MEMBRANE FILTRATION
FRESH FERMENTED AND CONCENTRATED DAIRY PRODUCTS
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The nomination “fresh fermented and concentrated dairy products” covers a wide range of product compositions and processes with products such as strained yogurt, soft cheese, cream cheese, Quarg, Tvorog, Skyr, Pâte Fraîche and Mascarpone. These are packed in containers of many different shapes and sizes and final products are typically ready for distribution or consumption when adequately cooled from process temperatures.

Membrane filtration, compared to more traditional ways of manufacturing fresh fermented dairy products, offers a flexible, high yield process solution which is already well proven in the dairy industry and can be adapted to give producers the ability to increase production capacity and produce wider product varieties from a specific milk supply.

Traditionally fresh cheese types have been made by straining or draining a fermented or rennet coagulated milk curd. Over time new techniques have been applied that optimize process yields and efficiency. Fresh fermented and concentrated dairy products can be produced using membrane filtration as a key part of the process line.

The main advantages of applying membrane filtration for fresh fermented products include:

1) Easy adaption of the Membrane plants to variations in the feed/product quality or the downstream line capacity.

2) Avoid the need to add external dry matter sources if the product range is based on origin protected milk types (geographical, animal, etc.).

3) Generally, the membrane technology provides a higher process yield compared to the use of centrifugal separation.

4) Low concentration levels allow concentration of unfermented milk. The resulting sweet permeate can be used in the production of other dairy products.

5) Low fat loss when concentrating fermented whole milk and cream.

SPX FLOW is ready to contribute with expertise to support New Product Developments (NPD’s), and for building complete process lines for fresh fermented and concentrated dairy products.

We understand the need for “standing out from the crowd” and offer a variety of different forms of technological support covering:

- Development Agreements where you can test your process under optimized conditions in pilot scale at one of our Innovation Centers.

- Purchase or Rental Agreements for pilot units, allowing you to perform pilot testing “in-house” utilizing “real life” feed products.
VISION AND COMMITMENT

SPX FLOW designs, manufactures and markets process engineering and automation solutions to the dairy, food, beverage, marine, pharmaceutical and personal care industries through its global operations.

We are committed to helping our customers all over the world improve the performance and profitability of their manufacturing plant and processes. We achieve this by offering a wide range of products and solutions from engineered components to design of complete process plants supported by world-leading applications and development expertise.

SPX FLOW continues to help customers optimise the performance and profitability of their process throughout its service life with support services tailored to their individual needs through a coordinated customer service and spare parts network.

CUSTOMER FOCUS

Founded in 1910, APV, an SPX FLOW brand, has pioneered groundbreaking technologies over more than a century, setting the standards of the modern processing industry.

Continuous research and development based on customer needs and an ability to visualise future process requirements drives continued mutual growth.

GENERAL PRINCIPLES AND TYPES OF MEMBRANE FILTRATION

Cross flow membrane filtration (Fig. 1) can be used to separate and concentrate milk components. The process uses a flow parallel to the membrane surface to reduce blockage of the membrane pores and thereby optimize the flow through the membrane. As with other membrane separation processes, the membrane flux (l/m²h) or the flow through the membrane is influenced mainly by the feed quality, the retentate quality and the flow and pressure conditions at the membrane surface. In a production environment, efficient cleaning membranes after production is highly important.

The membrane cut-off value relates to its pore size. Fig. 2 shows an indication of pore size ranges of different membrane types illustrated with the approximate size of the main milk components. Normally concentration of the products in the range “fresh and fermented products”, would be performed using cut-off values in the ultrafiltration (UF) range where fats and proteins are concentrated and soluble components like lactose, lactic acid and dissolved minerals pass through the membrane.

Different membrane types can be utilised to concentrate fresh fermented dairy products. In recent times, the organic spiral wound and plate and frame (P&F) membrane modules have been the most popular choices. However, other types such as ceramic membrane modules can also be used. Each membrane type will normally be designed for a maximum product viscosity, which is mainly influenced by milk fat and proteins. The choice of membrane type depends significantly on the content of fat and protein in the feed and in the finished product. The area of each membrane type will, to a great extent, determine the plant capacity.
Fig. 1. Cross flow filtration.

Fig. 2. Dairy membrane filtration range.
The membrane elements are typically made from a combination of different polymer layers. In spiral wound membrane elements (Fig. 3) a polymer based membrane layer is fixed onto a more porous support layer/layers to form a rectangular sheet. Two of these sheets are glued together from the support layer side, forming an "envelope" with the membrane layer on the outside.

Channels are made in one side/edge of the "envelope" and are fixed to the side of a perforated permeate collection pipe. When product passes across the "envelope", permeate will flow through the membrane and the support layer into the envelope and, once inside, will flow towards the channels into the permeate collection pipe.

A number of "envelopes" are fixed onto the sides of the permeate collection pipe and the whole thing is wound into a rolled-up spiral. To keep the different polymeric layers apart, a net type spacer material is inserted between them. Spiral wound membrane elements are typically used in applications with lower concentration/product viscosity levels (Fig. 4).

In P&F membrane elements, flat sheets of membrane and support material are mechanically fixed between supporting plates. These plates are stacked, holding the flat sheets in place between them while they allow product in or out through dedicated channels. In this way, the feed product enters at one end of the membrane sheet and exits at the other in a more concentrated form, having given off permeate through the membrane surface. To optimize the membrane efficiency the product may also be prevented from traveling straight from the feed inlet to the retentate outlet by a physical barrier as illustrated in Fig. 5.

The size of the product flow channel between membrane sheets is varied by the support plate design. This ensures a uniform pressure drop for product traveling both short and long distances between inlet and outlet.

As shown in Fig. 6, feed product is concentrated by passing the membrane sheets which cover the support plates. The support plates have channels for receiving permeate as it passes the membrane. The permeate flows via the support plates to a connecting hose to the central permeate pipe from where it can be removed from the process.

The number and order of support plates and membrane sheets depend on the product type and plant capacity. A membrane module is often designed for different capacities of multiple products and parts of the membrane area may stand idle for certain product types / batches. The
modular design enables flexibility for easy future plant expansions.

The plant concentration level can be controlled using a simple volume control where the retentate flow is controlled as a percentage of the feed flow. Alternatively, it can be controlled via the pump power consumption, which reflects the product viscosity or, in some cases, via a product refractometer.

As the product viscosity increases through a concentration process, positive displacement (PD) pumps may also be used within the system to facilitate product flow.

**Fresh Fermented and Concentrated Dairy Products**

The basic process steps used to produce fresh fermented and concentrated dairy products utilizing membrane filtration are fairly standard and often only need to be modified slightly to produce different types of products.

**Fat standardisation**

The fat content of milk or cream is adjusted to fit the composition of the final product. In many cases this is to meet legislative or other demands, especially if products belong in a specific category. Being able to control the fat and dry matter content of the products accurately is further vital to optimizing yield. Cream may also be added later on in the process to enhance process conditions and flexibility.

**Pasteurisation**

Standardised milk is heated at a relatively high pasteurisation temperature (e.g. 95°C for 5 minutes) to inactivate any unwanted microflora. This pasteurisation stage also denatures whey proteins, thus increasing the curds’ ability to hold water, improves product viscosity and improves final product mouthfeel. After pasteurisation the product is cooled to around 20-30°C depending on which starter fermentation is required.

**Acidification/fermentation**

The temperature of the milk/cream is set to fit the acidification/fermentation process. A certain volume of suitable dairy starter culture is added to start fermentation. Some products can be acidified by adding a food grade acid such as citric acid. Acidification/fermentation improves product quality and helps to maintain it over a longer shelf life.

During fermentation/acidification the milk calcium phosphates will dissolve, and hence can be drained off later to avoid the formation of bitter taste notes caused by a combination of microbiological activity and a high calcium phosphate to protein ratio.
Rennet can further be added during the fermentation step to improve product quality. A typical fermentation time would be 16-18 hours to achieve a pH of 4.5-4.6.

**Uniforming**
After acidification/fermentation, the product is agitated or taken through an SPX FLOW Cavitator, to produce a uniform product phase ahead of further processing. The type and strength of agitation influences the final product quality and must be adapted accordingly.

**Heat treatment**
Next, the uniform, fermented product is heated to stop fermentation. This will stabilise the concentration process and the shelf life quality of the finished product. For a typical process, the product is heated to 55°C and held at this temperature for 90 seconds. After thermisation, the product is cooled to a concentration temperature of around 45-60°C. The choice of temperature depends on the fat content in the product. Products acidified using food grade acids such as citric acid can be heated to around 95°C. Under these conditions the milk proteins will precipitate and the product is then typically cooled to the highest possible concentration temperature.

**Ultrafiltration (UF) concentration**
Inside the membrane filtration plant, fat and protein are concentrated in the retentate phase and lactose, lactic acid and minerals partly leave the product in the permeate phase. The concentration level depends on the type of product and may also allow for additions of cream or other additives later on. Acid milk permeate can be utilised in areas such as animal feed, bio-fuel/gas production or milk mineral extraction. When the retentate leaves the membrane filtration plant it can take different routes depending on the required properties of the finished product.

### ADDITIONAL PROCESS STEPS

Following UF concentration a range of more variable product-dependent process steps can be modified, rearranged or left out to produce a variety of different products.

**Pre-cooling**
On leaving the UF plant, the concentrated product is cooled to around 12-20°C to slow down the remaining starter activity and maintain the correct product viscosity for filling. The method of cooling selected depends on the viscosity of the product. More viscous products would be cooled in scraped surface heat exchangers, while less viscous fluids are cooled in tubular heat exchangers or even in plate heat exchangers with extra wide gaps between the product plates.

**Mixing and storage**
Various ingredients such as flavourings, fruits, herbs/spices, salt or vegetables can be added at this stage of the process to produce the required final taste notes. Cream may also be added to improve taste and change the final product composition. Finally stabilizers, whey protein concentrates, or other food additives may also be introduced to maintain customer appeal for longer shelf life periods. Dosing of the various ingredients is sometimes carried out under aseptic conditions to optimize the bacteriological quality of the end product. Mixing of these products (Fig. 7) can take place in an in-line or batch mixer.

![Fig. 7. Mixing in a batch mixing tank, dynamic and static mixer.](image-url)
In-line mixing typically takes place in a dynamic type mixer where products are under forced agitation or in a static mixer where the product flow is forced by a pump through a restricted space to generate mixing.

Batch mixing often uses a special mixing tank equipped with frame type agitators and a steep tank cone to ease pump extraction of viscous products. At this point of the process the line may further include a buffer in the form of product silo(s) or extra mixing tank capacity. This makes the process less sensitive to capacity variations in downstream filling. Tanks or buffer systems may be equipped for high temperature sterilisation, sterile air supply and agitator seals with condensate flushed shaft seals to ensure food safety and maintain stable product shelf life.

Heat treatment
Some products undergo further heat treatment to temperatures around normal pasteurisation levels (70-80°C) to increase product shelf life stability. Added ingredients will also be pasteurised in the process and possible food stabilizers can be activated if necessary.

Homogenisation
A homogenisation stage ensures cream and other ingredients are thoroughly mixed in and can add firmness to the final product.

Cooling and mixing
The product may be cooled just ahead of filling. A relatively high filling temperature, say of around 20°C, and a slow final cooling in the cold store can produce a firmer end product. The choice of cooler for the final cooling depends on the dry matter content and viscosity of the product. Tubular type coolers or scraped surface heat exchangers are most commonly used for this purpose. Ingredients (flavourings, fruits, herbs/spices, vegetables, salt, cream or pressurized air) may also be added at this point and, if these are pre-cooled, this can speed up final product cooling. It is important that the ingredients are of premium bacteriological quality and that they are dosed under optimum hygienic conditions. Food grade gas types can further be mixed into the cooled product using specialized equipment to improve product spreadability and mouthfeel.

Packing
To avoid reduction in product shelf life, primary packing equipment is usually designed to keep the dosing and closing section as clean and free of microorganisms as possible. For products with long shelf lives, it further helps if the system maintains a minimum of head space between the product surface and consumer packaging. If possible, packaging materials should also have low oxygen and light transmission properties to protect the product from oxidation throughout its shelf life.
cure a prolonged shelf life. In such cases the final cooling of the product takes place inside the consumer package. Cooling tunnels are often used to reduce the product temperature ahead of cold store cooling. Combining the process steps, changing parameters of each step, and adding ingredients further makes it possible to produce and develop a wide range of products with different sensory properties from basically the same process line.

**DIFFERENT PRODUCT TYPES**

There are a wide variety of fresh fermented and concentrated dairy product types. Soft and cream cheese product types, for example, may often be competing for the same customers. Distinctions between products can be hard to make for the average consumer. Often the best distinctions are the legal demands (if any) and the product composition. Following is a listing of the main product categories and their basic compositions. A few general properties are mentioned where general product trends are available.

**Strained yogurt and fermented milks**

This type of product is known in many countries under different names. Some are made using thermophilic and some mesophilic starter cultures.

Examples include:
- Skyr (Iceland)
- Greek yogurt (Greece)
- Shrikhand and Chakka (India)
- Ymer (Denmark)

Products have a typical protein content of around 5-10% (concentrated 2-3 times) and dry matter content in the range 10-16%. Fat content normally varies between 0-10%.

Following fermentation and concentration, the products are often cooled and mixed to give a homogeneous product phase. Filling at a relatively high temperature ahead of cold store cooling will produce a firmer product while filling at low temperature will give a more paste-like product.

In some cases it is possible to concentrate the milk ahead of fermentation. Instead of generating an acid permeate, this process generates a sweet UF permeate which can be used for standardisation of milk ingredients. After concentration, heat treatment is used to stop fermentation. Please note that bitter taste notes and some whey separation can be generated by this process approach.

**Fresh fermented skimmed milk cheese**

This type of product is made using a mesophilic starter culture and is referred by many names in different countries around the world. It is typically made using a mesophilic starter culture.

Examples include:
- Quarg (Germany)
- Topfen (Austria)
- Skimmed milk soft cheese (UK)
- Baker’s cheese (USA, European, and some eastern countries)
- Pâte Fraîche (France)
- Tvorog (Russia)

Product composition normally must follow local rules and regulations but generally the dry matter content needs to be in the range of 16-24% total solids (TS). There may also be further demands on the product composition for protein and fat in dry matter (FDM) content.

**Fresh fermented full fat cheese**

These products originate from skimmed milk cheese but with added milk fat. The cream may be fermented or unfermented before dosing into the skimmed milk cheese after fermentation. Alternatively, the cream may be added to the skimmed milk ahead of fermentation and
concentration. The dry matter content of these products is normally in the range 18-30% and the FDM typically 10-50%. Making these products usually requires mixing of 5-50% cream into the skim milk/skim milk fresh cheese.

Labneh is a product originating from the Middle East. It normally has dry matter content around 22-24% and FDM around 40%. A thermophilic starter is usual for these products.

**Cream cheese and double cream cheese**

When making cream cheese, a standardised cream may be fermented using a mesophilic starter culture. Cream cheese types often have fairly high viscosity at lower temperatures and so hot-filling is commonplace. This creates a suitable speed for the filling process; obtains desirable product firmness, and secures a long shelf life. In general, cooling to the storage temperature takes place in a cooling tunnel/cold store.

Cream cheese and double cream cheese types normally have dry matter content in the range 40-45% with FDM in the range 50-85%.

**Mascarpone**

Mascarpone is most often made by adding a food grade acid, such as citric or tartaric acid, to the cream instead of using a dairy starter. The acidified product has a pH of around 5.8-6.0 and is heat treated at 95°C for 5 minutes before being heated to the highest possible UF concentration temperature. Following concentration the product is packed and cooled in a cooling tower/cold store.

Mascarpone would normally have dry matter content around 60% with FDM in the range 85-90%.

**Fresh Fermented and Concentrated Dairy Products**

**QUARG SEPARATOR**

Quarg separators are frequently used for making fresh fermented and concentrated dairy products and fit into the process in generally the same way as a membrane filtration plant. A separator based solution can utilize two basic pre-treatment processes: A “Thermo process” and a “Traditional process”

In short, the “Thermo” process includes high temperature pasteurisation of skim milk and thermisation of the concentrated product similar to the processes used in the membrane line design. The “Traditional process” typically only has a normal legal pasteurisation step for the skim milk and no temperature treatment of the concentrated product. The “Traditional” product could be conceived as fresher but the “Thermo” product has better shelf life properties.

The process yield of the “Thermo” process is higher compared to the “Traditional” process due to a greater protein yield. It may, however, be feasible to recover protein from the whey of the “Traditional” products using UF membrane filtration. Whey from the “Thermo” process contains only small amounts of recoverable protein and it would not normally be economically feasible to try to recover it through membrane filtration.

By adding membrane filtration, the “Traditional” product yield will increase and be a little higher than the “Thermo” process. The difference between the two, however, will depend on many factors but for indicative purposes a general rule of thumb would say that the whey from the “Thermo” separator process could contain around 0.1-0.2% true protein while the permeate from the UF plant would most often contain below 0.1% true protein.
Filtration processes may be less sensitive to changes in feed conditions compared to solutions based on separator technology. If there is for example, fat in the feed, the separators will often let more fat flow to the whey than the filters let into the permeate. The separator lines are often designed to work at fixed capacities, whereas membrane solutions can be designed for any specific need to allow for variations from product to product – thereby reducing the need for buffering systems.

The investment cost of installing a membrane based process line is comparable to that of a separator based line. However, the cost of running and servicing a membrane based process line is typically a little higher; mainly due to more specialised cleaning requirements and the need for membrane replacement.

To maintain an unchanged product specification, changing between separator and membrane based processes often requires changes to one or more of the upstream and downstream process steps. Normal consumers may have difficulty differentiating between products made using the two technologies, especially when the products are consumed together with other foods and flavours at the dinner table.

CERAMIC MEMBRANE ELEMENTS

Ceramic membrane elements are also used for production of fresh fermented and concentrated dairy products in specific geographical areas and for particular products. They are very robust to physical and chemical stress and can, for example, take high temperature sanitation ahead of production. The physical conditions (flows, pressures, etc.) in the plant can generate specific product functionalities.

Ceramic membrane solutions typically produce a yield in the same range as a solution based on a “Thermo” separator.

MIXING IN DRY MATTER AS AN ALTERNATIVE TO CONCENTRATION

It is possible to mix different dried ingredients and make a product which does not need the normal level of concentration. These products could fall outside the normal definition of “fresh fermented and concentrated dairy products” and one could argue that they are not all together fresh. They may, however, appeal to the same consumer segment and preferences. Ingredients may be mixed with a fermented milk product or the mix is fermented or acidified to produce the final product.

If a producer is marketing a product with a particular geographical origin or specific milk type, using dry ingredients to fulfil the origin claim might not be possible. In such cases a concentration process would be needed.
Membrane plants can be equipped for different automation levels. They normally work downstream of a thermisation line and must, therefore, be able to process the product coming from it. Due to the requirement for special CIP cleaning agents and CIP programs, the membrane system is disconnected after production and cleaned independently from the rest of the line.

In order to make the most of a membrane plant, it is necessary to treat it with care and watch for signs of fouling. A daily record of process parameters should be kept to maintain knowledge of how the plant operates within normal variations.

If the filtration plant is showing signs of gradual decrease in performance, there may be a need for an improved cleaning procedure. It is advisable to consult the supplier of the cleaning chemicals for assistance in order to resolve the issue. A typical cleaning regime for a membrane plant is shown below (Fig. 9.).

<table>
<thead>
<tr>
<th>PRODUCT DISPLACEMENT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. STEP</td>
<td>3% CAUSTIC TYPE CLEANING AGENT</td>
</tr>
<tr>
<td>WATER FLUSH</td>
<td></td>
</tr>
<tr>
<td>2. STEP</td>
<td>0.3% ACID TYPE CLEANING AGENT</td>
</tr>
<tr>
<td>WATER FLUSH</td>
<td></td>
</tr>
<tr>
<td>3. STEP</td>
<td>1% CAUSTIC/ENZYMATIC TYPE CLEANING AGENT</td>
</tr>
<tr>
<td>THE PLANT WILL REST FOR 12 HOURS WITH CLEANING CHEMICALS INSIDE</td>
<td></td>
</tr>
<tr>
<td>4. STEP</td>
<td>3% CAUSTIC/ENZYMATIC TYPE CLEANING AGENT</td>
</tr>
<tr>
<td>WATER FLUSH</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 9. Example of cleaning program – For Spiral Wound and Plate & Frame membranes in combination.
Conclusion

There are many process line designs available for creating a fresh fermented and concentrated dairy product. Process steps must be put together in the right order to produce just the right product properties. Adding membrane filtration to a processing line for fresh fermented and concentrated dairy products can make it possible for producers to broaden their product range based on their specific milk supply. It is a high yield process solution which is already widely used in the dairy industry and can be easily adapted for future production expansion.

SPX FLOW understands the need for producers to “stand out from the crowd” and can offer development agreements to have your process tested under optimized pilot plant conditions.

SPX FLOW designs, manufactures and markets process engineering and automation solutions to Food & Beverage industries through its global operations.

It has more than 30 years of experience using membrane filtration for making fresh fermented and concentrated dairy products and is able to support customers in integrating membrane solutions into process lines for optimum performance.

SPX FLOW is one of the leading suppliers of engineered process line solutions for the dairy industry and can support all project phases for making the right choices for your process. Apart from making Your product the way You like it, SPX FLOW can help design lines with minimum environmental impact.
Examples of SPX FLOW Membrane Filtration Systems

As a leading provider of membrane technology to the dairy industry, SPX FLOW offers a wide range of membranes, membrane systems and dairy membrane applications.

**MICROFILTRATION (MF)**

Microfiltration is based on a membrane with a very open structure allowing most dissolved substances to pass whereas non-dissolved particles, bacteria, spores and fat globules are rejected. Depending on the specific application, membranes and process parameters are chosen to secure optimal performance of the plant.

**ULTRAFILTRATION (UF)**

Ultrafiltration for concentration of milk or whey is widely used in the dairy industry. UF concentration is used as a concentration step in the process of making different whey or milk powder products. Furthermore, fresh cultured cheeses like cream cheese, Feta and Queso Fresco can be produced by UF concentration with substantial higher yield.

**NANOFILTRATION (NF)**

Nanofiltration is a RO process in which a more open membrane allows small monovalent ions such as sodium and chloride to pass. This means that NF combines concentration (like RO) and partial demineralization. The NF process can be used for a wide range of applications in the dairy industry, such as demineralization of whey, milk and permeate from UF of milk or whey.

**REVERSE OSMOSIS (RO)**

Reverse Osmosis filtration is based on a very dense membrane that rejects virtually all substances except water. This is possible due to high system pressure. RO is used for concentration of liquids with higher solids levels, depending on application. The purpose of RO can be pre-concentrate prior to evaporation to minimize transport costs or to increase capacity in different dairy processes.