Quality of HTST Sterilized Milk Products

1 - Introduction

Old sterilization processes are reputed to give cooked taste and brown color to the end-products, those alterations of the original products being due to the intensity of the heat treatment.

The 2-stage HTST sterilization is an improved process where all these alterations have been suppressed. The purpose of this paper is to explain the reasons of this improvement and to give the result on a very sensitive product: cow milk.

2 - Production of non acidic long-shelf life products

2.1 - Classification

Long shelf-life milk is currently produced by three different processes:

1st process: **Conventional sterilization**
After a preheating stage to 80°C in bulk, milk is bottled in a conventional filler. After sealing, bottles are sterilized on a datum of 110/115°C for 30 minutes. This process gives often a strong cooked flavour and brown color to the end-product, and is now limited to the production of small batches of flavoured milk. Failure rates remain generally within acceptable levels but sometimes increase with high ambient storage temperatures - 25/30°C -.

2nd process: **UHT treatment**
Milk in bulk is heat-treated at high temperature - 140/145°C - during a short holding time - 2 to 10 sec - before being aseptically filled in aseptic packaging (plastic bottles, cardboard/plastic/al complex,...). Heat resistant proteases can affect the stability of milk during the UHT treatment itself or during its storage. A selection of raw milk in which only limited bacterial growth has occurred can be useful to produce stable UHT milk. UHT treatment limits the brown color of the milk, denaturation of proteins and development of cooked flavour.

3rd process: **2-stage sterilization**
Milk in bulk is first heat-treated at high temperature (the highest possible for the stability of the milk), is then filled in plastic or glass bottles in a conventional environment and finally in-bottle sterilized. According to the quality of the raw milk, it is easy to adjust parameters of this process. The best quality of the end-product will be obtained when the first treatment will be a UHT one and, in that eventuality, a sterilizing value Fo between 1 and 1.5 will be adequate in the in-bottle sterilization.

2.2 - Sterilizing and cooking values

2.2.1 Definition

When it is applied on a raw product, heat has two effects: sterilization and cooking. If canners are looking for both effects simultaneously to save time, milk processors want to sterilize with the smallest possible cooking effect.
The calculation of the sterilizing value Fo is based on temperature/time effect on life of micro-organisms. With the following definitions:

D values

At a given temperature, **D** is the time required to 90% of a given micro-organism.

Z values

Z is the temperature variation giving a 10 times variation of **D**.

References	Enzyme source	T (°C)	D (min)	Z (°C)
PROTEASES				
Bengtsson -1973	P. fluorescens	120	4	20
Mayerhofer -1973	Pseudomonas	149	1.5	32.5
Adams -1975	"	150	1.7	32
Kishonti -1975	"	149	0.4	
Barach -1976a	"	150	0.5	32.5
Barach -1976b	P. fluorescens	130	11	34.5
Malik -1976	"	150	27	28
Law -1977	B. cereus	150	0.016	
Niroumand -1977		142	0.12	29
LIPASES	P. fluorescens	130	16	
Driessen -1973	Pseudomonas	150	1.7	25
Kishonti -1975	"	160	1.25	37
Hedlund -1976	Micrococcus	160	1	63

In a given point of the bottle where the temperature has a constant value T for the time t, the sterilizing value Fo will be :

$$Fo = 10^{(T-121)/Z} * t/60$$

with a Z value of 10 for many heat resistant spores.

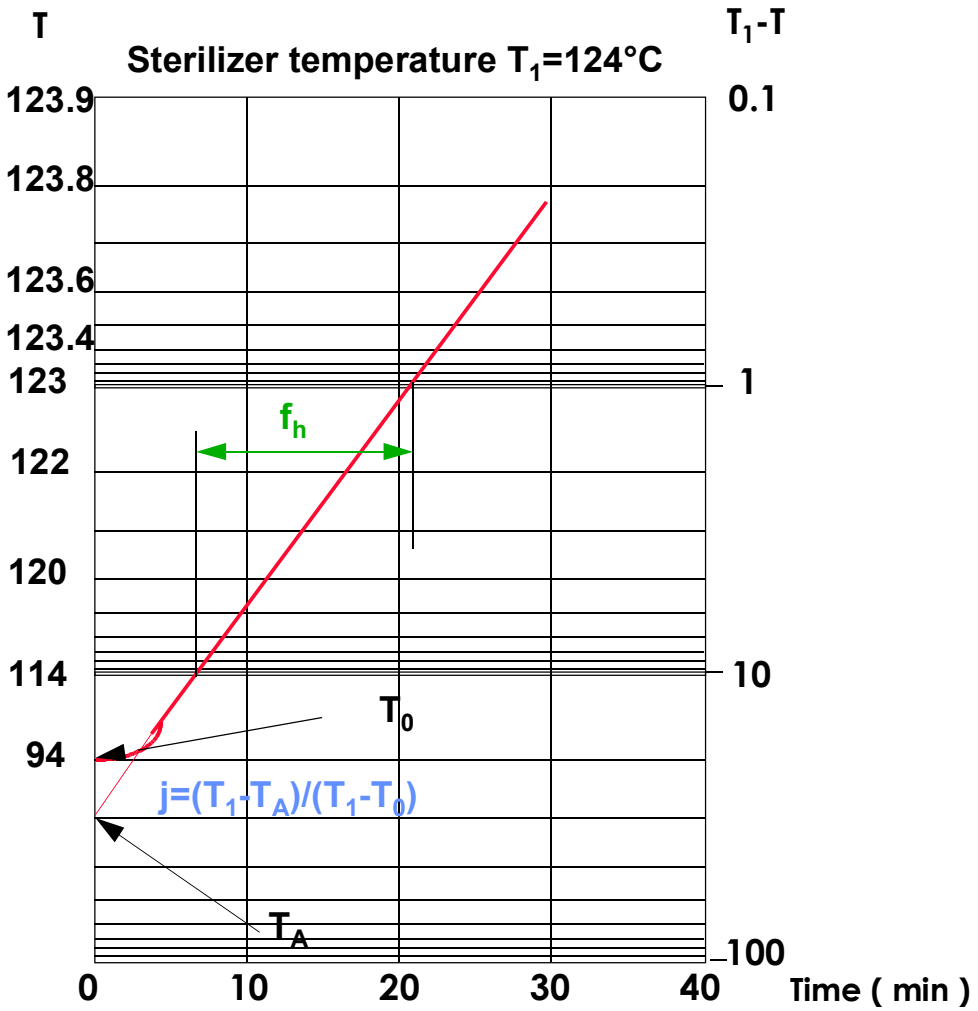
Similarly, a cooking value Co has been defined as :

$$Co = 10^{(T-100)/Z} * t/60$$

with a Z value between 15 and 33 according to the product.

2.2.2 Heat penetration

For in-bottle sterilization, to calculate Fo and Co values, it is necessary to know the time-temperature data at the coldest point of the bottle. Heat penetration time and temperature data are measured during heating period by using special sensor (datatrace) and are plotted on a semi-logarithmic scale paper as shown on the following figure.



From this plot, it result two factors used in calculating processes : j (lag factor) and f_h (slope).
The value of j remains constant for a given product and does not change when converting to another size of bottle. The f_h value characterizes the sterilizing process : it increases when the size of the bottle increases, when the material of the bottle is thicker or more insulating but also decreases drastically when the product is agitated during sterilization, thus showing the better heat penetration which results of this agitation.
Similarly, during the cooling period, j and f_c are determined and used in calculating process.
The f_c value is influenced by the same parameters as the f_h value.

2.3 - HTST sterilization versus other sterilization processes

2.3.1 Sterilizing and cooking values

For the three sterilizing methods, following plots show time/temperature data with resulting Fo and Co values.

For retorts, rotary retorts give lower Co value than static ones. However, in batch sterilization, the accumulation and temporary storage of filled bottles and the fact that the milk is generally just pre-heated before filling need a severe sterilization (Fo values around 5). The results on the cooking effect Co are the following :

	Static retort	Rotary retort
Fo	5.45	4.58
Co	83.2	67.2

For continuous sterilizers, where in-bottle sterilization is achieved after continuous flow preheating, a Fo value of 1.5 is generally satisfying. The results given by the following table are :

	Hydrostatic	Hydrolock
Fo	2.93	3.04
Co	49.3	36.2

These values clearly show how HTST sterilization on HYDROLOCK is more efficient.

- ***Versus retorts***, because of the lower temperature of the milk when it is loaded into the retorts (which results of the previous storage and basket loading time) and of the relatively long come-up and cooling time. Static retorts are worth than rotary showing the benefit of agitation during heating.

- ***Versus tower sterilizers***, because of the long pre-heating of the milk when bottles go through the first water column (typically 7 minutes from 60 to 90°C) which increases the cooking effect. Besides the absence of agitation of the product and the lower operating temperature make treatment time longer.

2.3.2 Effects on quality and economy

The comparison of HTST sterilization with HYDROLOCK sterilizer versus batch sterilization on retorts and continuous sterilization in tower sterilizer shows the following advantages :

1) Quality
In batch sterilization, the accumulation of milk filled bottles after filling and before sterilization results in variations of temperature between first to last bottles forming a batch and in risks of developing undesirable bacteria in first filled bottles. Thus, the batch sterilization process has to be more drastic and gives often a strong cooked flavour and brown color to the end-product.
Use of tower sterilizer for PE bottles has limitations by the fact that the relative pressure given by the columns of water is generally limited to 1.4 bar. In order to maintain equality of external pressure to internal bottle pressure during sterilization to avoid bottle deformation, an overpressure of 0.6 to 1 bar of air is required. This results for tower sterilizer in a steam pressure between 0.4 and 0.8 bar which limits the processing temperature below 120°C and, by this fact, requires a longer holding time to reach the required Fo sterilizing value. In addition, the preheating of the milk which exists in the in-coming column of water increases the cooking effect.

Thanks to its higher operating temperature and to the continuous rotation of the bottle during sterilization, HYDROLOCK allows a faster heat penetration into the bottled milk. The transfer of the bottles from the atmospheric to the sterilizing conditions is achieved by the rotary paddle wheel waterlock of the HYDROLOCK, the time of this transfer being very short compared to the time into the columns of water of a tower sterilizer. These two points allow the HYDROLOCK to reach a given sterilizing value in 8.5 min. only, when a tower sterilizer requires 6 min. of preheating and 12 min.in steam chamber at least and explain the better organoleptic qualities of the HTST 2-stage sterilized milk.

2) Economy
Batch sterilization is used where only relatively small quantities of sterilized milk are required : for each batch, the retort with its internal rotative structure and its baskets is heated from room temperature to sterilization temperature and it results a relatively high consumption of utility per bottle.
Tower sterilizer and HYDROLOCK are quite comparable on the point of view of operating

expenses, however special building and civil works required for tower sterilizer increase its investment cost. Besides, tower sterilizer is built on-site and cannot be moved without disassembly, this results in difficult removal of the equipment to another plant and in a lower value as second hand machine.

3 - Results on long shelf life cow milk

The major concern today is the quality of the milk which must appeal to the consumer.

The quality of a long-shelf life milk depends mostly on:
- raw milk quality;
- qualification of the operators and respect of the quality assurance procedures;
- strength of the heat treatment.

The heat treatment must be selected according to the raw milk quality, with two objectives in mind:
- Safety for the consumer;
- Quality: taste and colour appealing to the consumer.

Recent development with the HYDROLOCK sterilizer have shown that a HTST sterilized milk has the same quality as a UHT milk and can be produced much more safely.

3.1 - How to mesure the results of the heat treatment

The cooking effect and the quality of the milk can be measured thanks to the lactulose content.

You will find below an information on the milk classification used in Europe, the effect of heat treatments on lactulose content, and the optimization of process parameters for long life milk.

3.1.1 Classification of long life milk:

The Dairy Organisation in Europe has defined measurable parameters allowing to control the quality of long life milk produced by the dairies:

- It is aknowledged for more than 10 years, that the modification of lactose into lactulose is a reliable indicator of the strength of the heat treatment applied to the milk.
- Another parameter is the denaturation of whey proteins in the milk through the heat treatment (lacto-globulin is taken as the reference). This parameter confirms the evaluation given by the lactulose content.

The usual milk classification according to heat treatment is as follows:

Milk classification	Lactulose content
Pasteurised milk	0 mg/l
UHT milk	< 600 mg/l
Conventional sterilized milk	> 600 mg/l

3.1.2 Effect of the heat treatment on the lactulose content

The temperature and the holding time at high temperature during sterilization will influence directly the sterlizing value Fo and the cooking value, which can be controlled by the lactulose content.

<u>UHT treatment</u>

The nature of the UHT treatment will also influence the cooking value: the cooking effect is much lower during direct UHT than during indirect UHT.

UHT treatment type	Lactulose content
Indirect UHT	350 to 600 mg/l

Direct UHT (steam injection)	100 to 150 mg/l

Second stage sterilization in a 2-stage sterilization process

As for the UHT, the type of second stage sterilization will influence the cooking value: in one conventional sterilizer (hydrostatic) the cooking time is much longer than in one HYDROLOCK sterilizer, and this affects directly the cooking value.

Second stage sterilization type	Lactulose content
Hydrostatic	400 to 600 mg/l
Hydrolock	150 to 200 mg/l (*)

3.2 - Optimization of two-stage sterilization

3.2.1 Laboratory results

From the following remarks :

- The second stage sterilization is only used to eliminate all possible contamination which might have occured during filling, or which might be present in the bottles, which are not sterile.
- The spore formers of milk are destroyed by the UHT pre-sterilization.
- Consequentely, the second stage sterilization does not require a high sterilizing value.

It becomes clear that it would be useful to limit as much as possible the strength of this second stage sterilization just to the sterilization of the 50% bottles which are not safe after filling.

Sterilization tests performed on STERIPILOTE® simulator after a UHT pre-sterilizer at different operating parameters have given following results :

Test N°	Filling temperature (after UHT)	Sterilization time in HYDROLOCK	Steam temp.in HYDROLOCK	Max. milk temp.	Fo sterilizing value	Lactulose due to 2nd stage sterilization
	°C	minutes	°C	°C		mg/l
2/007	58°C	8.00	120	108.2	0.10	145
3/008	57	12.00	120	114.9	0.70	292
4/009	58	8.00	124	113.7	0.30	221
7/012	74	10.00	120	114.7	0.78	317
8/013	66.6	8.50	122	114.0	0.46	208
11/021	63.0	8.50	122	112.5	0.31	263
13/025	62	6.75	127	115.2	0.52	272
13/032	42.0	6.50	127	111.1	0.16	156
20/032	42.0	6.50	127	111.1	0.16	182

This is exactly the policy that our customer « Candia », has followed. This company is the French leader of long-shelf life milk and operate both aseptic and sterilization. On sterilization, they have worked a lot to optimize the process parameters, and their conclusions were the following :

- They use steam injection and optimized HYDROLOCK treatment with a **very low sterilizing value** for the 1.0 litre bottles marketed under the name of « Grand'Lait », which is the best quality milk sold by Candia.

- The central laboratory of the French Ministry of Agriculture has done tests on long life milk for « Candia »: these tests confirm that the combination of steam injection for UHT and HYDROLOCK treatment (milk temperature 110°C) gives the best result.

Comparing various qualities of long shelf life milks available on the market, the « Central Laboratory for Food Hygiene » of the French Ministry of Agriculture had the following results :

Sample	UHT Treatment	Second stage	Comments
N° 1	Direct UHT 140°C	HYDROLOCK Milk 110°C max	milk produced by « La Prospérité Fermière »
N° 2	Direct UHT 135°C	HYDROLOCK Milk 116°C max	milk produced by « La Prospérité Fermière »
N° 3	Direct UHT 140°C	Hydrostatic sterilizer Milk 116°C max	Commercial sterilized milk bought in retail store
N° 4	Indirect UHT 140°C	no	Commercial UHT milk bought in retail store
N° 5	Direct UHT 140°C	no	Pre-sterilized milk of the sample N°1 (before HYDROLOCK)

Sample	Lactulose content (mg/l) IDF 147 : 1991	α-lactalbumine content (mg/l) CLHP reverse phase	β-lactoglobuline content (mg/l) CLHP reverse phase
N° 1	191	68	38
N° 2	287	67	36
N° 3	628	24	24
N° 4	953	57	53
N° 5	88	511	819

4 - Conclusion

The best results in terms of quality is obtained by a combination of direct UHT and HYDROLOCK treatment.

Heat Treatment	**Lactulose content**
Indirect UHT	350 to 600 mg/l
Direct UHT	100 to 150 mg/l
HYDROLOCK	150 to 200 mg/l
Direct UHT + HYDROLOCK	250 to 350 mg/l

In an aseptic filling system, indirect UHT is necessary because there is no second stage sterilization to destroy the enzymes. Indirect UHT leads to equal or higher lactulose content than Direct UHT + optimized HYDROLOCK.

In terms of quality of the end-product, both processes are similar. But the 2-stage sterilization process gives a safety level unmatchable by the aseptic filling.