New Separation Process for Double Bacteria Removal for Longer Shelf Life of Milk

White Paper on GEA Westfalia Separator **pro**long

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engineering for a better world

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GEA Westfalia Separator: the Powerful Partner to the Dairy Industry

Did you know? Every fourth liter of milk worldwide is processed through GEA equipment.

Mechanical separation technology from GEA Westfalia Separator Group has characterized the dairy industry from the outset. In 1893, the firm was founded as a dairy technology company, and many times, separation technology by GEA Westfalia Separator Group has made significant advances to the development of the field as a whole.

Today, dairies profit more than ever from the unique experience gained in 120 years and from the innovative strength of the technology leader. Systems, processes and production lines provide valuable impulses for greater efficiency and higher returns under any conditions and in a tough competitive environment.

Whether it's butter, yoghurt or quark: there is hardly another natural product from which as many foods can be produced as raw milk. For dairies, this product variety is coupled with a range of different processes used for raw milk preparation and post-processing.

Technology from GEA Westfalia Separator Group supports the following processes:

- Clarification of milk and whey
- Milk and whey cream skimming
- Standardization of milk, cream and whey
- Bacteria removal from milk and whey
- Cream concentration

Special processes for the manufacture and yield increase of:

- Butter / butter oil
- Fresh cheese
- Whey proteins
- Calcium phosphate
- Phospholipids
- Lactose
- Casein
- Cheese fines

and many more.

1. Introduction

Traditionally, drinking milk is preserved by pasteurization and by inactivating the pathogens. The shelf life of milk treated in this way is up to 10 days. Upon request of the trade as well as of the consumers, it has become necessary to extend the shelf life of drinking milk.

In order to achieve a longer shelf life, various routes have been pursued with microfiltration and high-temperature treatment.

The negative aspect of these processes is a change of the sensory properties, here in particular the taste, and a potential reduction of the vitamin content caused by the effects of heat as well as higher operating costs.

GEA Westfalia Separator Group now offers another route: centrifugal separation. The **pro**long process can be used to separate the shelf life relevant microorganisms contained in the raw milk and to produce pasteurized fresh drinking milk which has a longer shelf life.

At the same time, the freshness character as well as all advantageous properties of traditionally pasteurized drinking milk is retained.

Another advantage is the potential subsequent integration of bacteria removing separators in existing pasteurization lines, which makes the investment costs very low compared to the known shelf life extending processes.

On account of the easy integration, advantages in the operational processes and on the cost side of operation are achieved.

GEA Westfalia Separator **pro**long:
- New process for double bacterial removal from raw milk
- Creates a new product: EFL milk (Extended Fresh Life) with a longer shelf life
- An innovation of the technology leader in mechanical separation technology
- Suitable for all dairies all over the world
- Can be used flexibly in milk production
- Maximum product quality at ideal economic efficiency for the companies

2. GEA Westfalia Separator Technology

Our separators have been designed especially for liquid-oriented applications. By means of centrifugal force they separate substances and solid matter from liquids. Equally effectively, they separate mixtures of liquid at the same time removing solid matter.

The application areas cover separating processes in the chemical and pharmaceutical industry, from oil and fat recovery to the production of dairy products, beer, wine, fruit and vegetable juices or the processing of mineral oil and mineral oil products.

Separator variants:

- Solid-wall separators are used to separate fluids
- Chamber separators, also in coolable version, are used for the fractionation of human plasma blood, for example
- Self-cleaning disk separators for clarification and separation processes
- Nozzle separators for the concentration and washing of suspensions

Separators from GEA Westfalia Separator Group are specialists in fine clarification right up to polishing of liquids and liquid mixtures.

3. Bacteria Removing Separators

Bacteria removing separators were developed in the 1970s when these separators became an integral part of a processing line for cheese-making milk. Today, this type of separator is fitted also in front of micro-filtration plants to remove coarse impurities and to remove bacteria of various types of whey, such as whey concentrate, pressed whey, et cetera.

The clostridia spores undesired in the production of cheese are separated by bacteria removing separators preventing cheese problems, such as blowing. In addition, there is absolutely no need to add nitrate when using bacteria removing centrifuges whereby the whey produced is absolutely free of nitrate.

In the production of drinking milk, the bacteria removing separators have the task to safely remove impurities from the raw milk, such as non-milk constituents, somatic cells, undesired germs and bacteria.

For this purpose, the milk is heated to about 55 °C and is passed to the bacteria-removing separator. In the bacteria removing bowl, the milk is gently accelerated to the bowl's rotational speed by means of the GEA Westfalia Separator hydro**soft** inlet and then passed to the disk stack. By using a disk stack without rising channels, the disk gap can be configured as narrowly as possible as the impurities take the direct route in to the solids chamber. This permits the bowl to be provided with the maximum clarification area.

The return lines employed in the bacteria-removing separators from GEA Westfalia Separator Group pass a certain quantity of concentrate (trailing fluid) into the milk feed to the separator. This trailing fluid is an intermediate phase between the light clarified milk phase and the heavy solids phase.

On account of the continuous withdrawal of the trailing fluid, the bacteria-removing effect is increased as the bacteria contained in this fluid phase can be separated in the centrifugal field again.

On account of the discontinuous emptying of the bowl solid chamber, the impurities including bacteria are removed from the bowl. In this case, the **pro**plus system is used which increases the emptying interval by up to double the time in order to permit minimal product losses.

4. Microbiology

Raw milk has a versatile bacterial flora which is influenced by the food and feed of the lactating cow, milking technique and soil and climate conditions.

The bacteria of raw milk can be classified and differentiated in various different ways.

4.1. Bacteria
A classic distinctive feature is to differentiate bacteria according to their preferred temperature conditions:

Rod-shaped micro-organisms which have a density of 1.070 g/ml to 1.115 g/ml are subsumed under bacteria.

- Psychrotropic, i. e. cold-adapted bacteria grow at a preferred temperature of up to 7 °C
- Psychrophilic, cold-loving bacteria enjoy perfect growth at a temperature of below 20 °C
- Mesophilic bacteria grow ideally at a temperature of between 20 °C and 44 °C
- Thermophilic bacteria prefer a temperature of between 45 °C and 60 °C to be able to grow
- Thermodural, heat-resistant bacteria tolerate even higher temperatures of higher than 70 °C

Another distinctive feature is the demand for oxygen which is required for the metabolism of almost all types of organic life.

- Aerobic bacteria require this oxygen from the ambient atmosphere
- Anaerobic bacteria cultivate the required oxygen from the chemical composition of their nutrition.

Some, so-called facultative anaerobic bacteria adapt to their respective environment.

Some germs are present in vegetative form only, whereas other, so-called spore-formers, can survive in non-vegetative form even. These spores are able to survive even under adverse conditions and germinate only when the ambient conditions permit an active metabolism. Various bacilli and clostridia are exemplary germs to be mentioned here.

If spores are to be thermally eliminated in a safe way, temperatures of at least 120 °C have to be employed at a heat retention time of 20 mins..

Vegetative germs (bacteria with a density of 1.070 to 1.115 g/ml) as well as spores (with a density of 1.13 g/ml) have a higher density than raw milk (1.03 g/ml). Thus they can be removed by centrifugal force.

Spores grow from bacteria, if they are removed from the natural living conditions. Raw milk contains natural enzymes as well as enzymes produced by bacteria. These bacteria enzymes are produced by the metabolism of the microorganisms.

Enzymes are considered the triggering mechanism for chemical reaction primarily in high-heat treated milk products, and thus are frequently the cause of sweet coagulation. These enzymes are frequently heat-resistant and are still active even after pasteurization and/or after high-heat treatment.

Some of the germs contained in the raw milk are pathogen. This genotypic feature of a type of germ causes symptoms of disease in a certain host given natural pathways of infection.

The elimination of vegetative pathogenic microorganisms is ensured by pasteurization (72 to 75 °C for 15 to 30 s). For this reason, pasteurization has to be considered the minimum requirement, but at the same time the maximum necessary heating procedure during the production of high quality and safe drinking milk, if centrifugal means are used for the removal of bacteria.

Below please find some temperature-resistant bacteria which have an influence on the shelf life of drinking milk.

It can be recognized that only very high and long heating and heat holding variants can deactivate all bacteria.

Type of bacteria	Temperature resistant	Effect
Acinetobacter gram	≤74 °C	• metabolically relative inactive • no growth < 10 °C
Bacillus (spores)	≤148 °C	• spoils pasteurized milk by cold-tolerant bacteria (Bc. cereus) • growth in UHT milk as heat resistant
Clostridia	≤140 °C	• sensitive to oxygen • possibly spoils milk which is not cooled and processed in sterile
Enterococci	≤90 °C	• little growth < 20 °C • growth in case of milk powder
Micro bacteria	≤90 °C	• when stored cool (8 °C) spoils cereus after > 35 days when free of Bc.
Micrococci	≤85 °C	• metabolically relative inactive • no growth < 10 °C
Streptococci	≤90 °C	• increased bacteria count in exported milk, milk powder • does not spoil when cooled < 8 °C

5. Process Variants for the Treatment of Milk

In order to remove the temperature-resistant bacteria from the drinking milk in the pasteurization process, different processes can be used.

These processes include:
- Centrifugal separation (**pro**long process)
- Filtration with pasteurization of the retentate and of the milk cream
- Heat treatment of the milk

All process variants are preceded by the process of standard milk pasteurization.

5.1 Standard milk pasteurization

In the conventional pasteurization process used for the production of drinking milk, the raw milk is heated to approx. 55 °C and fed to the skimming separator. The milk is separated into skim milk and cream and segregates non-milk constituents.

In the GEA Westfalia Separator **standomat**, a certain quantity of cream is subsequently added to the skim milk again in order to achieve the requested fat content in the drinking milk.
The standardized milk is then homogenized, and is subsequently pasteurized at temperatures of between 72 °C and 75 °C and a heat retention time of between 15 to 30 s. Subsequently the drinking milk is cooled down to a storage temperature of approx. 4 °C.

This process is used to kill most micro-organisms and all pathogenic bacteria, achieving a shelf life of the pasteurized drinking milk of up to ten days.

The fresh character and the low loss of vitamins on account of the pasteurizing temperature are the decisive advantages of this procedure. The low investment and operating costs play an important role here as well.

Surviving thermodural micro-organisms are, among others, bacteria of the genus Bacillus and Clostridium. A non-intact cold chain reduces the shelf life as a

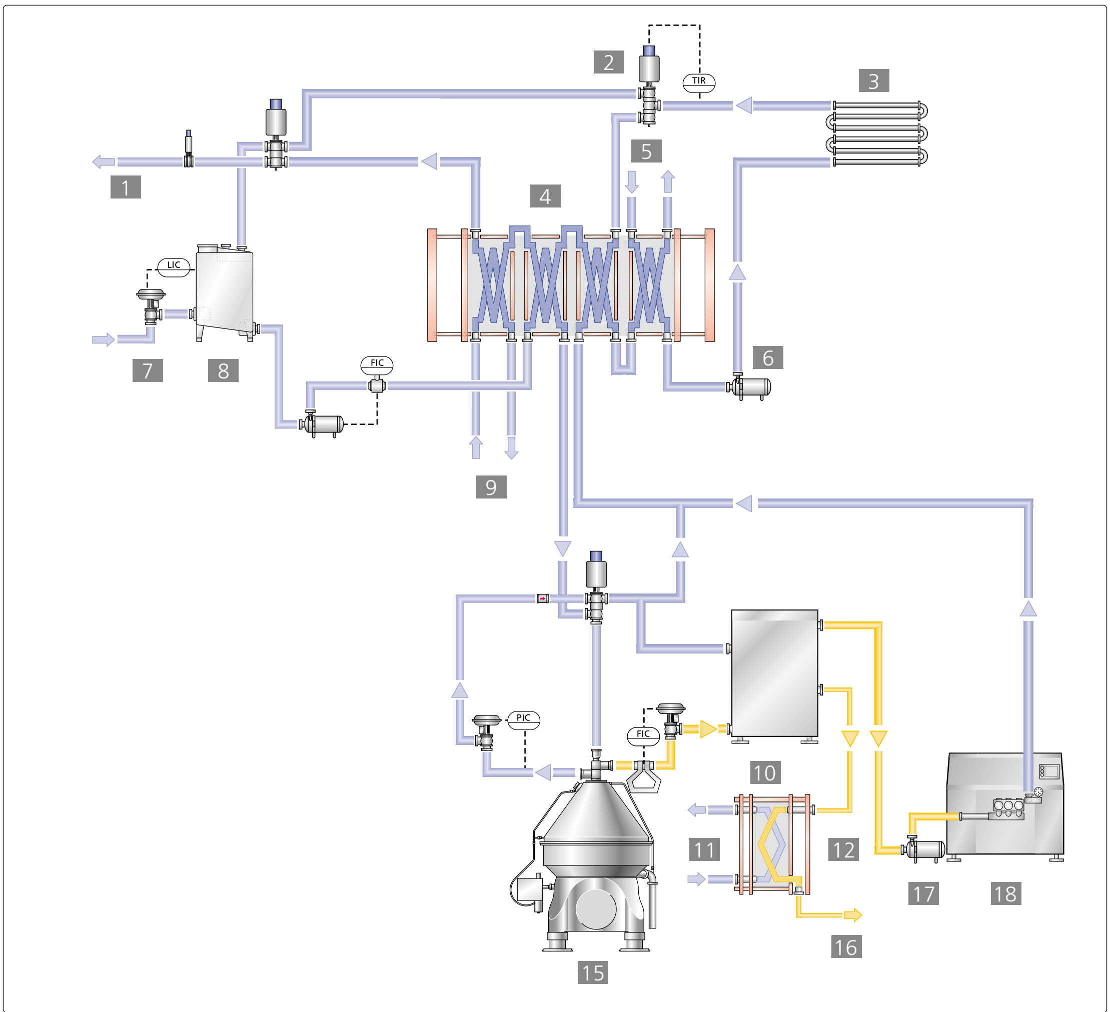

Fig. 1 Conventional process of the milk pasteurization

1 Pasteurized, standardized milk	7 Raw milk	12 Cream cooler
2 Switching valve	8 Flow vessel	15 Skimming separator
3 Heat retention unit	9 Iced water on/off	16 Surplus cream, cooled
4 Heat exchanger (renewable)	10 GEA Westfalia Separator **standomat** MC	17 Product pump
5 Hot water on/off	11 Iced water on/off	18 Homogenizer
6 Pressure increasing pump		

lack of a competitive flora leads to a quick reproduction of bacteria. This restricted shelf life is a logistic disadvantage.

5.2 High-heat treatment

High-heat treatment is differentiated between direct and indirect heat treatment. In both procedures, the raw milk has to be heated to 55 °C first of all, and the skimming separator is used to separate skim milk from cream. Subsequently a certain quantity of cream is returned to the skim milk. The milk standardized in this way is now cooled and stacked at 5 °C for the step of high-heat treatment.

Whilst homogenization is carried out after the high-heat treatment at 127 °C in case of direct heat treatment, homogenization in the indirect heat treatment is done in an intermediate stage before the heat treatment at 127 °C.

Due to the high-heat treatment of the milk, the taste changes and the vitamins decrease by about 30 %, in particular vitamins B_1 and B_2 are reduced. And, a reduction of lysine, an essential amino acid, reduces the nutritional use of milk heated in this way.

5.3 Microfiltration

In this process, the raw milk is separated into skim milk and cream first of all in a skimming separator at a temperature of 55 °C. The skim milk is passed through a microfiltration plant in order to remove bacteria. The pore size of this filtration membrane is between > 0.8 µm and 1.4 µm, which leads to a high separation rate of bacteria. However, the cream cannot be bacterially clarified by the filter modules as it would block the modules. The separated quantity, the so-called retentate, is now heated to at least 125 °C to kill the bacteria. Subsequently the retentate is cooled down and added to purified skim milk again.

The cream phase separated by the skimming separator has to be heated to 125 °C as well before a partial stream of the cream is added to the skim milk again for standardization purposes. In a last step, the milk is at first homogenized and then pasteurized and rendered available for filling in containers.

In order to pass the skim milk through the membranes of a filtration plant, pumps with a high motor rating are required. The membrane plant requires special cleaning, and the production time this plant is lower than that of a separator line.

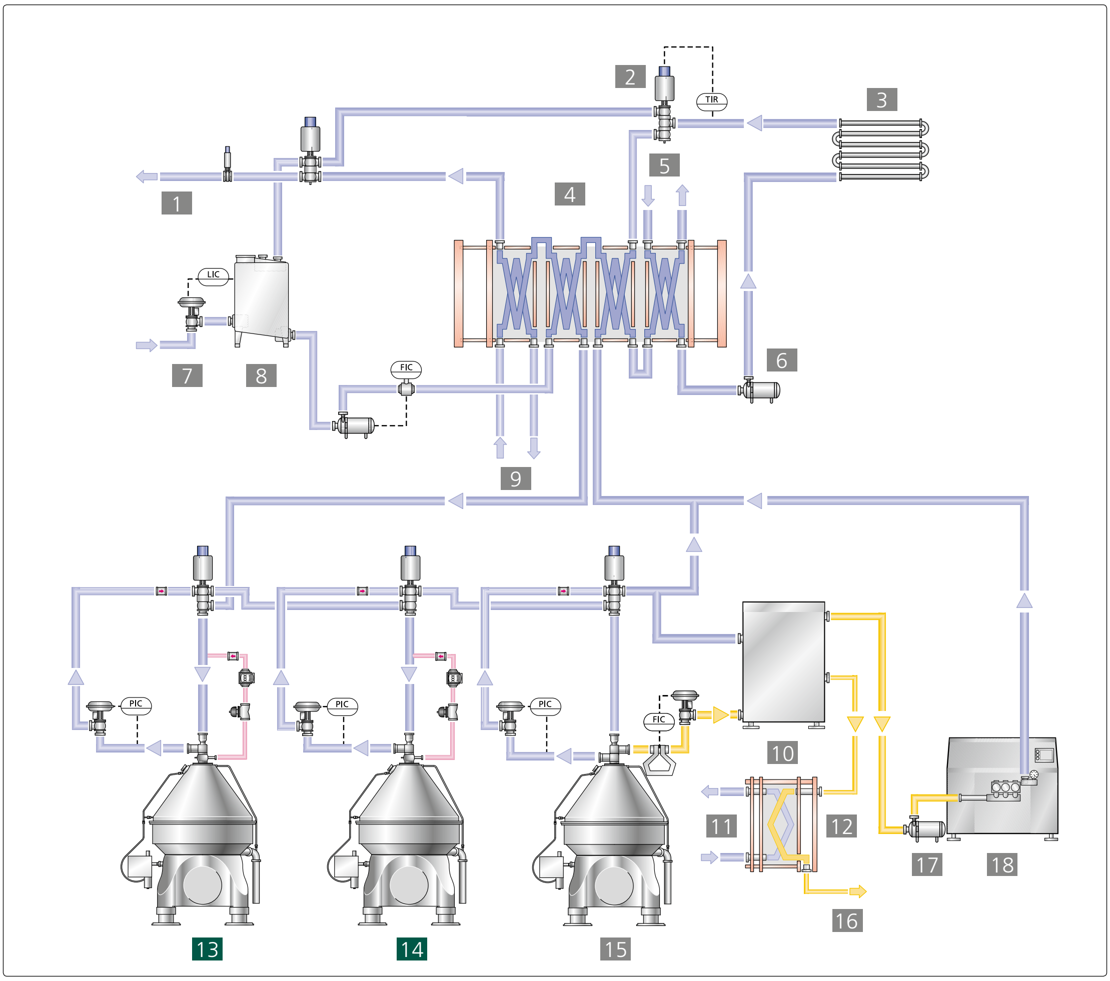

Fig. 2 GEA Westfalia Separator **pro**long process

1 EFL milk
2 Switching valve
3 Heat retention unit
4 Heat exchanger (renewable)
5 Hot water on/off
6 Pressure increasing pump
7 Raw milk
8 Flow vessel
9 Iced water on/off
10 GEA Westfalia Separator **standomat MC**
11 Iced water on/off
12 Cream cooler
13 Bacteria removing separator I
14 Bacteria removing separator II
15 Skimming separator
16 Surplus cream, cooled
17 Product pump
18 Homogenizer

In order to increase the service life of a membrane filtration plant, some dairies use bacteria removing separators in front of the membrane filtration.

5.4 GEA Westfalia Separator prolong process

In the GEA Westfalia Separator **pro**long process, the entire raw milk is also heated to approx. 55 °C, and then passed through two bacteria removing separators connected in series.

In these high-performance clarification separators, the raw milk is safely separated from all impurities. The disk stack without rising channel used in modern bacteria removing bowls today permit the intermediate gap of these disks to be reduced to a minimum, which increases the clarification surface enormously at the same time. The second advantage of a disk stack without rising channel is the separation of solids outside of this disk stack with the effect that the disk is not covered with impurities.

The separation of the thermodural bacteria is ensured as well by the difference of density of raw milk (density 1.011 g/ml) and bacterium (density 1.070 g/ml to 1.13 g/ml). The efficiency of this bowl is increased by carrier liquid returning to a mixed phase between the light milk phase and the heavy solid phase by recycling into the feed of the machine.

The GEA Westfalia Separator **pro**plus system avoids the separation of proteins into the solids. The bowl's ejection intervalls are increased whilst in a separator bowl without this system, the proteins removed to the solids chamber are drained from the bowl. Thus, the loss of proteins is reduced.

After the removal of the bacteria, the milk is fed to the skimming separator and separated into skim milk and cream. In a next step, a partial flow of the separated cream is added to the skim milk again, thus standardizing the milk in the fat content.

Subsequently, the standardized milk is homogenized in full or partial flow (fat content between 13 and 20 %). The next step to be mentioned is pasteurization between temperatures of between 72 °C and 75 °C and a heat retention time of 15 to 30 s.

The standardized and homogenized fresh drinking milk is then regeneratively cooled down to approx. 4 °C and is rendered available in a sterile tank for packaging.

This process step guarantees a reduction of the Bacillus cereus share to < 1 spore/10 ml and thus prolongs the shelf life.

Moreover, the normal pasteurization temperature avoids a potential Maillard reaction which may lead to browning of the milk due to a high process temperature. A separate heating of cream and milk is not required as the entire raw milk is bacterially clarified.

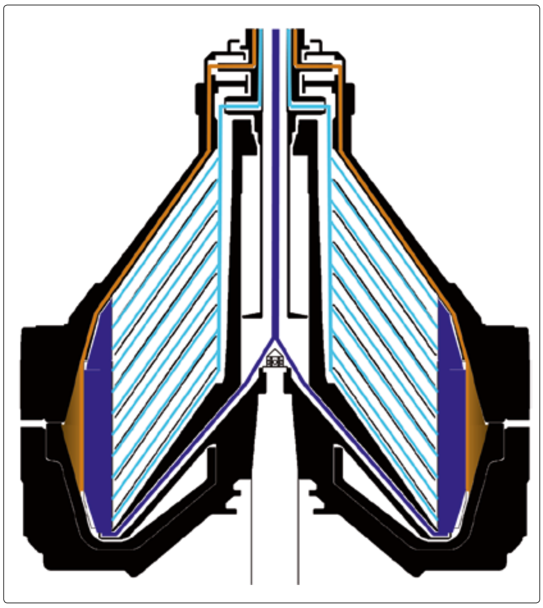

Fig. 3 The disk stacks in the clarification separator ensure safe bacteria removal from the milk

- Raw milk
- Clarified milk
- Concentrate or carrier liquid
- Solids

6. Proof of Heating

The intensity of heat treatment of the milk can be assessed by means of indicators. Here especially, the indicators lactulose and ß-lacto globulin have to be mentioned which change compared to the initial product by heat treatment.

6.1 ß-lactoglobulin

As an amino acid, ß-lactoglobulin has an essential nutritional significance. For vitamin A and selenium it is an important transport protein which has a value of approx. 3800 mg/kg in raw milk.

A reduction of this value to approx. 2500 mg/kg for microfiltered and even to 1600 mg/kg and/or 1000 mg/kg in heated ESL milk is possible.

The pasteurized drinking milk produced by the **pro**long process has a ß-lactoglobulin value of approx. 3000 mg/kg which corresponds to the traditionally pasteurized milk.

6.2 Lactulose

An increase in the lactulose values due to the heat treatment of the milk has a negative influence on the sensory acceptance. Higher contents in lactulose – cooks' taste is possible.

Whilst pasteurized drinking milk (approx. 10 mg/kg) has only a slightly higher lactulose value than raw milk (approx. 8 mg/kg), this value is much higher in micro-filtered milk at approx. 16 mg/kg and in directly (22 mg/kg) and indirectly heated milk (32 mg/kg).

The drinking milk produced by the **pro**long process has lactulose values which are comparable with the pasteurized drinking milk.

6.3 Peroxidase

Milk which has been pasteurized exclusively has to have a positive proof of peroxidase. High-heated milk is heated to over 85 °C which completely inactivates the enzyme lacto-peroxidase (POD).

6.4 Phosphatase

Milk has a naturally sour and alkaline phosphatase share which is deactivated by the pasteurizing process.

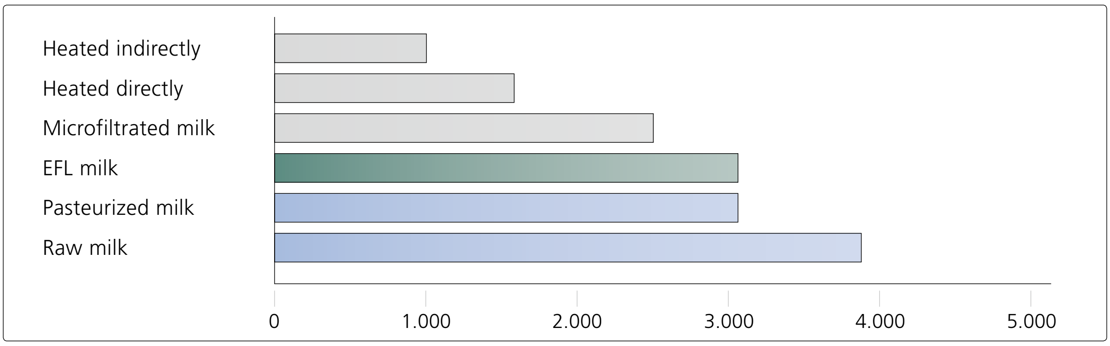

Fig. 4 Residual content of ß-lactoglobulin in native form after heating

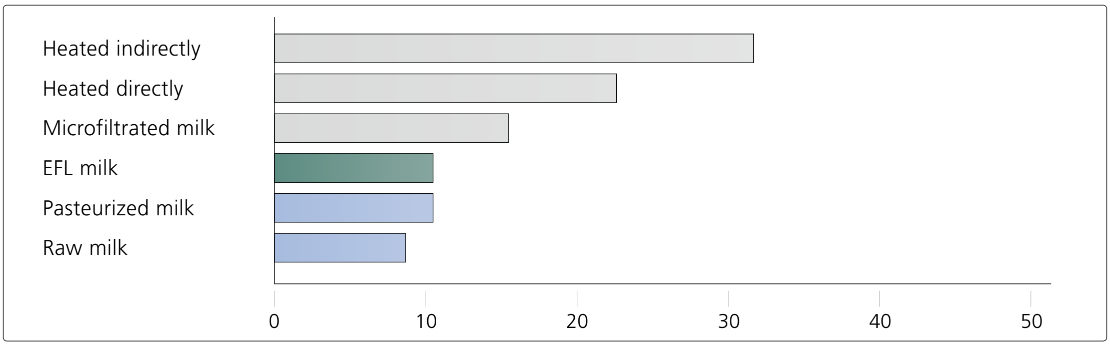

Fig. 5 Lactulose content

7. Sensory Properties

Fresh milk has a characteristically mild taste. Its sensory perception is determined by its "pleasant gustatory sense", its physical composition, its sweet and at the same time salty taste, which comes from lactose and / or the salts and from the various volatile aromatic components (ethyl butaniate, ethyl hexanoat et cetera) (NURSTEN, 1997, p.48; BOELRIJK et al., 2003, p.134).

In a dairy, more than 2200 samples of EFL milk have been assessed. First of all, the retained samples were tested for pH value deviations after a certain time of storage. No deviations were found from samples which had a storage time of less than 23 days. It is only as from 24 days that individual deviations occurred, which means in 0.6 % of the storage samples. After 28 days of storage, a pH deviation was found in more than 1 % of the samples.

In a sensory comparison with other milk products, the EFL milk produced by the **pro**long process achieved the best and / or comparable number of points in all test criteria. In the area of natural and fresh taste it achieved the highest number of points whilst in the "off-flavor" categories it got the best mark as well with zero points.

In addition, EFL milk was tested in packaging which had a differently long period of storage. Here as well, the analysis revealed that all valuations of the individual test categories were close to each other, which means that milk stored for a longer period of time is classified as being very fresh and does not differ considerably when compared to milk stored for a short period of time.

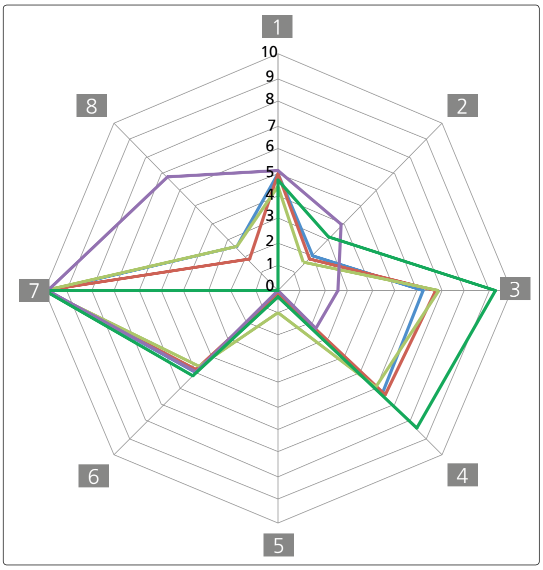

Fig. 6 Comparison of different types of milk

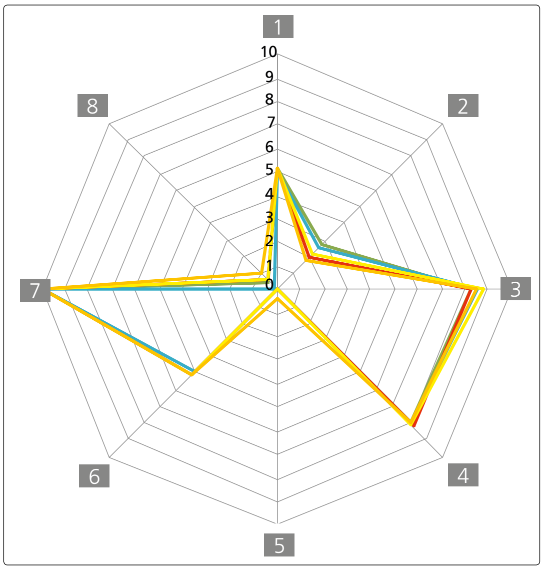

Fig. 7 Comparison of EFL milk after various storage times

1 Appearance / color
2 Smell freshness
3 Taste pure
4 Taste freshness
5 Taste boiled
6 Mouthfeel
7 Homogeneity
8 Off Flavor

Milk I 1.5% microfiltrated
Milk II 1.5% microfiltrated
Milk III 1.5% traditional
Milk IV 3.7% traditional
EFL Milk 3.5%

1 Appearance / color
2 Smell freshness
3 Taste pure
4 Taste freshness
5 Taste boiled
6 Mouthfeel
7 Homogeneity
8 Off Flavor

15 days storage time
20 days storage time
25 days storage time
27 days storage time
30 days storage time

8. Process Evaluation

8.1 Flexibility
Apart from the production of pasteurized fresh drinking milk with a longer shelf life, the GEA Westfalia Separator **pro**long process is also suitable for the production of vat milk for cheese production as well as for the removal of bacteria from the milk to be used for milk powder.

8.2 Investment costs
As a basic prerequisite all processes require a pasteurizing plant consisting of

- Balance tank
- Feed pump
- Heater
- Skimming separator
- Standardizing equipment
- Homogenizer
- Pasteurizer

with all valves and controls.

Moreover, all processes for an extended shelf life need an ultra-clean or an aseptic process standard, which means that all pipelines, valves, pumps, heaters and pasteurizers as well as the homogenizer have to correspond to the ultra-clean standard at least.

The storage tank of the standardized homogenized drinking milk has to be sterile with a sterile air blanketing. The filling of the drinking milk has to be carried out at temperatures of $< 4\,°C$ by a packaging machine that also has at least ultra-clean standard.

In addition, the subsequent cool storage of the packed drinking milk must not exceed a storage temperature of 8 °C.

8.3 Operating costs
The parts mentioned hereinbefore are required for the production of pasteurized drinking milk. As the bacteria removing separators can be integrated in this line, there are only minor additional costs caused by motor current and quantities of waste water.

The bacteria removing separators are cleaned in the same way as is usual in a pasteurizing plant. Here as well there are no changes of the service life. After a production of eight hours, however, an intermediate cleaning should be introduced in order to ensure that no bio-film develops in the heater / pasteurizer.

8.4 Water Consumption
For draining the separator bowl, which is carried out every 20 mins. in a standard procedure, approx. 20 l of water are required. Thus, when using two bacteria-removing separators approx. 120 l of water is needed more per hour.

Using a **pro**plus bacteria-removing bowl, the draining interval is extended by up to 60 mins. and thus the additional water consumption is reduced to 40 l / h.

8.5 Motor current consumption
A separator needs approx. 0.8 kW current for one cubic metre of supply quantity. A bacteria removing separator, such as Separator CSI 400-01-772, needs about 32 kW current for a supply quantity of up to 40,000 l / h.

For your comparison: apart from the additional outlay of water and current, a microfiltration plant needs also compressed air, steam and iced water. The separate cleaning expenses have to be taken into account as well, so that the additional operating costs are considerably higher.

9. Conclusion

With centrifugal double bacteria removal from raw milk by means of the prolong process, dairy businesses are producing a new type of drinking milk: EFL milk with an Extended Fresh Life.

For the first time, this EFL milk combines a longer shelf life of at least three weeks with the freshness properties of a traditionally pasteurized milk.

Due to the gentle treatment of the raw milk and the avoidance of additional heat treatment of the milk, the vitamin content and natural flavor are preserved.

In sensory comparison to milk treated in different processes, EFL milk scores best in many of the test criteria. Especially the natural and fresh taste is rated best. All investigations have shown that all the undesired non-milk elements are reliably removed.

To implement the process, two bacteria removal separators are simply integrated into a conventional pasteurizing line. Based on this simple integration, compared with microfiltration and high-temperature heating, the prolong process generates further advantages in the **pro**long operation flow and in terms of operating costs.

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GEA Group is a global engineering company with multi-billion euro sales and operations in more than 50 countries. Founded in 1881, the company is one of the largest providers of innovative equipment and process technology. GEA Group is listed in the STOXX® Europe 600 Index.

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