td>
<td>Protease, Lipase</td>
</tr>
<tr>
<td><em>Alcaligenes</em></td>
<td>8</td>
<td>4</td>
<td>Protease, Lipase</td>
</tr>
<tr>
<td><em>Chromobacteria</em></td>
<td>9</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><em>Enterobacter</em></td>
<td>30</td>
<td>8</td>
<td>Protease, Lipase</td>
</tr>
<tr>
<td><em>Flavobacteria</em></td>
<td>7</td>
<td>5</td>
<td>Protease, Lipase</td>
</tr>
<tr>
<td><em>Gemella</em></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><em>Pseudomonas</em></td>
<td>93</td>
<td>13</td>
<td>Protease, Lipase</td>
</tr>
<tr>
<td>Gram positive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aerococcus</em></td>
<td>19 (8%*)</td>
<td>24 (10%*)</td>
<td>Spores</td>
</tr>
<tr>
<td><em>Bacillus</em></td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><em>Micrococcus</em></td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><em>Staphylococcus</em></td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td><em>Streptococcus</em></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

*percent of the total bacterial population*
Heat Stable Microbial Products

The cumulative effect of low concentrations of enzyme and long holding periods can have a large impact on the physical condition and flavor of the stored UHT milk (Mottar, 1981). Bacterial enzymes, especially lipases and proteases produced by \textit{P. fluorescens} and \textit{P. fragi}, withstand UHT processing and cause flavor changes in milk stored for long periods (Fairbairn, 1986; Stead, 1986; Stead, 1987), indicating that sensitive assays are needed to detect these products. Extensive work to characterize and control these enzymes (Fairbairn, 1986; Griffiths et al, 1981; Kohlmann et al, 1991; McKellar, 1982; McKellar and Cholette, 1986; Stead, 1986; Stead, 1987; Stepaniak, 1987) shows the need for low psychrotrophic counts and good refrigeration of milk before processing, especially since the most prevalent psychrotroph in raw milk is \textit{Pseudomonas}. Therefore, an effort must be made to minimize the presence of heat stable enzymes in raw materials going into long shelf life products. Methods to control heat stable bacterial products rely on an effective sanitation program at the farm and factory.

\textit{Lipase:}

Milk is a good medium for microbial lipase production (Dring and Fox, 1983) and lipolytic activity (McKellar, 1986). The catalytic mechanism for most known lipases is stimulated by adsorption to the water/fat interphases causing conformational changes in the enzyme to expose the active site (Verger, 1980). In milk, the fat globule membrane provides this interface which increases in surface area with homogenization. Milk becomes perceptibly rancid with in 5 min of homogenization due to the efficiency of fat dispersal (Deeth, 1983). Lipase activity is greatest immediately after homogenization, plateaus, and can be reactivated by a second or third homogenization (Deeth, 1983). Lipase activity is also stimulated by calcium and magnesium ions and low levels of NaCl contributing to activation in milk (Fitzgerald, 1983; Deeth, 1983).

Flavor defects in milk associated with lipase activity are due to release of free fatty acids (FFA) from the milk fat. Chain lengths of \(C_4 - C_8\) are associated with rancid flavors; \(C_{10} - C_{12}\) are associated with unclean, soapy flavors; and \(C_{14} - C_{18}\) contribute little to flavor changes (Stead, 1987). Released FFA are susceptible to chemical oxidation to aldehydes and ketones that lead to cardboardy, oxidized, or metallic flavors (Stead, 1987). Detection
thresholds for the short chain FFA are lower than the longer chain FFA contributing to the rancid flavor of milk spoiled by lipases (Deeth, 1983).

*Lipase Detection:*

Various methods to assay residual activity lipases in milk have been developed however most are to slow or lack the robustness and ease required for widespread factory use. Results from an assay should be obtained within a few hours if they are to be used to direct high quality milk during processing. Deeth et al. (1975) developed an extraction-titration method which measures the total FFA released and correlated the amount of titratable FFA to milk quality, however this method is time consuming and does not lend itself to routine testing or automation. To improve the speed and ease of lipase detection a fluorimetric method was applied to milk by Stead (1983). This assay measures release of fluorescent 4-methylumbelliferone from an emulsion of oleate conjugated to non-fluorescent 4-methylumbelliferyl oleate. Stead noted this method was deficient when measuring opaque solutions limiting its use in milk. de-Monpezat (1990) noted that 4-methylumbelliferyl oleate is unstable limiting its usefulness in industry. The fluorescent substrate, umbelliferone oleate, offered as a stable alternative is not commercially available. A colorimetric assay developed by McKellar (1986b) measures the release of β-naphthyl from β-naphthol caprylate as the colorless ester is hydrolyzed and a purple color develops. This procedure requires a quenching step with centrifugation and a secondary dye making it cumbersome for routine testing and offering little advantage the Deeth et al. extraction method.

Diffusion plate assays using tributyrin agar and butterfat agar are currently used in industry (Shelly, 1987b). These methods are simple to perform and interpret, but lack sensitivity required to detect lipase activity in fresh milk and require long incubation periods (24 h to 48 h) to detect lipolysis. While this assay is used by industry it does not meet industry needs for UHT products. To develop an rapid assay that is suited to milk, Richardson et al. (1988) used reflectance colorimetry and tributyrin to monitor reduction of turbidity or change in pH. This method is able to measure pancreatic lipase activity rapidly, but the detection limit is to high for general use in thermally processed products.
Proteases:

Many extracellular proteases from different bacteria are active after UHT processing and will therefore be of concern in long shelf life milk products. These proteases contribute to bitter flavors due to short peptides from enzymatic breakdown of milk proteins (Griffiths, 1981; Lemieux, 1992) and age gelation due to their activity on α- and β-caseins (Kohlmann, 1991a; Griffiths et al., 1981). However, age gelation does not occur before 60 to 80 d in milk stored at 7°C and is therefore of little concern in pasteurized or ESL milk.

*Pseudomonas* MC60, a raw milk isolate that is killed during pasteurization, produces a protease that is 4000 times more heat resistant than spores of *B. stearothermophilus*. This illustrates the heat tolerance of some microbial enzymes found in milk, even though the organisms that produce these enzymes are often killed by pasteurization (Fairbairn, 1986). The most prolific protease producers found in milk are members of the genus *Pseudomonas*, in particular *P. fluorescens*. Although the optimum growth temperature of *Pseudomonas* is 30–40°C, the optimum conditions for protease production are at refrigeration temperatures and neutral pH, which describe conditions found in raw milk (Dring, 1983). To quantitate the levels of these proteases released into milk several assays have been developed.

Protease Detection:

The most widely used assay involves labeling the amino terminal groups released from the action of proteolytic activity over a known period with o-phthalaldehyde (OPA) and β-mercaptoethanol (Church et al., 1983). The OPA adduct absorbs strongly at 340 nm and can be related to a standard curve for quantification of proteolysis. More recently, a method utilizing the degradation of Luciferase (the protein responsible for catalyzing the ATP/Luciferin light reaction) has been developed and is commercially available (Rowe et al., 1990). An ELISA specific to a protease from *P. fluorescens* has been developed but does not correlate with protease activity in milk during storage (Clements et al., 1990).

Spores in Milk.

Some *Bacillus* species found in raw milk can survive, grow, and form spores that will survive heat processing. The spores resistance to thermal destruction is primarily due to the low water content of the core, but also because of the heavy wall that protects the core which is comprised of the cortex and spore coat. Many of these bacteria have
psychrotropic growth temperatures, but their spores withstand UHT heating; hence, they are termed thermoduric psychrotrophs.

Psychrotrophic, sporeforming, spoilage organisms were first reported in milk by Grosskopf and Harperin in 1969 (Grosskopf and Harperin, 1974). Since then many researchers have investigated spoilage of refrigerated milk products by sporeforming bacteria (Farkas, 1990; Grosskopf and Harperin, 1974; Lee and Kim, 1985; Rama, 1989; Washam, 1977; Westhoff, 1981). The primary source of spores in milk is contamination from silage. When a cow eats silage, spores enter the digestive tract, and although no growth occurs, they are found in the dung ten times more concentrated (Stadhouders, 1983). Small traces of dung on the teats of the cows, which occurs even in modern dairies, leads to contamination of raw milk (Stadhouders, 1983).

Burton (1988) found spore counts in milk around the world to be variable depending on the climate and region (Table 4). Bacillus species, especially Bacillus circulans, Bacillus cereus, Bacillus licheniformis, Bacillus subtilis, Bacillus megaterium, and B. stearothermophilus dominate species found in milk (Jayne-Williams, 1960; Meer et al. 1991; Rama, 1989; Schmidt et al., 1991; Thomas et al., 1950, Westhoff 1981), some of which will grow at 10°C (Sneath, 1986). B. stearothermophilus is thermotrophic and therefore of less importance in refrigerated milk, but can grow in shelf stable milk products exported tropical regions without refrigeration. Spores from B. stearothermophilus are often used as indicators for heating systems because of their high heat tolerance. Recently, Bacillus badius has been reported to survive UHT processing in milk, flavored milk, cream, and milk powder in many dairies across Europe (Hammer et al., 1995). This species is a mesophilic sporeformer with a D_{147} = 5 sec which describes a single log reduction under severe UHT processing conditions. Presence of B. badius may not be easily detectable by the consumer since it can grow to 10^5 cfu/ml without changing milk composition or sensory properties. However, this organism has led to the closing of a UHT plant, and a dairy in Italy due to a new milk ordinance (EC-Directive 85/397) that sets a maximum colony count in UHT milk of 100 cfu/ml after 15 d at 30°C. There have been 52 confirmed cases of B. badius in UHT milk reported across Europe including Germany, France, Italy, Benelux, and Spain, and 2 cases outside of Europe (Hammer et al., 1995).
Table 4. Mesophilic spore counts of milks from different warm-weather countries (Burton, 1988).

<table>
<thead>
<tr>
<th>Country</th>
<th>Samples</th>
<th>Spore Count (cfu/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Barbados</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chile</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>Kenya</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Iran</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>India</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Lebanon</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Madagascar</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Pakistan</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Senegal</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>England</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Australia</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Ohio, USA</td>
<td></td>
<td>&gt;25</td>
</tr>
</tbody>
</table>

_Bacterial Spore Detection:_

No rapid assay currently exists that allows milk to be quickly assayed for spore concentration before milk processing. If such a test existed it would allow selection of high quality (i.e. low spore count) milk for use with long storage products. Current methods of detection involve heating the milk sample at 80°C for 10–15 min to destroy viable cells, then incubating the sample on nutrient agar at an appropriate temperature for 24 to 48 h before counting colonies. This method does not differentiate between spore species which is of great importance to the milk industry since not all types of spores will survive process conditions and grow in milk. Additionally, this method relies on the assumption that all spores survive the heat shock and that all spores are immediately culturable. Additionally,
multiple incubation temperatures are required since multiple species are present. To address the need for a rapid spore assay Chang and Foegeding (1993) developed a immunoassay for spores from *Bacillus*. The antibody used in this assay cross reacted with all *Bacillus* spore types tested to varying degrees, although no other genera were tested, resulting in an assay with a sensitivity of \(>10^6\) cfu/ml.

**Summary:**

Good quality raw milk is important for the production of any processed milk, but is critical for production of milk that will be stored for long periods after UHT processing. If poor quality raw milk is used, heat stable enzymes such as lipases and proteases may cause sensory defects in processed milk, or heat stable bacterial spores from *Bacillus* species will be present to cause disease or spoilage. Rapid detection methods are being developed that will allow real time selection of high quality milk for use in long shelf life products.
Time/Temperature Relationships and the Destruction of Spores

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Abstract

Thermal process calculations for the sterilization of UHT food products have been made traditionally using D-values and Z-values. These calculations provide accurate and safe values for thermal processes at temperatures within 20°C of the experimentally determined Z-value. At temperatures outside of this range, the Z-value cannot be assumed to be a constant value if bacterial inactivation follows classical 1st order kinetics. Thermal process calculations using reaction rates and energies of activation suggest that significant increases in process times and/or temperature may be required to assure commercial sterility.

Introduction

The destruction of bacterial spores has been traditionally modeled using the concept of D-values and Z-values to calculate thermal processes. The D-value is defined as the decimal reduction time at a defined temperature with the normal reference temperature being 250°F. The D-value may also be defined at other temperatures using that temperature as a subscript to reference that temperature i.e. D260.

Process calculations using D-values at the reference temperature are quite simple for isothermal processes since the product of the required logarithmic reduction and the D-value yields the desired process hold time. For a 12 decimal reduction of C. botulinum in an isothermal hold tube at 250°F, the process time required could be calculated as follows:

\[
12D \times 0.25 \text{ min/D} = 3.0 \text{ minutes at 250°F}
\]
This time dependent inactivation of bacteria can be modeled with classical first order chemical kinetics using the equation:

\[-\frac{dc}{dt} = kc\]

**Time Dependent Inactivation of Bacteria at the Reference Temperature**

At temperatures other than the reference temperature, a factor \(Z\) is used to approximate the temperature dependence of the decimal reduction. The \(Z\)-value is the temperature increase required to cause a 10-fold change in the bacterial destruction rate. \(Z\)-values are assumed to be constant as long as they are used in a temperature range close to the reference temperature. This temperature dependency of the \(D\)-value can be calculated by the equation:

\[D_T = D_{250} \times 10^{(\frac{(250-T)}{Z})}\]
Time Dependent Logarithmic Reduction of C. botulinum at Different Temperatures Using a Z-Value of 10 Degrees Centigrade

The log of the time for a 12D process versus the temperature yields a straight line. This operating line has all of the points with a "bot cook" calculated using D and Z-values.

Process Times and Temperatures for a "Bot Cook" Calculated Using D and Z-values

Using a constant Z-value introduces significant errors when the processing temperatures lie outside of the range of the reference temperature (Kessler, 1981). For UHT processing systems, the holding tube temperature often exceeds 140°C. Process calculations in this region may significantly underestimate the process lethality. The purpose of this paper is to

1) Understand the influence of UHT process temperatures on D-values calculated using traditional methods versus a corrected D-value.
2) Propose a method for calculating corrected Z-values using the Arrhenius equation.

3) Suggest areas of investigation to determine the accuracy of calculated Z-values at UHT processing conditions.

Methodology

The temperature dependency of first order chemical reactions is expressed by the Arrhenius equation

\[ k = k_0 \exp \left( -\frac{E_a}{RT} \right) \]

If the reaction rates (or D-value) at two temperatures are known, it is possible to determine the energy of activation \( E_a \) using this equation

\[ \frac{\ln k_1}{k_2} = \frac{E_a (T_1 - T_2)}{R (T_1 T_2)} \]

Since bacterial inactivation is treated as an example of 1st order kinetics, it is possible to derive a corrected D-value from the Arrhenius as described by Datta (1993)

\[ DT = 2.303 \exp \left( \frac{E}{RT} \right) \]

\[ \frac{k_0}{k_0} \]
Results

Using this equation, the corrected D-values can be compared to the corrected D-values using $E_a$.

Corrected D Values for C. botulinum Using $E_a$ to Calculate the Decimal Reduction Time Compared to Values Calculated with a $Z$-

Using the calculated D-values, a 12D "bot cook" can be calculated using a comparison of the methods.

12 D Reduction of C. botulinum Calculated from $Z$ Value and Using $E_a$
As can be seen from the above figure, the error in estimating process increases with the difference from the reference temperature. The correction factor can be expressed as a ratio of the D-value calculated using E compared to the D-value determined using the z-value

\[ \frac{D_T}{D_z} = \text{Correction Factor} \]

Process Correction Factor for Thermal Processes Over the Reference Temperature of 394 Degrees Kelvin Using Ea and Z-value of 10 Degrees
Conclusions

At UHT process temperatures in excess of 140°C, the correction factor to account for the increased D-values should be utilized for process calculations. Process systems operating in this range are generally direct heating systems since indirect systems would have a more pronounced chemical effect on the product. Direct heating systems which operate above this temperature range should consider using the correction factor if reference D-values are not sufficiently accurate.

Additional research needs to be conducted in this area to

1) Determine the D-values for *C. botulinum* and other test organisms at reference temperatures in excess of 140°C.

2) Develop methods to determine D-values in the millisecond range. New methods employing flow cells developed for chemical kinetics studies may be applicable to UHT processing conditions if suitable cooling procedures can be developed.

3) Determine the coldest "particle of milk" in systems having holding tubes with residence times less than one second.
References


Choosing A UHT System

Bob Simpson
Director of Dairy Technology
APV Engineering
UHT SYSTEMS
DIRECT VS. INDIRECT
Indirect systems

- Tubular types
- Plate and frame
- Scrapped surface (not covered)
Customer Considerations

- What products are to be produced?
- What are energy costs?
- What particulate or fibers are present?
- What is the expected viscosity range?
- What is the raw milk quality?
- What does the market demand?
- Is taste the deciding factor?
Objectives

- Review operational features of various systems
- Evaluate strengths and weaknesses of these systems
- Evaluate product capabilities of these systems
Products processed on tubular systems

- Milk
- Flavored milk
- Cream
- Ice cream mix
- Condensed milk
- Desserts and puddings
Multi Tube
Direct systems

- Injection
- Infusion
Process flow plate and frame system

1. PLATE REGENERATIVE
2. HOMOGENISER
3. PLATE HEATER
4. HOLDING TUBE
5. PLATE COOLER
6. PLATE CHILLER
7. PLATE COOLER
8. STERILE TANK
Plate and Frame
Strengths of plate and frame indirect systems

- Lower capital investment
- Will run lower quality raw milk
- Little aroma loses in the process
- Variable capacity capabilities
- Low hold up volume
- Large capacity plants available
- Easy to inspect
Process flow tubular system
Strengths of tubular indirect systems

- Less vulnerable to fouling giving long production runs
- Operates under high pressures when necessary
- Process products with small particulate
- Processes higher viscosity products than plate and frame systems
- Low shear characteristics for cream
- Reduced maintenance costs
Common strengths for indirect systems

◆ Easy to operate
◆ Higher regeneration capabilities
◆ Accomodates variable flow rates using split heating
Limitations of plate and frame systems

- Limited capability for products containing particulate and fibers
- Must maintain plate pack
- Limited pressure capabilities
- Some product degradation is expected
- Run times are based on the fouling factor of the product
Time Temperature profiles

![Graph showing time-temperature profiles for preservation of liquid products by heat treatment.](image)
Process flow direct systems
Injector
Strengths of infusion systems

- Superior product quality
- Long production runs
- Wide viscosity range
- Gentle heating due to contact in a quiescent steam atmosphere
- Handles highly heat sensitive products
Strengths of injection systems

- Higher product quality
- Long production runs
- Easy to scale up to larger capacities
Limitations of injection systems

- Higher capital costs than for indirect systems
- Higher operating costs because of reduced regeneration capabilities
- Volatiles lost during flash cooling process
- Better on lower viscosity products
- Requires source of culinary steam
- Lower quality high fat products due to shearing effects of injectors
Limitations of infusion systems

- Relatively higher capital costs than for indirect systems
- Higher operating costs because of reduced regeneration capabilities
- Some volatile flavors are lost during the flash cooling process
- Requires source of culinary steam
- Requires more automation than injector
Products processed on injection systems

- Milk
- Cream
- Flavored milk
- Chocolate milk
- Eggnog
- Soya milk
- Ice cream mix
- Coffee whiteners
Products processed on infusion systems

◆ Milk
◆ Cream
◆ Whipping cream
◆ Flavored milk
◆ Chocolate milk
◆ Eggnog
◆ Yogurt
◆ Skim and milk concentrates
Products processed on infusion systems

- Soya milk
- Baby food
- Ice cream mix
- Processed cheese
- Puddings and desserts
- Coffee whiteners
- Other heat sensitive products
UHT Systems
Audience questions?
Times up!
APV and Bob Simpson

Thank

- The Utah State University
- The audience
Thank You
Limitations of tubular systems

- Ten to fifteen percent less regeneration than plate and frame systems
- Higher degrees of product degradation
- Higher initial capital investment than plate and frame systems
Products processed on plate and frame systems

- Milk
- Fermented milks
- Drinking yogurt
- Cream
- Coffee whiteners
- Juices
UHT Processing

Some thoughts on future developments

Presented at the Utah State University Seminar on UHT processing

March, 1996.

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March, 1995
UHT Processing

Some thoughts on future developments

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UHT - Some thoughts on future developments

J. G. Zadow,
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1. General

It is the purpose of this paper to explore some of the options that could develop in the next decade or so for UHT processing, products and markets - all in just a few pages!

A crystal ball (with a guarantee) is really what is required for such an exercise, but unfortunately, I haven't been able to find one. In spite of this, I will try to look a little into the future and to make some suggestions regarding future developments in UHT.

A good place to start is to try to identify the sole driving force in new developments. Simply put this is:

* Increased profits.

Increased profits can come about through a number of developments:

⇒ Overcoming existing problems which reduce profitability
⇒ Improving process technology to improve efficiency of operation
⇒ Improving process technology to improve product reliability
⇒ Improving process technology to improve effective product life
⇒ Increasing market share

It should be noted that in many cases of course, increased profitability will come about through reduced costs - a dollar saved is a dollar extra profit.

Essentially therefore, the key areas of new technical developments in UHT will be:

* Development of technology to overcome problems in existing process technology within the framework of existing technology
* Development of new process technology (often as a response to overcoming problems of existing technology)

These matters are considered further below looking at existing problems of UHT operations, and options for the future.

2. Existing problems in UHT operations and options for the future.

The major problems facing UHT operations have been described in detail by other presenters at this Seminar. However, I will briefly run through them to put them into the context of this paper.
The major problems of UHT operations at present are:

- Age gelation
- Fat separation
- Poor flavour
- Limited run times
- Microbiological contamination
- Slow packaging rates
- Lack of knowledge about performance of product after manufacture

These are considered in detail below.

2.1 Age gelation

Age gelation is a major problem to many UHT processors. Many processors have exported product to, for example, South East Asia, only to find that it gels shortly after arrival. It is a problem that currently is quite unpredictable, and one which leads to much concern on the part of processors.

It is generally accepted that age gelation likely involves part the action of heat resistant proteases which destabilise the casein micelle leading to the formation of a curd-like product - the product is still sterile, but resembles a rennet cheese curd/whey mixture in appearance. The source of the enzymes is either (or both) microbial or so-called native milk enzyme. If age gelation appears comparatively quickly in the product (say within 6 months of manufacture) the major cause is likely to be bacterial protease. These proteases are generally thought to be formed by the metabolism of psychrotrophic organisms which were present in the raw milk. The time required for age gelation depends on the level of enzyme present and the storage temperature profile, in general gelation occurs most quickly at about 28°C - a temperature commonly encountered in many areas of South East Asia - an area targeted by many UHT exporters.

It should be noted that the rate of attack of the enzyme is not at a maximum at 28°C. In fact it is at its fastest at about 40°C. But the gelation occurs most quickly at 28°C. Further, at temperature above about 35°C, gelation of UHT milk does not occur! These facts, together with other observations, have led to early suggestions that age gelation involves a two stage mechanism, firstly involving attack by protease enzymes (leading to casein micelle destabilisation), and then involving a (possibly calcium-mediated) gelation stage.

Recently, McMahon (1995) has proposed that age gelation of UHT milk involves the release of the β-lactoglobulin/κ-casein complex (βκ-complex) that is formed during heating from the casein micelles followed by subsequent aggregation of the βκ-complexes and formation of a three-dimensional network of crosslinked proteins. Release of the βκ-complex is observed as protuberances and tendrils on the micelle's surface. Involvement of the casein micelles in age gelation occurs through the attached βκ-complex appendages, and not through direct contact between micelle surfaces.

McMahon suggests that age gelation of UHT milk can be considered as a two phase process. In the primary (or lag phase) reactive units are formed by release of βκ-complex from micelles. This can be induced by any action (enzymic or non-enzymic) that weakens the bond that anchors the complex (via κ-casein) to the micelle. The secondary (or aggregation stage) consists of the accumulation of βκ-complex...
in the milk serum between micelles. When the concentration of proteins in the serum reaches a critical level, gelation occurs. Those micelles that still have $\beta$-complex attached will be incorporated into the network.

Current technology to control age gelation can only suggest that the level of proteolytic enzyme in the raw milk should be reduced to as low a level as possible. To add to the confusion, we also know that it takes only very low levels of the wrong type of psychrotrophs present in milk to produce sufficient enzyme to help initiate age gelation problems in the product. So that even a low level of psychrotrophs in the raw milk is no guarantee of performance - if the wrong types (those which produce high levels of heat resistant proteases) are present, then problems may well be encountered (further, as indicated by McMahon, many other factors besides protease activity may play a part in the onset of age gelation).

2.1.1 Current options

What is left to the manufacturer then - only to use the best milk that he can get, and UHT process it as quickly as possible.

But, once the product is UHT processed, can we then assess the likely shelf life of the product before gelation occurs? A few options are available, none of which are very satisfactory.

2.1.1.1 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 28°C 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, 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.

One method of assessing protease activity involves the use of fluorescamine to link with the primary amino groups. Evidence at the moment is that raw milk has a fluorescamine value of about 20 - UHT milk with values below 40 do not gel, and those above 40 may (the higher the value, the more likely - but some of low value fluorescamine value (but greater than 40) gel, presumably because the calcium mediated gelation step is more favoured in these samples, for reasons unknown). However, high fluorescamine values also mean the development of bitterness in the product (due to the peptides produced by the protease) - thus even if gelation does not occur, the sample becomes unpalatable.

It should be noted however that the warning the manufacturers get is not great. No answers are available for at least 4 weeks, and possibly 8 or 12 weeks regarding the likely life of the product - by this time the product is well and truly in the market place.

2.1.1.2 Measurement of viscosity

A simper 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.
2.1.1.3 Low Temperature Inactivation

In 1976, a very interesting study on age gelation was carried out by workers in North Carolina (Barach, Adams and Speck, 1976). These workers were able to show that use of a very specific heat treatment of raw or UHT milk could result in a significant decrease in protease activity in the product. The heat treatment recommended was a period of about 60 minutes at 55°C (the technique was known as low temperature inactivation (LTI)). Studies by Kocak and Zadow (1985) assessed this observation in more detail. The mechanism proposed by Barach, Adams and Speck (1978) was particularly interesting. These authors proposed a reversible complex formation between the caseins in the milk and the protease, giving a complex which remained firmly bound, thus preventing proteolysis during storage. This complex was not affected to a significant degree by UHT processing. However, the conditions of formation of this complex were very specific - a few degrees either side of 55°C would prevent the complex from forming, and the protease activity would remain.

Barach et al (1978) suggested this mechanism in part as a result of the observation that if the casein micelles in milk which had been LTI processed were dispersed (through the addition of, for example, calcium sequestering agents) the proteolytic activity would reappear. More recently some workers have suggested that self digestion and aggregation with casein are responsible for the effectiveness of LTI (Stepaniek et al, 1991). LTI also is effective in the reduction of lipase activity.

Practical applications of this technology have not occurred however, because of two major factors:

* The specific temperature required for LTI to be effective was found to vary by a few degrees depending on the organism responsible for production of the protease. Since the mechanism is very temperature specific, it is not possible with current knowledge to select the appropriate temperature for treatment.

* The time required for the inactivation to occur is considerable (although useful inactivation does occur after 15 minutes). This would require holding bulk volumes of raw milk for considerable periods prior to processing - not a simple matter.

However, Bucky, Robinson and Hayes (1987) and Bucky, Hayes and Robinson (1988) have suggested a two phase treatment for UHT processing of milk, based on LTI. Firstly the milk is treated under normal UHT conditions of 140°C for 5 seconds. It is then cooled to 60°C, and held at this temperature for 5 minutes. These authors reported this system was effective for LTI of both proteases and lipases. By contrast, Kocak and Zadow found LTI after UHT processing not as effective.

Overall, in its current state, LTI does not appear to be overly reliable for manufacturers.

Thus we have the situation where we have a process (LTI) that is not very reliable, and two methods (viscosity and assessment of primary amino groups) that only gives warning well after the product has been distributed.

2.1.2 What of the future for control of age gelation?

I suggest that developments will be three fold:

2.1.2.1 Better assessment of raw milk quality

It is very likely that more rapid means will be developed to assess the extent of proteolytic activity in raw milk. Such developments will result in markedly improved consistency of product, and could allow for distribution of product to markets based on expected shelf life and rates of consumption. Already tests
are available which give a result more quickly than that used in the past, but they are still not of sufficient speed to allow their use as a means of raw milk quality assessment.

2.1.2.2 Better assessment of product performance

This is a key factor. In the past, most UHT manufacturers have not routinely checked their product after manufacture. Rather a few samples have been kept on the shelf in case of complaints. This approach is changing rapidly. Routine ongoing testing of UHT products after distribution is now becoming the norm. Simple tests like fluorescamine values and viscosity already allow manufacturers to assess the likely lifetime of products in different markets. Unfortunately, these methodologies still require at least 2 months (in general) before they can be of value. However more sensitive protease activity tests will be developed which should shorten this to less than 4 weeks. In addition, there is a case for storing samples for proteolysis testing at about 35-40 (where proteolysis is more rapid) so that a very quick assessment can be made.

The whole aspect of better assessment of product performance permeates most of the discussion in this paper, and it is in this area that I see the major changes in the way in which UHT operations will be carried out in the next decade.

2.1.2.3 Development of new means for reduction in protease levels in raw or UHT milk

LTI in its current form does not seem reliable. But given the knowledge that we have, it should not be beyond our expertise to develop for example a column with the appropriate ligands to bind the protease enzymes when raw milk is passed through it. There are many techniques now available to the biochemist which can be employed to specifically exclude or bind individual components of products onto columns. One factor mitigating against this may be the contact time required - to date the period required for effective LTI has been considerable, although the work of Bucky et al (1987) gives reason for confidence that the extended periods suggested by Barach et al (1976) can be reduced.

Currently I am unaware of studies in this area, but it seems to me that some consideration of a pretreatment of milk to reduce or remove proteolytic activity would likely be worthwhile. A range of further research options have also been suggested by McMahon (1995).

2.1.3 Mechanism of age gelation

McMahon (1995) has indicated areas of further research which might be undertaken to further elucidate the mechanism of age gelation. An increased understanding of the mechanism is likely to lead to new options for control of this defect.

2.2 Fat Separation

Complaints regarding fat separation are probably even more common than complaints concerning age gelation. (Age gelation problems seem to affect manufacturers in certain countries, more than others. This is probably a result of both milk harvesting and processing differences, and in differing markets - sellers to tropical countries are more likely to encounter age gelation problems.)

Fat separation problems are more ubiquitous however, although again, as would be expected are more common when product is sold to tropical areas.

The importance of fat separation should not be minimised - it is a major concern to the industry. There have been cases where container loads of product have been rejected because of severe fat separation.
Simplistically, one can consider Stokes Law (see Section 2.2.3) as defining (to some extent) the likely magnitude of a fat separation problem with UHT milk. Essentially, the rate of fat separation is dependent on both the average radius of the fat globules, and the viscosity of the aqueous phase.

Fat separation (or creaming) is simply the result of an excessive rate of rise of milk fat in the product during storage. The normal means of controlling creaming in stored liquid dairy products is through the use of homogenization, which reduces fat globule size, and thus their rate of rising.

2.2.1 Unhomogenized milk fat

The size distribution of globules in milk (homogenized or unhomogenized) cannot be effectively described by a single value. In raw milk, more than 75% of the particles are less than 1μm in diameter. The "number average" diameter is therefore small, about 0.8 μm. However, the large number of small globules is difficult to measure exactly, and such values are often not precise. Perhaps a better measure is the "volume-surface" average, which is about 3.4 μm. This is essentially a "surface area" weighted average, relating the total volume of material to the total surface area.

As well as average globule size, a major factor controlling creaming is the size distribution of the fat globules.

In raw milk, the size distribution can be split into three sections:

(a) small globules, comprising about 80% by number but only a small percentage of the fat

(b) the central portion, comprising perhaps 95% of the fat by volume, and

(c) the large globules or "tail" of very large particles.

2.2.2 Homogenization

2.2.2.1 General

The main effect of homogenization is the disruption of the fat globules into smaller particles, thus reducing creaming. The overall efficiency of homogenization is influenced considerably by homogenizer design and flow rate, particularly as affecting Reynolds number. Without going into the theory of homogenization in any detail, there exists for each homogenizer a critical globule size $D_{cr}$: larger globules will be disrupted, smaller ones are not. This value depends in part on the energy input (through its effect mainly on Reynolds number) and time of contact in the valves. The overall influence of this fact is that there will be a wide range of particle sizes in the homogenized product. It also implies that repeated homogenization decreases both average globule size and distribution width.

Many factors affect the efficiency of homogenization. These include:

(a) Homogenizer type, particularly through different energy inputs, time of contact and slit design

(b) Homogenizer pressure, particularly regarding its effect on energy input

(c) Two stage homogenization. By applying some back pressure to the first stage valve exit, cavitation is increased and this may result in enhanced homogenization and disruption of aggregates. In general there is little significant homogenization in the second stage valve.
(d) Fat content and the ratio of surfactant to fat. These affect energy input per unit of fat, and their ability to coalesce after disruption.

(e) Temperature of homogenization. It is much more difficult to effectively disrupt particles which contain solid fat - cold homogenization is therefore likely to be much less effective.

Homogenization enlarges the total fat globule surface area. The new area is covered in general by casein micelles (perhaps >90%) rather than whey proteins, and large micelles are preferentially absorbed. In general, the micelles are absorbed more rapidly as temperature increases (much faster for example at 70°C than at 40°C). Heating also influences absorption - the casein-whey protein reactions which occur at higher temperatures which will prevent the absorption of the whey proteins by the micelle surface. Further, some surfactants such as monoglycerides, can readily replace or be preferentially absorbed in comparison to casein.

2.2.2.3 Clustering during homogenization

After homogenization a partially coated globule may contact another partially coated globule, to form a cluster. Although these can be broken by further turbulence, they may survive and persist. The degree of clustering is determined in the main by fat content, protein content and heating. In milk, the percentage of fat is low enough to reduce the formation of such clusters to quite low levels. Two stage homogenization will also assist in prevention of clusters.

Clusters formed may be of 10 to 100 μm diameter and contain up to 10^6 particles.

2.2.3 Creaming

Inevitably the difference in the density between fat (920 kg/m^3) and milk plasma (1030 kg/m^3) will result in the globules of fat tending to rise. The rate of rising is determined by Stoke's law:

\[ v = \frac{d^2g(\rho_p - \rho_f)}{18 \eta_p} \]

where \( v \) is the velocity of rising, \( d \) the globule diameter, \( \rho_p \) the plasma density, \( \rho_f \) the fat density, \( \eta_p \) the viscosity of the plasma, and \( g \) the acceleration due to gravity.

In passing, the rate of rising is about three times greater at 50°C than at 25°C.

There are a number of factors to consider in evaluation of this relationship:

- Brownian motion (not considered in Stoke's law) can also be of significance in small particles.
- The smallest particles have the thickest surface layers, and may in fact be heavier than the plasma, and thus may sediment.
- In higher fat products (say >7-8%) the mutual hindrance of rising of globules results in a sharp reduction in creaming rate.
- Temperature influences the ratio \( \frac{\rho_p - \rho_f}{\eta} \)

\( \rho_f \) increases when the fat crystallizes, and thus supercooled fat globules cream faster than partially crystallised globules at the same temperature.
Of key importance is the role of thickening agents. These increase $\eta_p$ and slow creaming. Agents such as $\kappa$ carrageenan which may form networks within the product are a particularly effective means of control of creaming.

In consideration of the above, it should be borne in mind that Stoke's law describes effects under "ideal" conditions, and that the viscosity of concern in the plasma is that immediately surrounding the globule - this may be greater than the bulk viscosity of the plasma.

The principles outlined by Stoke's law do however indicate the parameters of importance in controlling creaming. In essence, the key factors are $d$ and $\eta_p$. It is essential to keep $d$ as small as possible, and to ensure the number of clusters and larger particles are at a minimum, to ensure that the viscosity of the plasma surrounding the globules is as high as possible.

2.2.4 The effect of fat globule size on fat separation

Table 1 below shows the effect of fat globule size distribution on the extent and rate of rising of globules. The figures should be interpreted as only broadly indicative of the practical effects.

Table 1.
The Effect of Fat Globule Size Distribution on Volume Distribution and Rate of Globule Rising

<table>
<thead>
<tr>
<th>Size (10)</th>
<th>Number %</th>
<th>Volume %</th>
<th>Rising rate of largest particles (smallest =1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>99</td>
<td>78</td>
<td>1</td>
</tr>
<tr>
<td>1.5</td>
<td>1</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>0.5</td>
<td>99</td>
<td>44</td>
<td>1</td>
</tr>
<tr>
<td>2.5</td>
<td>1</td>
<td>56</td>
<td>25</td>
</tr>
<tr>
<td>0.5</td>
<td>99.9</td>
<td>97</td>
<td>1</td>
</tr>
<tr>
<td>1.5</td>
<td>0.1</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

As may be seen, what might be considered to be small levels of larger particles can in fact represent a significant volume of the total fat present, and of course these larger particles also rise much more rapidly.

In essence therefore, fat separation can be seen to be controlled by two major factors - the actual size distribution of the fat globules in the product (and particularly the comparatively small numbers of larger globules which can represent a significant proportion of the total fat volume), and the prevention of clustering of globules after homogenisation.

To a large extent this latter consideration is determined by the protein composition of the product, the homogenising conditions, and the sequence of process operations.

2.2.4.1 Homogenising conditions
There is little doubt that the homogenising conditions, particularly temperature and pressure, single or double valve systems, valve design and maintenance can have a very considerable effect on both the overall fat globule distribution and on the effectiveness of the proteinaceous coating on the fat globule membrane. Homogeniser maintenance in particular is often overlooked in UHT operations, but unlike pasteurised homogenised milk, the homogeniser must always operate at maximum efficiency. There is also little reported in the literature regarding the effectiveness of different valve designs and their energy effectiveness.

Although it has been maintained by some that increased homogenisation pressure will eliminate clustering, there are research studies which indicate that as homogeniser pressure increases, protein load on the fat particles is decreased, and thus the resistance of the globules to clustering also decreased.

2.2.4.2 Sequence of operations

There is much anecdotal evidence that the location of the homogeniser upstream or downstream of the sterilisation section can have a significant influence on the size distribution and formation of clusters of milk fat globules in UHT milk. A recent paper from New Zealand reported a study on the effects of upstream and downstream homogenisation on UHT milks. These workers reported clustering in products manufactured with downstream homogenisation. Of particular interest was the inability to completely disintegrate the large diameter clusters, consisting of fat globules in a protein complex, by a second homogenization after heating.

It should be noted however that for many years, downstream homogenisation has been commonly used by UHT operators. It is also likely that some of the recent concerns about fat separation may have been the result of excessive shelf life claims by some manufacturers.

2.2.5 What of the future for control of fat separation?

More effort will be put into development of energy efficient homogeniser valve design, and to ensuring that the valves can be operated for extended periods without requiring replacement. The effects of different parameters on protein load on the fat globule membranes and particle size distribution will be precisely determined.

A range of other homogeniser systems are also being evaluated. For example, research has been carried out on a high pressure, valveless homogeniser known as a microfluidiser. These devices are used commercially in the pharmaceutical industry, and operate by dividing the feed into two high velocity streams and colliding them. The impact results in homogenisation of the product. Pressures of about 100 Mpa are used. Research to date suggests that the effects of the process are different from conventional homogenisation.

Homogeniser maintenance will be recognised as a key factor in ensuring control of the required fat globule distribution. Regular preventative maintenance schedules assessing homogeniser performance and valve wear will be a routine part of UHT operations.

2.2.5.2 Homogeniser location

Inextricably linked with homogeniser design will be studies on the effect of upstream and downstream homogenisation on fat globule structure. These are already in place in some centres. A combination of the results from these two areas should lead to more reliable homogeniser operations.

2.2.5.3 Product evaluation

At the moment, it is not easy to relate fat globule size distribution to observed fat separation of stored samples. One factor contributing to this is that most particle size distribution methodologies are not
very effective in precisely assessing the distribution of the last say 5% by number of the largest globules, and yet it is these that are responsible for most of the problems, as they usually represent a very significant proportion of the fat by volume. Currently, in my view, the best methodology to assess these larger globules is a visual microscopic examination. However, it is certain that in the near future technology will be developed that will give a precise measure of the size distribution of the larger 5% of globules. This will allow a much more rapid assessment of the likely life of the product. Such studies would also form a part of the ongoing assessment of product after manufacture as outlined in Section 2.1.2.2 Better Assessment of Product Performance.

2.3 Poor flavour

In many parts of the world (particularly the UK, the US, Australia and New Zealand, the differences in flavour between UHT milk and pasteurised milk have significantly retarded consumer acceptance of the product. There is no doubt that over the past 20 or 30 years, there have been enormous strides in improvements in the flavour profile of UHT milk. However the fact remains that the product has a life of say 6 months, and significant changes in flavour can occur over this period, apart from the inherent differences between UHT milk flavour and that of pasteurised milk.

Early suggestions for flavour improvements include those of Swaisgood ( ), who used an immobilised sulphydryl oxidase to treat UHT processed milk to remove the sulphurous notes in the product. Whilst this was very successful, it was not commercially practical to treat sterilised milk with such a system. Inevitably, we are left with improving processing conditions and improving packaging methodology, and where possible controlling storage conditions to try to improve flavour.

2.3.1 Improved processing conditions

There is no doubt that here will be incremental improvements in the processing and packaging systems to reduce the total heat load suffered by the product, whilst at the same time ensuring that the process is sufficiently severe to ensure sterility. In terms of packaging, a simple variation is to modify the oxygen content in the product. Such changes alter the flavour profile of the product during storage, although only to a comparatively minor degree.

2.3.1.1 VUHT processing

In theory, the use of a very short holding time at a higher temperature will reduce the chemical damage undergone by the product, whilst still ensuring sterility. After all, if we have gone from 120C for 15 minutes for in-can sterilisation to UHT operation at say, 140 for 5 sec, to get an improved product, why not go to say, 160C for say, 0.5 sec?

Thus, one might think it possible to reduce the holding time below the current minimum of about 2 seconds, by increasing holding temperature even further. However, in practice, it has not been possible to rely on holding times of less than about 1 second. It should be remembered that such a holding time is a mean or average holding time, calculated from the gross flow rate throughout the system. With fully developed turbulence in the holding tube, and with a holding time of a mean of 1 second, the minimum actual residence time is likely to be about 0.6 seconds.

As the probability of destruction of micro-organisms is related to the actual holding time and temperature, the probability of organisms survival is greatest at the shortest time in the flow distribution. For example, in a holding tube with a mean holding time of 3.1 seconds, the minimum holding time is 1.0 seconds. If one calculates the distribution of surviving organisms passing through the holding tube, based on the product of the number expected (calculated from the holding time distribution and the probability of survival at a given holding time), the bacteriologically effective mean holding time is only 2.3 seconds. Thus, to calculate the sterilizing performance of a UHT system, it is important to use the bacteriologically effective holding time. This value is not greatly different from the holding time calculated from the flow
rate at lower sterilization temperatures, but the difference increases rapidly as temperature of processing increases. The bacteriologically effective holding time is about 40% shorter than the holding time at a sterilization temperature of 150°C. When all of these factors are considered, short holding times at temperatures above 150°C could possibly introduce unnecessary risks, and slight changes in flow rates during a run would make reproducibility difficult. Conversely, at temperatures below about 135°C and lower, the sterilization effect is unlikely to be sufficient unless the holding time is undesirably lengthened.

But there certainly are trends towards VUHT processing, with higher temperatures and shorter times being assessed by a number of operators, in part because of the perceived benefits to the flavour of the product.

2.3.2 What of the future for poor flavour?

It is not impossible that a carefully designed and controlled VUHT system could operate at a very short time, deliver a product with an improved flavour profile and still ensure sterility. However these comments should be considered with those made in Section 2.6.1 Heat Resistant Micro-organisms below, concerning microbiological contamination.

2.4 Run time

Most manufacturers would prefer to have an increased run time before fouling makes cleaning required. Direct UHT systems are in general able to operate for longer periods than indirect systems. However, indirect systems are now much more common world wide, and concerns about run times are therefore increasing.

Studies on fouling have been carried out for many years - the process seems to be mediated by many factors, including mineral composition, pH and milk protein composition and distribution. There is also some evidence that the addition of calcium sequestering agents to milk can reduce the fouling in UHT operations.

Other manufacturers have looked at alternative UHT methodologies to tackle this problem (and the problem of off flavour development). Some steam infusion systems for example are designed so that the first surface touched by the UHT heated milk is cooled with a cold jacket. However in indirect systems the problems remain. Certainly it is likely part of the reason for the general trend to tubular rather than plate indirect systems has been as a result of concerns about run time.

One important aspect is the fact that manufacturers notice both seasonal and short term problems with run time. These are most likely related to a low pH in the product, and perhaps a high calcium content.

The elimination or reduction of fouling can be achieved in three ways:

(i) Modification to the heat treatment

(ii) Modifications to the design of the heat exchanger

(iii) modifications to the fluid (through for example decreasing calcium content)

It should also be noted that sedimentation is a major problem to some processors, and this appears to be linked to similar factors that control run time.

2.4.1 What of the future for extending run time?
This is a crucial factor in process selection for many manufacturers. Of the three methods listed above, the first two are to a large extent in the hands of equipment designers. It is difficult to see what can be done in terms of product design by the end users. However the demand for improved run times will ensure that the equipment suppliers continue to improve their operations. With regard to the latter, research is required to determine more precisely the compositional properties which influence fouling.

Thus, in terms of the factors controlling run time as far as raw milk composition and processing parameters are concerned, there is room for considerable research.

2.5 Use By dates

Pressure on manufacturers to extend Use By dates for UHT products is a world wide phenomenon. Most UHT products now have a 6 months Use By date, and many have 9 months or more. I consider this to be excessive. Many of the problems of age gelation and fat separation would not be of concern if realistic Use By dates were set by the industry. The simplest, most effective means of combating the technical problems of UHT milk would be to revert to the 3 to 4.5 months Use By dates which were common in the past. However, this is also the least likely remedy to be applied. Commercially, marketing arms of manufacturers will not concede such options - but then the marketing people do not have to deliver a product with a 9 month life regularly and reliably - they rely on the technical staff to do that.

2.5.1 What of the future of Use By dates

It is certain that pressure on extending Use By dates will continue, and that 9 months will become the norm for most UHT products. Such pressure will emphasis the need for technically acceptable answers to fat separation, age gelation and flavour problems currently encountered.

2.6 Microbial contamination

2.6.1 Heat resistant microorganisms

Until recently, microbial contamination of UHT operations has been simply a matter of determining the precise source of the problem - it was nearly always a failure of some part of the process, generally either a failure in the homogeniser (if located downstream), the aseptic tank, the filling system or inadequate cleaning. The types of organism found were generally a good clue to the cause of the problem.

It was almost an article of faith that the raw milk could not contain sufficient heat resistant organisms to carry over into the product, and the UHT processing conditions were more than adequate for sterilisation - any failure was a downstream failure.

However in the past few years, these concepts have changed. There now appears to be considerable anecdotal and research evidence that UHT plants are selecting, through their very nature, particularly heat resistant organisms which do survive UHT processing conditions in sufficient numbers to be of major concern to the industry. A number of these particularly heat resistant organisms have now been isolated and typed. The source of these is unclear, although there is some evidence that they may be present in raw milk arriving at the factory, rather than occurring through infection at the factory itself. This is however far from certain.

Kessler (1994) reported on this phenomenon at the 1994 International Dairy Congress. Figure 1 shows limiting lines for destruction of spores in whole milk with a thermal death value of 9.
**Limiting lines for the destruction of spores in whole milk with a thermal death value 9**

A mesophilic spores  
\[ D_{121^oC} = 11 \text{ s; } E_a = 286 \text{ kJ/mol} \]

B thermophilic spores  
\[ D_{121^oC} = 25 \text{ s; } E_a = 289 \text{ kJ/mol} \]

C heat resistant mesophilic spores  
\[ D_{121^oC} = 34 \text{ s; } E_a = 240 \text{ kJ/mol} \]

D upper limit for UHT-heat treatment of milk as recommended by Kessler in 1981

Kessler (1994) stated *that for years UHT milk could be produced with temperature/time combinations which are given by the range in Figure 1 surrounded by the lines B, D, 133°C and 150°C. During the last years, not yet defined mesophilic spores which are more heat resistant were detected in some European dairies. These require higher heating conditions as defined by the line C as a new lower limitation to get a sterile UHT-milk. Consequently the optimum range for a careful UHT-treatment has become more narrow.*

Essentially therefore, we may be faced with two conflicting possibilities for the future - a VUHT process designed to use higher temperatures for shorter times so as to obtain an improved product, or a SUHT (Severe UHT) process designed to operate at higher temperatures and holding times similar to those as currently used, simply to overcome the increased level of heat resistant microorganisms encountered. However, note that at this stage, Kessler’s work does not recommend an increase in the maximum levels of UHT, rather an increase in the minimum levels - the minimum holding time at 140°C recommended by Kessler is now about 10 seconds! Clearly any such recommendations have major implications regarding flavour.
Kessler also reported on the influence of seals on sterilising efficiency. It is clear that certain seals are very effective in offering protection to spores when plants are steam sterilised - such seals should not be used in UHT equipment.

2.6.2 Product assessment.

A major concern to manufacturers is the means of assessing the microbiological quality of the product. With current techniques, it is similar to a game of Russian roulette!

Manufacturers have two major concerns - the time taken for the assessment, and the accuracy of the assessment.

2.6.2.1 Time required.

Currently batches of UHT milk are quarantined after manufacture for periods of 7 to 14 days (depending on the manufacturer) whilst microbiological checks are made. This is a considerable cost to the manufacturer - more rapid means of assessment are highly desirable.

One option which has been suggested relies on changes in the rheological properties of UHT milk when microbial growth occurs in it. In this system each sample is stored for a week or so, and then individually tested to ensure that its rheological priorities are unchanged. The handling costs involved in this process are considerable, and it has not been adopted commercially to any great degree.

2.6.2.2 Accuracy of the assessment.

A major concern to all manufacturers is that the current Quality Assurance programs can only tell them of a catastrophic failure in the process - if the contamination rate is say 1 in 50, they will find this out. But if it goes from say 1 in 4000 to 1 in 2000 because of a change in the system, the current QA methods simply will not be able to assess such a difference. UHT operators to a large extent rely on the fact that in general UHT works well or badly, so that contamination rates will generally be low or very high. But there are cases of low level contamination which are very difficult to run down, but which can have severe market consequences.

There is a simple answer to this, but it is uneconomic - larger numbers of samples need to be tested. Manufacturers in general have considered and rejected this option, and therefore live with the current uncertainty.

2.6.3 What of the future for microbiological contamination?

UHT operations have already been responsible for a number of food poisoning cases, although fortunately none, of which I am aware, that have involved fatalities. In fact the safety record of the industry is very good, considering the number of packs of UHT product produced world wide each year. However, the appearance of the very heat resistant organisms will pose a challenge to the industry to develop better and faster methods for quality assessment, and to develop processes which ensure that the sterility rate of UHT processing remains acceptable.

Kessler's work on seals will have an important impact on the design of seals for UHT operation, and may lead to reduced contamination rates.

2.7 Lack of ability to assess performance of product from assessment of raw milk

This has been discussion above in a number of areas, in particular with regard to age gelation. As indicated earlier, I believe that a series of tests will be developed which will allow the processor to more
carefully select his milk for UHT processing, such that he can have confidence that it will be more resistant to age gelation and fat separation. Currently the role of seasonal variation in milk composition with regard to run time, age gelation or fat separation is not at all well understood. For example, recent work by Hardham and Auldist (1995) for example has suggested a linkage between stage of lactation, somatic cell count and the onset of age gelation.

2.8 Lack of ability to assess performance from assessment of freshly prepared product

Again this has been touched on earlier. I suggest that the industry will develop a series of tests which will give a clear indication of the likely life of the product in terms of age gelation, fat separation and flavour development. These evaluations are likely to be completed with a few weeks of manufacture, and with the development of an appropriate data bank regarding seasonally changes could be used to allow the most effective distribution of product to different markets.

2.9 Slow packaging rates

Rates of packaging on UHT operations are almost an order of magnitude slower than packaging in the bottle or can industries. Much of the difference is due of course to the different requirements of UHT technology compared to conventional sterilisation/pasteurisation technology. But it is a considerable cost burden to the industry, both in terms of capital and operating charges. Future developments for such matters lies firmly in the hands of the packaging equipment suppliers. It seems likely that increase speeds will be more easily achievable by utilisation of plastic containers, rather than paper-laminate based systems. However, I do not foresee major increases in speed being achievable within the foreseeable future.

3. Alternative UHT processing options

The development of alternative UHT processing options is again driven in the main by the desire to improve profitability through increased efficiency, throughput or improved product quality. A number of options have been suggested over the years, but generally these have not been adopted by industry.

3.1 Ohmic heating

Ohmic heating has been developed to allow even heating of the product, through the passage of electric current. It has been claimed that the even heating of the product improves flavour. Unfortunately “Ohmic cooling” does not exist, so that some of the potential benefits of system are lost, as an indirect cooling system must be used, It has been claimed that the process has particular benefits with regard to particulate processing. However some concerns have been raised about either overheating or inadequate heating in such products, because of differences in the conductance of the mother liquor and the particulate present.

3.2 Non-heat based options

Non-heat based options are generally designed to result in sterilisation of the product, by various means. However, they all suffer from the disadvantage that they are likely to have little or no effect on milk enzymes present. The key aspect of UHT processing is not only the production of a sterile product, but also one which is virtually free of enzymic activity. As is well known, raw milk contains many enzymes, most of which are destroyed though pasteurisation, and virtually all (with some exceptions) on UHT processing. Any new technology aiming at replacing conventional UHT processing must also result in effective destruction of the full range of enzymes present in the milk.

3.2.1 High pressure applications
The application of high pressures (300-1000 MPa) is causing interest in the research establishments as a means of reducing microbial count in milk, but the technology is not likely to be available in the short to medium term, and its effectiveness as a true means of sterilisation remains to be proven. However it does offer an option whereby the flavour of the product should be comparatively unchanged compared to pasteurised milk.

3.2.2 High pressure homogenisation with a microfluidiser

Microfluidisation will result in a reduction in the count of a number of microorganisms. However, multiple passes are often necessary to achieve useful results. This process also has potential to replace existing homogenisers in UHT operations.

3.2.3 Microfiltration

Processes which utilise membrane filtration for sterilisation also have considerable potential. However the main problem is of course the fat fraction. All systems currently separate the cream microfilter the skim milk fraction (thereby effectively sterilising it, heat treat the cream and recombine the fractions to produce a "sterile" product. Such systems include the Purelac (APV) and Bactocatch (Tetra Laval) systems, which produce a product which is almost sterile, although not perhaps to UHT standards.

However the potential of these process is considerable, provided they can be made to operate at UHT requirements of sterility. The end product again should have a very good flavour profile, and thus be very readily accepted by the consumer.

3.3 What of the future for new UHT technology?

At this stage, it seems unlikely that any of the currently considered candidates to replace UHT will be technically, much less commercially viable. Putting technical matters to one side, in terms of energy requirements, heat is a comparatively cheap source of energy for most dairy operations, electrical energy such as that required for MF or high pressure operations is generally much more expensive.

It is therefore likely that new technology will be represented by improvements in current methodology to reduce heat damage and perhaps to increase temperature of operation whilst reducing holding time.

4. Scenarios for the future

These have been divided into four sections - raw material factors, process factors and product factors, and markets.

4.1 Raw material

There is little doubt that major improvements will be made in the ability of the processor to evaluate the suitability of raw milk for UHT processing, particularly with respect to:

* Run time
* Likelihood of onset of age gelation
* Likely development of fat separation
These activities will require development of rapid effective analytical methodology for testing of raw milks, coupled with the ongoing use of data banks relating past information with product performance.

4.2 Process development

Ideally a UHT product should:
- be sterile
- be free of all contaminating enzymes
- undergo virtually no chemical changes during storage
- have a flavour identical to pasteurised milk

Appropriate heat or other treatment can often ensure microbiological sterility but the high heat resistance of some protease and lipase enzymes means that a significant fraction of activity can survive normal UHT treatment. To overcome this residual activity, increased severity of heat treatment can be employed, but at the cost of causing additional undesirable chemical and organoleptic changes in the product. Ideally therefore a means for either prevention of formation or removal of heat resistant proteases and lipases would form apart of any future ideal UHT operation. If this could be achieved (by for example modified LT or affinity techniques) then the resultant product could undergo minimal heat treatment to ensure least chemical and organoleptic change.

It is not likely that alternative methodologies will be commercially viable for UHT processing in the foreseeable future. Incremental improvements in design of existing methodology will allow improved run time, assurance of sterility, improved flavour, and more reliable and effective homogenisation of the product.

Major problems will the assessment of the route to take with regard to the use of higher temperatures and perhaps shorter times. The appearance of very heat resistant microorganisms is likely to result in the application of more severe heat treatments, with concomitant loss in flavour profile. Provided that problems due to such organisms can be avoided, I perceive the development of VUHT systems will occur as the result of incremental changes in design.

4.3 End product assessment

Methodologies will be developed to assist manufacturers in assessing the effective life of the product, from the point of view of age gelation flavour and fat separation. These results should be available within a few weeks of manufacture, and in conjunction with the appropriate data base, should allow direction of product to appropriate markets.

4.4 Research options

Major research endeavours will be required to support the ongoing development of UHT processing. Key areas for further work include:

⇒ Development of a detailed understanding of the mechanism of age gelation
⇒ Development of a better understanding of the factors controlling age gelation
⇒ Development of means for controlling the level of heat resistant enzymes in UHT milk
⇒ Development of an understanding of factors controlling fouling
Development of an understanding of factors affecting homogenisation efficiency, fat globule distribution and fat separation in UHT milk

Studies on VUHT operations, and microbial contamination, control and assessment.

All of the above need to be assessed in light of raw material composition and variation, and with the aim of developing early warning systems of practical use to the manufacturer.

4.5 Overall technical changes

The major technical change in the next decade that I see for the industry is that it will turn from a simple “in and out” operation, to an industry that selects its raw material with more care, and assesses long term product performance on or shortly after manufacture. The development of performance databases coupled with ongoing raw material and early product evaluation will result in a more reliable and desirable product, and increased industry profitability.

4.6 Markets

UHT products sell as both white-milk based products (full cream, skim, Hi-Lo,...) and formulated products (custards, desserts,...) on both local and export markets. World wide markets in both areas are very strong, with the major exceptions being the USA, the UK and Australia (all for particular reasons) Even there, the market for UHT products is growing strongly, although from a very small base. In many countries, UHT products represent more than 50% of the white milk market, and export sales, particularly to the Middle East and Far East are growing rapidly.

The major competitors on the local market for UHT milk are pasteurised products. Major competitors for UHT milk on export markets are recombined product (manufactured in the country of sale), and more recently ESL products (often exported) to the country of sale. On the local market, price will be a major factor determining UHT sales and growth. However, UHT products have inherent advantages in the export market over both recombined products and ESL products, in particular with regard to price and quality.

Overall, I believe that UHT processing will become the norm for milk processing, in the same way that pasteurisation of milk is currently the norm. The increasing quality, better flavour and reliability of UHT milk will make it the product of the future for the dairy industry.
References


Swaisgood, H.
Captions to Figure

Figure 1. Limiting lines for destruction of spores in whole milk with a thermal death value of 9 (Kessler, 1994)
Membrane Filtration is a separation technique that operates at molecular level
Cross flow filtration in a multichannel element
Conventional cross-flow Microfiltration
Uniform transmembrane pressure
Microfiltration

Pressure profiles

0 1 2 3 4 bar

0 1 2 3 4 bar
Industrial Microfiltration Loop

Type MFS-38
<table>
<thead>
<tr>
<th>Bactocatch</th>
<th>MFS = MicroFiltration Sanitary</th>
<th>HTT = High Temperature Treatment</th>
<th>BCP = BactoCatch Plant = MFS + HTT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The Filtration System</td>
<td>The Plate Heat Exchanger</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The feed stream is divided into</td>
<td>- Mix = Retentate + Cream</td>
<td></td>
</tr>
<tr>
<td></td>
<td>two fractions:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Permeate (low bacteria amount)</td>
<td>The mix is temperature treated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Retentate (high bacteria amount)</td>
<td>(120 °C)</td>
<td></td>
</tr>
</tbody>
</table>
Pasteurization line with Tetra Therm ESL

Single heat treatment
Partial double heat treatment
Protein and fat balance of bactocatch process

**Rawmilk**
- Protein 3.47%
- Fat 4.05%
- T.S. 12.92%

**Skim milk**
- Protein 3.60%
- Fat 0.05%
- T.S. 9.26%

**Retentate**
- Protein 3.98%
- Fat 0.24%
- T.S. 9.83%

**Permeate**
- Protein 3.58%
- Fat 0.04%
- T.S. 9.23%

**Bactocatch**
- Protein 3.50%
- Fat 3.00%
- T.S. 11.94%

**Cream**
- Protein 2.16%
- Fat 40.00%
- T.S. 45.50%

**HTT-mix**
- Protein 2.86%
- Fat 24.71%
- T.S. 31.72%
<table>
<thead>
<tr>
<th>Process impact</th>
<th>Bacteria content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurized milk</td>
<td>Tetra Therm ESL</td>
</tr>
<tr>
<td>90–97 %</td>
<td>99.9–99.999</td>
</tr>
<tr>
<td>Reduction of total plate count (TPC)</td>
<td>Number in processed milk, if 30,000/ml TPC in raw milk</td>
</tr>
<tr>
<td>900–3,000/ml</td>
<td>0.3–30/ml</td>
</tr>
</tbody>
</table>
### Process impact

**Chemical changes**

<table>
<thead>
<tr>
<th></th>
<th>Raw milk</th>
<th>Pasteurized milk</th>
<th>Tetra Therm ESL</th>
<th>EU Draft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphatase</strong></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Peroxydase</strong></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>β-lactoglobulin mg/l</strong></td>
<td>3700–4000</td>
<td>3200–3400</td>
<td>3100–3400</td>
<td>&gt;2600</td>
</tr>
<tr>
<td><strong>Lactulose mg/l</strong></td>
<td>8–10</td>
<td>20</td>
<td>20–30</td>
<td>Not detectable</td>
</tr>
<tr>
<td><strong>Protein content %</strong></td>
<td>3.20</td>
<td>3.20</td>
<td>3.20 (3.17–3.19*)</td>
<td>-</td>
</tr>
</tbody>
</table>

* If retentate is bled off

* Document VI/5726/92 FR, rev 2 of August 1993
Process impact

*Organoleptical differences*

Comparison between pasteurized milk - 72 °C/15 sec and Tetra Therm ESL treated milk

<table>
<thead>
<tr>
<th>Day after processing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0 after processing</td>
<td>None</td>
</tr>
<tr>
<td>Day 1–12 after processing</td>
<td>None</td>
</tr>
<tr>
<td>Day 12 - 35–45 after processing</td>
<td>Tetra Therm ESL still tastes fresh</td>
</tr>
</tbody>
</table>
## Process impact

*Total processing costs as index*

<table>
<thead>
<tr>
<th></th>
<th>Pasteurized milk</th>
<th>Tetra Therm ESL</th>
<th>Additional cost of Tetra Therm ESL</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 18,000 l/h - 100 million litre per year</td>
<td>43</td>
<td>100</td>
<td>57</td>
</tr>
<tr>
<td>Country</td>
<td>Product Labeling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>Pasteurized milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Pasteurized milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>High pasteurized/pasteurized milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU Draft of August 1993</td>
<td>Pasteurized milk</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Development of microorganisms in milk stored at +6 °C and +10 °C

MF72 = Microfiltration + pasteurization at 72 °C
## Process impact

### Shelf life

<table>
<thead>
<tr>
<th>Pasteurized milk</th>
<th>Tetra Therm ESL</th>
<th>Approval criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk</td>
<td>16 days</td>
<td>More than 42 days</td>
</tr>
<tr>
<td>- TPC approx 10,000/ml</td>
<td>12 days</td>
<td>35–45 days</td>
</tr>
<tr>
<td>Storage temp</td>
<td>4–6 °C</td>
<td></td>
</tr>
<tr>
<td>Raw milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- TPC approx 50,000/ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage temp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>max 7 °C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Size comparison in milk

Microfilter pore

Fat globules in skim milk

1.4 micron

Bac. cereus

Casein micelles

Str. thermophilus

Cl. tyrobutyricum

Microfiltration pores, milk components, bacteria & spores
<table>
<thead>
<tr>
<th>Packaging</th>
<th>Tetra ALCross MB</th>
<th>Tetra ALCross M</th>
<th>Tetra ALCross UC</th>
<th>Tetra ALCross US</th>
<th>Tetra ALCross UT</th>
<th>Tetra ALCross NS</th>
<th>Tetra ALCross RS</th>
<th>Bactocatch</th>
<th>MF</th>
<th>UF</th>
<th>UF</th>
<th>NF</th>
<th>RO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESL milk</td>
<td>Clear Juices</td>
<td>Feta/Domiati</td>
<td>Feta/Domiati</td>
<td>Feta/Domiati</td>
<td>Juice clarification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BAF</td>
<td>Yellow cheese</td>
<td>Milk protein standardization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Milk protein standardization</td>
<td>Milk protein standardization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td>Spore removal for cheese milk</td>
<td>Protein fractionation</td>
<td>Defatted whey protein</td>
<td>Brine purification</td>
<td>Spore removal for whey</td>
<td>Cast Feta</td>
<td>Cheese milk protein standardization</td>
<td>Cast Feta</td>
<td>Cheese milk protein standardization</td>
<td>Whey protein concentrate</td>
<td>Desalting of whey</td>
<td>Waste reduction</td>
<td>Water recovery</td>
</tr>
</tbody>
</table>

TPFS:45, JF10
Problems and Issues in UHT Processing

What are the six most important issues facing the UHT milk processing industry in the USA? Please list them in order of importance:

1. ____________________________________________________
2. ____________________________________________________
3. ____________________________________________________
4. ____________________________________________________
5. ____________________________________________________
6. ____________________________________________________

What technical questions do you think the UHT milk industry could benefit from having further research or investigation? Would these benefits be short term or long term?

________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

Check one:
- Equipment Supplier
- Ingredient Supplier
- Processor
- Regulatory
- Consultant/Technical
- Researcher/Educator
Milk Processing Issues

At the 2nd Biennial UHT Milk Processing Symposium held at Utah State University on March 19-20, 1996, participants listed (in order of importance) the six most important issues facing the UHT milk industry in the USA, and to list areas of technical research that would be of benefit to the industry.

Areas of Technical Research suggested by Processors
Information on steam injection/infusion techniques.
Practical aspects of particulate containing products.
Information on mechanisms of enzyme pathways.
Controlling age gelation.
Improved packaging for ESL products.
Information on ingredient used to improve product quality.
Regulatory education of the UHT process to bring CFR and PMO together.
Affect of UHT on natural flavors.
Impact of UHT processing on product ingredients such as added sugar.
Testing of products with particulates.
Develop more rapid raw milk assays.
Develop formulations designed for distribution life of products.
Investigate processing of milk at temperatures above 140°C.
Identification of enzymes.
Develop means to distinguish between good and bad microorganisms
Develop better means of measuring taste properties of milk.

Areas of Technical Research suggested by Equipment Suppliers
Investigate lower temperature (1°C) storage of raw milk to control bacterial growth
Investigate potential for contamination of aseptic homogenizers
Verification of lethality of higher processing temperature/time parameters.
Determine D and Z values at higher temperatures.
Develop rapid detection methods for heat resistant substances.
Accurate determination of D values for C. bolulinum at 140°C.

Areas of Technical Research suggested by Consultants/Researchers
Reducing number of consumer complaints for spoilage/taste problems with ESL milk.
Predicting product stability (gelation and fat separation)
Non-destructive testing for spoilage

Send to attention: — will paper from milk
Send to Linda — contact Linda Robert.
Milk Processing Issues

At the 2nd Biennial UHT Milk Processing Symposium held at Utah State University on March 19-20, 1996, participants listed (in order of importance) the six most important issues facing the UHT milk industry in the USA, and to list areas of technical research that would be of benefit to the industry.

Ranking of Important Issues by Milk Processors
Marketing (Improving consumer acceptance of UHT)
Product stability (fat stabilization)
Product analysis (Real Time, Accurate shelf life prediction)
Product quality (Heat-stable enzymes)
Regulations (PMO vs. CFR113, product/processes standards)
Product stability (proteins, gelation)
Milk Analysis (Real time, spoilage organisms)
Processing (Advantages/different needs of UHT vs. HTST)
Marketing (ESL versus UHT)
Cost of UHT processing
Packaging
Level of expertise in UHT milk processing within USA
Feathering/Flecking of creamers in coffee
Effect of higher temperature processing on product quality
Processing Compatibility heating equipment vs. fillers

Ranking of Important Issues by Equipment Manufacturers
Marketing (Consumer acceptance of UHT)
Cost of UHT processing (capital, operating)
Taste of UHT milk
Price support impact on new technology investment
Distribution problems
Decreasing consumption of milk
Packaging
Marketing (HTST vs. ESL vs. UHT, distribution, shelf life)
Decreasing number of dairies
Process (flow rates)
Profitability of manufacturing fluid milk products

Ranking of Important Issues by Consultants/Researchers
Contamination of Product after heating (ESL)
Package integrity
Cost of UHT processing (capital, operating)
Packaging options
Product analysis (Real Time, Accurate shelf life prediction)
Heat resistant microorganisms

Overall Ranking of Most Important Issues
Marketing (Consumer acceptance of UHT milk)
Analysis (milk, product, rapid, quality, shelf life)
Cost of UHT processing (capital, operating)
Packaging (options, integrity)
Product stability (fat, protein)
Marketing (HTST vs. ESL vs. UHT, distribution, shelf life)
Product quality (Heat-stable enzymes, bacteria)
Regulations (PMO vs. CFR113, product/process standards)