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Trends in Membrane Technology Applications for Dairy Processing

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SUMMARY

Membranes have gained an important place in dairy and food industry are used in a broad range of applications. The key feature that is exploited is the ability of a membrane to control the permeation rate of a chemical species by membranes. Over the last two decades, the worldwide market for membrane technology in the food industry increased to a market volume of about D 800–850 million and is now the second biggest industrial market for membranes after water and wastewater treatment including desalination. The key membrane technologies in the food industry are the pressure-driven membrane processes microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) the key advantages of membrane processes over conventional separation technologies are gentle product treatment due to moderate temperature changes during processing; high selectivity based on unique separation mechanisms, for example sieving, solution-diffusion or ion-exchange mechanism; low energy consumption compared to condensers and evaporators. Concentration of milk, which conventionally is done by evaporation techniques, can also be achieved by RO, MF and/or UF are used in the production of milk protein concentrates (MPC). The module is comprised of multiple U-shaped bundles of polysulfone fibers. The module design allows the use of a high efficiency air scour in the feed side and permeate backwash that increases system recovery. The use of polysulfone allows the use of commodity cleaning chemicals including acids, bases, and oxidants. The UF 120 Polymem module has integrated significantly all the improvements of membrane and module manufacturing for reducing the module cost.

INTRODUCTION

Membranes have gained an important place in dairy and food industries. They are used in various applications. The key feature exploited of a membrane is the ability to control the permeation rate of a chemical species by membranes. Membrane technology application has sustainable increase in the food industry sector up to second largest market turnover after wastewater treatment. Their spectrum ranges from the millimetre (for coarse filters) to the Angstrom (Å) scale (for reverse osmosis and gas-separation membranes) (Lewis, 1996a; Cheryan, 1998; Pellegrino, 2000). The key membrane technologies in the food industry are the pressure driven membrane processes i.e. microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). The key advantages of membrane processes over conventional separation are gentle product treatment due to moderate temperature changes during processing, high selectivity, ion-exchange mechanism and comparably low energy consumption.

Membrane technology

Membrane technology is a pressure driven filtration process which discriminate the molecules primarily on the basis of size and to a lesser extent on shape and chemical composition. Membrane separations that are commonly used in the dairy industry are pressure driven processes, where hydraulic pressure is used as a means of overcoming and reversing the osmotic pressure and flow, caused by the difference in solute concentrations between two liquid phases (retentate and permeate), and also the frictional forces generated between the liquid phase and membrane pore walls. The difference between applied hydraulic pressure and osmotic pressure is called the trans-membrane pressure. The major pressure-driven membrane separation processes are microfiltration (MF), ultrafiltration (UF) and reverse osmosis (RO).

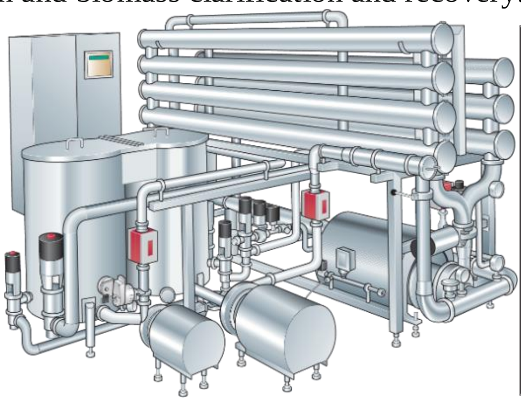
Types of membrane technology

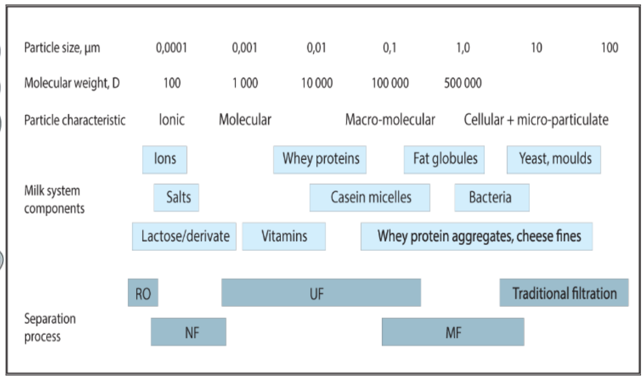
Reverse osmosis: This membrane technology is used to remove water from a product to increase the solids content. Evaporator condensate is often polished by reverse osmosis, so that it can be used elsewhere in the dairy. Reverse osmosis is a high-efficient technique for dewatering process streams, concentrating or separating low molecular weight substances in solution and cleaning wastewater. It has the ability to concentrate all dissolved and suspended solids. The permeate contains a very low concentration of dissolved solids. Reverse osmosis is typically used for the desalination of seawater.

Nanofiltration: This technology is used to remove mainly the monovalent ions from whey, so that partly demineralization and water removal is obtained. When Reverse osmosis and ultrafiltration are not the correct choice for separation then nanofiltration is selected. Nanofiltration can perform separation applications such as demineralization, color removal and desalination. In concentration of organic solutes, suspended solids and polyvalent ions, the permeate contains monovalent ions and low molecular weight organic solutions like alcohol.

Ultrafiltration: It is a selective fractionation process using pressures up to 145 psi (10 bars). Ultrafiltration is widely used in the fractionation of milk, whey and in protein fractionation. The whey proteins are separated to form a product with 35, 60 or 80% Whey Protein Concentrate. If ultra-filtration is applied to skim milk, then Milk Protein Concentrate is obtained. It concentrates suspended solids and solutes of molecular weight greater than 1,000. The permeate has low-molecular-weight organic solutes and salts. The protein fractions are typically evaporated in multi-effect evaporators with either TVR or MVR recompression to save steam, before spray drying. Generally in UF and MF, solvent and solute mass transfer are controlled by convective transport (Pontalier et al., 1997; Pellegrino, 2000).

Microfiltration: Microfiltration is a low-pressure cross-flow membrane process for separating colloidal and suspended particles in the range of 0.05-10 microns and as such used for bacteria removal, fermentation broth clarification and biomass clarification and recovery.





Applications of membrane technology in dairy and food processing

Reverse Osmosis

Fluid milk, buttermilk and whey can be partially concentrated economically using RO, particularly for the preparation of concentrated and dried products including indigenous dairy products like whey protein concentrate, whey protein isolate khoa, chakka, shrikhand, rabri, basundi and kheer.

Ultrafiltration

From milk, UF produces a permeate containing water, lactose, soluble minerals, non-protein nitrogen and water-soluble vitamins. The process has been used for the manufacture of several fermented dairy products like Yoghurt and Srikhand. UF retentate seems to be a highly promising base for chhana, rasogolla mix powder, long-life paneer. UF technology has also been applied to upgrade khoa manufacture from cow and buffalo milks. Fractionation of milk proteins for making cheeses, caseins and whey proteins and for milk protein standardization Separation and fractionation of milk fat globules.

Microfiltration

MF has been investigated as a competing technology to centrifugation for clarification and bacteria removal of milk and whey. Possible uses of MF include delipidizition of whey, shelf life extension of liquid milk, production of cheese with minimal risk of blowing and without nitrate addition, and several biotechnological applications. Membrane separations for removal of microorganisms.The combination of MF and pasteurization reduces bacterial numbers by 99.99% (4D) (Grandison and Finnigan, 1996).

Nanofiltration

In the dairy industry, nanofiltration is mainly used for special applications such as partial demineralization of whey, lactose-free milk or volume reduction of whey.

New trends

The integration of membranes has been implemented throughout the milk and dairy processing chains- milk reception, cheese making, whey protein concentration, fractionation of protein hydrolysates, waste stream purification and effluents recycling and treatment- all are membranes. A new emerging generation of membranes are the composite or thin-film composite membranes that have much better characteristics than cellulose acetate and polysulfone membranes (Cheryan, 1998).

Ultrafiltration technology is also widely used in dairy treatments, combined with other membrane techniques, such as for lactose recovery as a pretreatment step of an NF procedure, as a pretreatment step of a diafiltration stage for WPC and WPI production from purified skim whey and for the fractionation of whey protein to obtain β-Lactoglobulin and α-Lactalbumin.

Nanofiltration has been successfully implemented combined with other suitable membrane-driven techniques. The improvement in the design and fabrication of composite membranes is the main focus to satisfy the need of new applications. For that, several membrane properties are tuned: thermo-mechanical stability and physicochemical and morphology properties (e.g., zeta potential, hydrophilicity, charge density and porosity).

CONCLUSION

Membrane separation processes have become an emerging technology for the various treatments in dairy and food operations. The material properties of the membrane dominate the performance of the separation process. A significant advancement has been observed in membrane technology in terms of materials, techniques, modification and modules in last few decades. It has resulted in many new applications of membrane technology in dairy and food processing.

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