Membrane separation technology in dairy processes evolves

Derek Hibbard of Solecta explains the different types of membrane filtration and benefits

Dairy manufacturing is a complex process that requires precision and efficiency. As the demand for high-value dairy products rises, manufacturers look for innovative ways to improve their operations and maximise yields. The advancements in separation technologies have enabled dairy processors to access filtration methods that offer increased efficiency, selectivity, and sustainability.

Overview

Effective filtration methods in dairy processing plants are essential for maintaining high-quality standards and providing safe, nutritious products to consumers. Filtration processes enhance product quality, safety, and shelf life by selectively removing unwanted particles such as bacteria, yeast and other microorganisms while retaining desirable components like proteins, enzymes and minerals. In today's dairy processing environment, various separation and purification processes are utilised, including mechanical separation, crystallisation, ion exchange chromatography and membrane filtration.

Mechanical separation, such as centrifugation, separates particles based on density using centrifugal force. It efficiently separates milk solids from the liquid and helps separate cream from milk. However, it may not be effective in separating smaller particulates and requires high energy input.

Crystallisation is a selective method for separating and purifying specific components in dairy products based on solubility. It can be a slow process and requires complex temperature and concentration control.

Ion exchange chromatography is a method for separating components of a mixture based on their relative distribution between a mobile phase and a stationary phase, achieving high purity levels. However, it can be expensive and time-consuming, requiring multiple cycles for optimal purification.

Membrane filtration separates components based on size and/or charge, making it a versatile method for various applications. However, it typically requires a pretreatment step, and the membranes can present challenges such as fouling and degradation over time without proper cleaning protocols.

The choice of process depends on the specific components to be separated, the target final product(s), desired purity levels, the scale of operation, regulatory requirements and cost considerations.

Example of polymeric spiral wound membranes

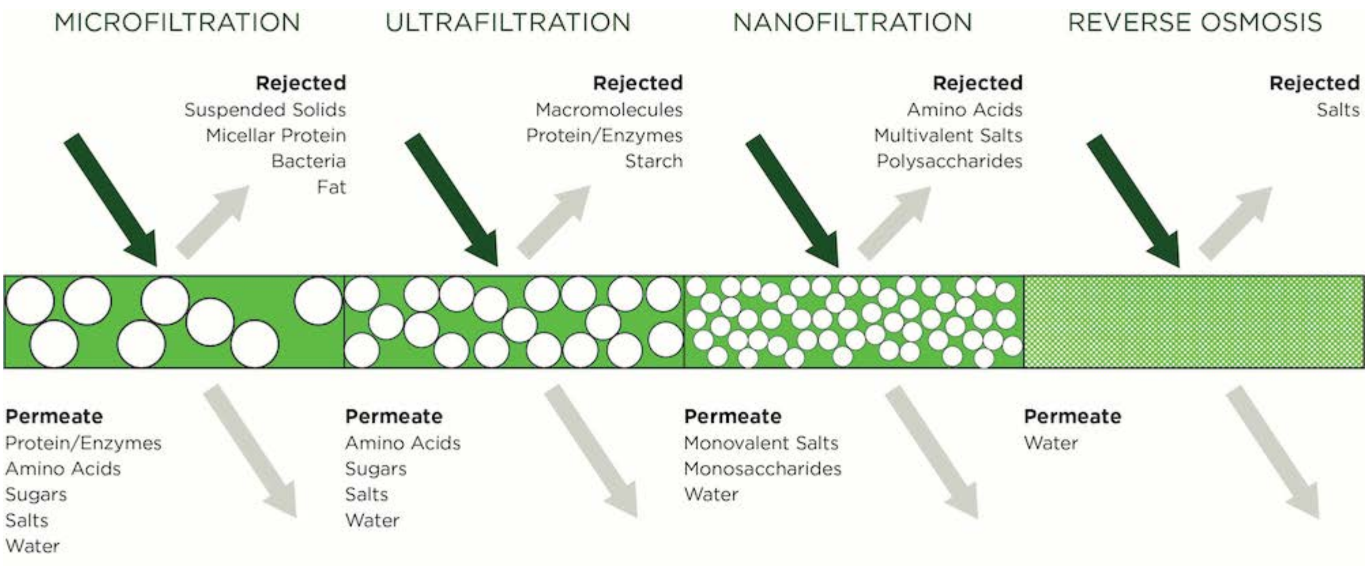
Overview

Membrane separation technology utilises semi-permeable membranes to separate particles and components of a liquid or gas. The membrane functions as a physical barrier, allowing only certain substances to pass through while retaining others. In recent years, it has gained significant popularity in dairy manufacturing due to its ability to provide precise and selective separation of dairy components, resulting in superior product quality and higher value products.

One of the advantages of membrane technology is its ability to achieve effective separation without using heat or chemicals. Membranes can operate at lower temperatures, preserving the natural properties of milk or whey components and resulting in high-quality dairy products with improved taste and texture.

The materials of construction for membranes must be compatible with the dairy products being processed, as well as the operating conditions of the membrane system, including temperature, pH, and cleaning procedures. Polymers and ceramics are the materials most used for constructing membranes in dairy processing, with each type having distinct properties that make it suitable for specific applications.

Polymeric membranes are made



The type of filtration *Credit: Solecta*

from synthetic polymers, such as polyethersulfone (PES), polyvinylidene fluoride (PVDF), polyethylene and polypropylene. The most widely used membrane types in dairy processing are PES and PVDF. Polymeric membranes have a porous structure with a specific pore size that allows for the selective separation of components based on size or charge. Ceramic membranes are made from inorganic materials, such as aluminum oxide, silicon carbide or zirconium oxide, and are known for their high thermal and chemical resistance. They are suitable for harsh operating conditions, such as high temperatures and corrosive environments.

The configuration of a membrane refers to its physical shape, which determines how it is arranged and used in a membrane system. Ceramic membranes come in different sizes and channel orientations and can be made of different materials. The three most common configurations for polymeric membranes are spiral wound, plate and frame, and hollow fibre. Both spiral wound and plate and frame use flat sheet membranes made of a semi-permeable material that separates substances based on their size, molecular weight and charge. They are typically made of polymers, such as PES or PVDF, cast or coated onto a support material, like polyester or polypropylene. These flat sheet membranes can be rolled into spiral wound elements or used in plate-and-frame modules.

Spiral wound membrane elements are made by sandwiching a flat sheet membrane between two spacer layers and rolling them into a spiral configuration, which is then sealed at the edges. The spiral wound configuration creates a series of channels or paths for the liquid to pass through, allowing for efficient filtration. Spiral-wound elements are the most used configuration in dairy manufacturing.

Plate and frame modules are filtration systems that use flat, thin membrane sheets between rigid plates to create a series of chambers for fluid flow. The fluid is forced through the membranes, and the separated components are collected in the chambers. The membranes are typically made from polymeric materials and are generally used in laboratory or pilot-scale applications.

Hollow fibre modules are made of small, hollow fibres typically bundled together and sealed at both ends. They have pores that allow for the separation of substances based on their size and molecular weight. However, they are not commonly used due to price, propensity for fibre breakage and higher capital expense.

Polymers and ceramics each offer advantages and limitations, and ongoing research and development in materials science and engineering are expected to drive further innovations in membrane technology.

Types of Membranes

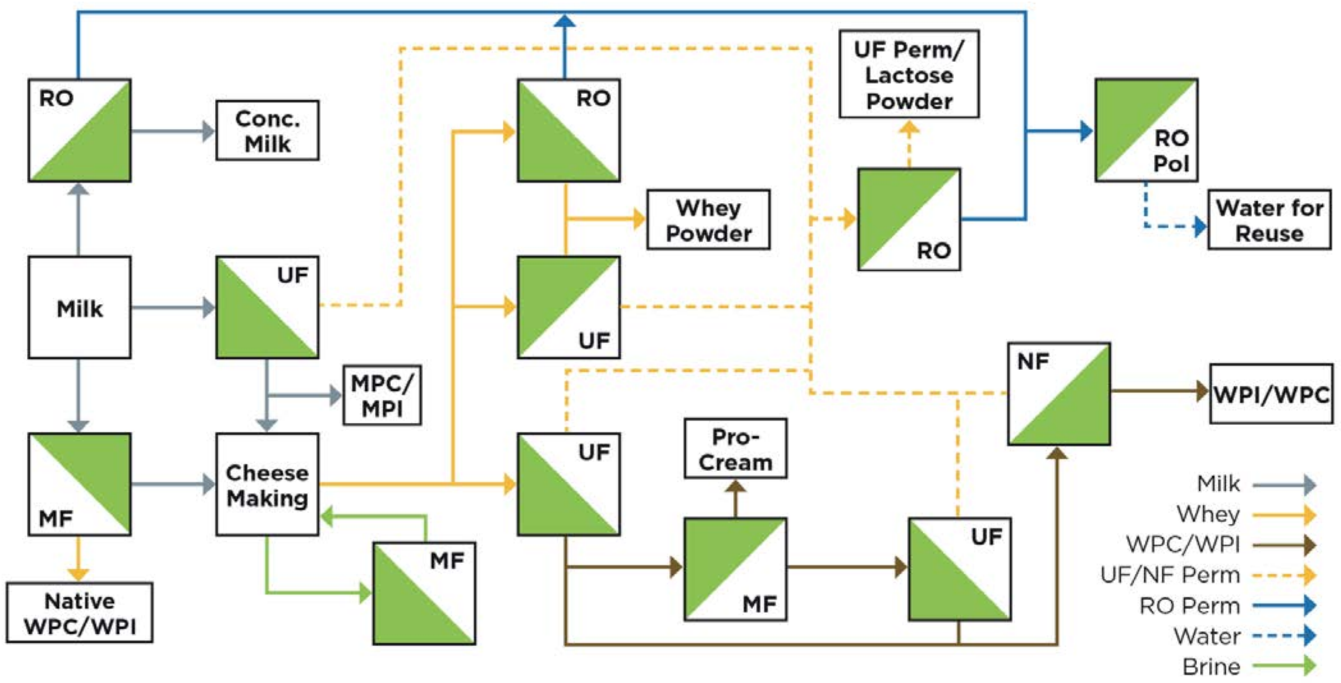
Membrane separation technology is important to the filtration process in dairy plants, allowing for the separation of different components. Each of these technologies differs in the pore sizes and selectivity, for different applications.

- Microfiltration (MF) separates particles in the range of 0.1-10 µm (also expressed in units of molecular weight, 800,000 to 3,000,000 Daltons), including bacteria, fat globules and casein micelles. It is commonly used to reduce bacteria and separate proteins, particularly casein.
- Ultrafiltration (UF) separates molecules in the range of 0.001-0.1 µm (1,000 to 250,000 Daltons), including proteins and milk fat globules. UF is often used to concentrate and purify milk and whey proteins and reduce lactose.
- Nanofiltration (NF) separates molecules between 0.001-0.0001 µm (200 to 1,000 Daltons). NF is used for the selective separation of components from milk, such as monovalent ions and smaller peptides.
- Reverse Osmosis (RO) separates water molecules from other components, such as salts and minerals. The pores in RO membranes are only several angstroms wide, which allows water molecules to pass through while retaining larger molecules.

Applications

Membrane separation technology is used throughout the dairy production process for clarification, purification, and concentration of dairy products to separate components based on size or charge. Membranes have a wide range of applications, with some of the most common found in milk and whey processing, as well as cheese production.

Milk processing. In milk processing, membrane separation enables the conversion of milk into various liquid and dry products. UF concentrates milk proteins, while RO concentrates milk >



solids, resulting in reduced transportation costs for liquid milk. Additionally, RO can be combined with evaporation and drying to produce various milk powder products that can be stored without spoiling. UF is also used to produce higher-value milk powders such as milk protein concentrate (MPC) and milk protein isolate (MPI), with higher protein concentrations on a dry-weight basis.

Cheese production. In cheese production, UF standardises milk protein concentrations, allowing increased throughput and/or consistent cheese making by eliminating the effect of seasonal variability in milk components. Some cheeses and certain parts of the world preferentially use MF to increase the casein to whey ratio improving cheese quality, throughput, and yield. MF also clarifies cheese brine.

Whey processing. In this, membrane separation is widely employed to manufacture numerous products aimed at increasing a plant's profitability. UF concentrates whey proteins resulting in the production of whey protein concentrates (WPC). Further purification of WPC can be achieved using MF to remove fat to manufacture whey protein isolate (WPI), a higher-value product.

Reverse osmosis is used to concentrate whey solids prior to transportation or whey powder production. Nanofiltration is employed for whey demineralisation, which reduces the mineral/ash content in whey powder, thus improving product value and functionality.

Optimising Operations

Maintaining standards while optimising yield and production uptime is an important aspect of dairy manufacturing. Key process indicators (KPIs) are quantitative metrics that enable dairy processors to assess the effectiveness, efficiency and reliability of membrane separation processes. By identifying and tracking KPIs, processors can determine if they are achieving their performance targets at each step of the production process.

Key process indicators are important to define and monitor throughout the life of a membrane system – from element installation and changeout, to process parameters and clean-in-place (CIP) protocols. Measuring and monitoring yields, quality, flow rates, throughput, and operating pressure profiles over time are critical for preserving the health of the membrane system and ensuring optimal performance. By closely monitoring these parameters, any deviations or issues can be quickly identified and addressed, ensuring that the system operates within its designed capacity and produces the desired results.

Proper cleaning protocols are essential for element efficiency and lifespan. Ensuring that the right cleaning chemicals are used at the right concentration, temperature, pH, and for an appropriate period of time, helps to maximise the time between element changeouts. Regular monitoring ensures timely maintenance or replacement of elements, preventing irreversible damage and minimising downtime for cleaning or repairs.

New trends

As the membrane separation technology market evolves, emerging trends are poised to reshape the landscape of dairy processing by introducing new products and technologies designed to address specific challenges and optimise operational processes. Advancements in materials and membrane designs are paving the way for more productive and sustainable membrane separation processes.

Membrane technology is becoming increasingly popular in producing and maintaining the texture and taste of low-fat and fat-free dairy products. Membranes can selectively remove or reduce specific components, such as fat, from dairy products while retaining desirable characteristics.

Processes can be customised to selectively retain or remove specific compounds based on their size, charge, and other properties, providing flexibility in flavour modulation, preserving flavour compounds' delicate nature and minimising flavour loss or degradation during processing. Dii

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