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Popular Article

Membrane Technology: A Boon to the Dairy Industry

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Abstract

The dairy industry has been revolutionized with the advent of membrane technology. The key applications of membrane technology in milk processing includes standardization, concentration, fractionation and purification of milk components, tailoring new products and also extending the shelf life of products. It causes low environmental pollution, low energy consumption, less use of additives and avoids thermal damage to the products. The major limitation of membrane technology involves membrane fouling/blocking, however, introduction of superior membranes for the processing has helped in overcoming the challenge to a greater extent.

Keywords: Concentration, Dairy, Fractionation, Fouling, Standardization

Membrane technology is used to collectively represent the separation processes by employing specific semi-permeable membrane filters to concentrate or fractionate a liquid into two liquids of different compositions by selectively allowing some compounds to pass while encumbering the others. The liquid that is able to pass the membrane is known as “permeate” and the retained liquid is known as “retentate” or “concentrate”. The major pressure-driven membrane technology includes microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). The evolution of membrane technology offers novel non-thermal environment friendly greener technological option with full future possibilities benefiting milk and dairy product processing, consisting of unit operations such as water removal, liquid–liquid or solid–liquid separation.

Milk being a multi-component poly-dispersed system is very prone to adverse processing effects which makes it an ideal candidate for membrane filtration. One major reason for membrane

technology to be suitable for milk for fractionating and other functions, is the broad particle size distribution range of milk, somatic cells with size range 15–6 µm, fat from 15 to 0.2 µm, bacteria (6–0.2 µm) and casein micelles (0.3–0.03 µm) providing a logical alternative for the fractionation of milk into various milk components on the basis of their size, thus, giving rise to various tailored products. It also minimizes the adverse effect of temperature rise such as change in phase, denaturation of proteins and change in sensory attributes of the product along with removal of unwanted components viz. microorganisms, drugs or sediments that have a negative impact on product quality, making the final product more attractive in texture and increasing its shelf life.

The membranes are suitable to different types of plant design and expansion due to their compact design and need very low maintenance. The operations of the membranes are very simple, competitive and do not require any specialized knowledge to operate them. Sometimes, it is necessary to use a combination of membranes in spite of one membrane to get the desired effect and redesigning overall industrial production by the integration of various already developed membrane operations.

Characteristics of Membranes

Microfiltration (MF) is a membrane separation process with a larger membrane pore size allowing particles in the range of 0.2 to 2 micrometers to pass through. The pressure used is lower than that of ultra filtration process. MF membranes are especially well suited for the separation of fine particles in the size range of 0.1 to 10.0 µm.

Ultrafiltration (UF) is a membrane separation process with 1 to 100 nm pore size. Suspended solids and solutes of high molecular weight (macromolecules, proteins etc.) are retained, while water and low molecular weight solutes pass through the membrane.

Diafiltration (DF) is a specialized type of ultrafiltration process in which the retentate is diluted with water and re-ultrafiltered, to reduce the concentration of soluble permeate components and to further increase the concentration of retained components.

Nanofiltration (NF) membranes have a slightly more open structure allowing monovalent ions to pass through the membrane and rejecting the divalent ions to a great extent.

Reverse Osmosis (RO) is a high pressure-driven membrane filtration process which is based on a very dense membrane. The membrane pore size is very small allowing only small amounts of very low molecular weight solutes to pass through the membranes.

Application of Membrane Technology in Milk Industry

1) **Extending shelf-life of milk and milk products:** It is a non-thermal method of removing bacteria and spores from milk, whey and cheese brine and extending shelf life without

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damaging sensory attributes. Microfiltration (MF) is an appropriate pretreatment process for the removal of bacteria. The significant reduction of mesophilic, salmonellae and listeria count have been reported upon using micro-filtration with 1.4 μm pore size.

2) **Processing of whey:** Whey is a dairy by-product which is obtained during the preparation of milk products viz. cheese, paneer and casein. Whey is drained in most of the cases in developing countries causing huge loss of valuable nutrients and also creates environmental hazards. The traditional method of separation or concentration of whey nutrients is cumbersome and time consuming. Membrane technology being a greener option allows the concentration, fractionalization or purification of nutrients in the whey such as whey protein concentrate/isolates, α-lactalbumin, β-lactoglobulin, lactose and salts. Application of reverse osmosis (RO) for whey concentration saves upto 60% of fuel over the traditional evaporation methods. Ultra-filtration (UF) and dia-filtration (DF) increases the protein content of the whey protein concentrate from 35 to 85% (total solids) whereas by removing bacteria and fat by passing whey through MF, the protein content of whey protein isolates can be increased to 90% (total solids).
3) **Milk protein processing:** Application of ultra filtration (UF), adjusts the level of protein content in milk without adding any extraneous protein source by removing the water. This causes the maintenance of the composition, nutritive value, physico-chemical properties and sensory attributes of the milk irrespective to the variation caused by the genetic as well as environmental factors. Adding of 1% ultra filtered protein enriched milk in skim milk has improved the viscosity and sensory attributes similar to full cream milk. The milk protein concentrate (MPC) containing 50 to 58% proteins of good functionality are prepared by application of micro-filtration (MF), ultra-filtration (UF) and diafiltration (DF) technologies either alone or in combinations.
4) **Fractionalization of milk proteins:** A lot of work has been performed to recover valuable proteinacious components from dairy waste streams. Dairy proteins are valuable products and used as high-value food additives, neutraceuticals and therapeutics. The milk protein can be recovered by using micro-filtration (MF), ultrafiltration (UF) and nano-filtration (NF) processes. At suitable ionic strength, it is possible to concentrate and fractionate casein as β-casein at 5°C, skim milk at 4°C and pH 4.2 to 4.6 using MF and UF separating β-casein in permeates and α and κ-casein in retentate.

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5) **Fractionalization of whey proteins:** Whey proteins are obtained by concentration and purification from whey. The β-lactoglobulin is separated by the membrane process followed by heat treatment. The β-lactoglobulin can be fractionized from defatted whey proteins by using MF and centrifugation followed by purification by UF with electrodialysis (ED) or DF. β-lactoglobulin is purified by diafiltration of supernatant, while immunoglobulins are separated from whey protein concentrates by using membrane technology. The α-lactalbumin is separated and purified by applying UF on solubilised MF retentate at neutral pH. With the introduction of inorganic membranes with polyvinylimidazole derivates, the pure α-lactalbumin can be obtained in filtrate but the fouling proves major constraint. The whey proteins can be separated from whey protein isolate (WPI) by applying UF/DF with more than 99% purity. Lactoferrin and lactoperoxidase are recovered from defatted whey protein concentrate (WPC) on industrial scale by using ion-exchange chromatography.
6) **Milk fat processing:** Traditionally, cream is separated from whole milk by energy intensive centrifugation. However, the cream separation is also possible by membrane technology producing skim milk with good storage quality and improved sensory attributes of cream without causing any damage to fat globular membranes. The size of fat globules have profound impact on textural and sensory attributes as the cream with smaller fat globules have fine texture and improved flavour than cream with large fat globules.
7) **Cheese making:** The ultra-filtration (UF) and micro-filtration (MF) are most commonly used in the cheese industry. UF is known as the complementary process of cheese making which produces good quality fresh and brine cheese with higher yield. The MF casein concentrated milk is very suitable for various cheese preparations due to its superior microbial quality achieved after removing bacteria and spores from milk, as well as optimization of the different major milk components. The MF pre-treatment of cheese milk improves the firmness of curd, accelerate ripening, reduces the number of additives e.g. $CaCl_2$ and facilitates heating at higher temperature. The MF has future possibilities in standardization of protein in cheese milk and fortification with casein micelle powder.
8) **Desalting or demineralization of whey:** The value of whey is significantly increased after demineralization; also, alleviating environmental hazards. The NF membranes with molecular weight cutoff (MWCO) ranging between 200 to 1,000 daltons are best suited for demineralization of whey as these membranes are permeable to salt and monovalent ions but impermeable to organic compounds. The carboxyl group of organic compounds are bound to

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these membranes under prevailing acidic conditions. This technology simultaneously demineralises whey at the time of concentrating, helping in savings in term of cost, time and water disposal. The NF is economical and a method of choice for partial desalting of whey. NF membranes are highly permeable to water and monovalent ions. The mineral contents of the whey are reduced by 35% and ash content by 3 to 4 times in addition to increase concentration of whey by applying nanofiltration (NF), making it suitable for the people having cardiovascular diseases.

9) **Introducing novel dairy products:** Several novel products are introduced in market as lactose free milk for lactose intolerant people, low calcium milk, nonfat yoghurt, high protein low lactose ice cream, protein fortified low fat milk, whey based beverages, etc with the advent of membrane technology.

Hence, membrane technology has proven to be a "waste to wealth technology" by offering the possibility of recovering valuable products from different by-products, effluents and wastewater, thus, bringing more benefits to the producers along with the environment protection. The advancement of membrane technology has unlocked new prospects in milk processing sector by enhancing the quality of milk and milk products; besides, it fosters new product development, and improves process efficiency and profitability. However, there is a need of further augmenting and diversifying the scope of membrane technology by continuing the efforts for the development of superior membranes so as to extend the role of this wonderful technology in food processing sector in general and dairy processing sector in particular.

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