Application of Membrane Technology in Food Processing Industries: A review

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ABSTRACT

The use of membrane technology as a handling and separation method in food industry is gaining wide application. Membrane separations can be used either as substitutes to conventional techniques especially in dairy, sugar, fruits juice processing, and beverage industries. Membrane separations are considered green technologies. In many cases, membrane processes are more advantageous than traditional technologies. For example, using cold pasteurization and sterilization with suitable membranes instead of high temperature treatment for the removal of microorganisms is more economical in terms of energy consumption, quality of products, minimize loss of nutritional value. Using membrane filtration to remove microorganisms for shelf-life extension of foods instead of using additives and preservatives also create a green image for the processed foods as well as for the processing procedure. Concentration by membrane filtration instead of thermal evaporation does not employ severe heating and that it preserves the natural taste of food products and the nutritional value of heat-sensitive components. The recovery of valuable components in diluted effluents and waste water treatment applications are among the most useful and currently active aspects of membrane technology. In sugar processing factories membrane clarification and concentration reduce the energy losses in evaporation and chemical usage in purification section by conventional methods. Pressure-driven membrane processes, namely MF, UF, NF and RO facilitate separation of components with a large range of particle sizes. It is for this reason that they find wide range of applications in food processing industry.

Keywords: ***Electro dialysis, Membrane Separation, Membrane filtrations, Milk, Reverse osmosis, Raw***

I INTRODUCTION

French cleric, J. Abbe Nollet in 1748 discovered the phenomenon of osmosis. The research and development on membrane science and technology in China started from ion exchange membranes in 1958 [1]Exploring research on reverse osmosis (RO) was set about in 1965. A national joint research project on sea water desalination began in 1967. This played an important role in training research team and laid a good foundation for the progress of membrane science and technology. A magnificent period for membrane research and development started at the beginning of the seventies. The membranes and related modules for electro dialysis (ED), RO, ultra filtration (UF) and microfiltration (MF) had mostly been developed in this period.

Vapour permeation, membrane distillation, membrane extraction, membrane reactor, membrane phase separation, membrane electrode, affinity membrane, control release, etc are the new processes available. Most of them now are still in their research and development stages. In recent years many studies have been performed in the field of membrane reactors (MRs) since one or more reaction products can be separated from reaction system, so the reaction rate and conversion rate can be raised significantly. MR is mainly tested in industrial chemistry and biochemistry, such as improvement and production of penicillin, fermentation and hydrogenation or dehydrogenation, etc. MR has its promising future.

II MEMBRANE SEPARATION: CLASSIFICATION

Membrane separation processes are classified in to two: physical processes and chemical processes. Chemical processes are: hemodialysis, liquid membranes, active transport, supported membranes and facilitated transport. The physical membrane separation processes are: pressure driven process (microfiltration MF, ultra filtration UF, Nano filtration NF, reverse osmosis RO, gas separation), diffusional process (pervaporation, perstraction, dialysis, membrane extraction, membrane absorption), heat process(membrane distillation, vacuum membrane distillation) and electric processes (electro dialysis, electrostatic pseudo liquid membrane).The key membrane technologies in the food industry are the pressure-driven membrane processes such as microfiltration (MF), ultra filtration (UF), Nano filtration (NF), and reverse osmosis (RO).Four membrane processes in their ascending pore diameter are Reverse osmosis (RO), Nano filtration (NF), Ultra filtration (UF) and Microfiltration (MF) is mainly used in food processing. UF systems as well as UF membranes have the maximum share (35%) in global membranes market followed by the share of MF systems and membranes (33%) and NF/RO systems and membranes (30%). Membrane contactors (MC), Electro dialysis (ED) and Pervaporation (PV) are the other membrane processes but contribute only for 2% share in total membranes market [2].

III MEMBRANE GENERATIONS

Membrane materials can be classified in four generations [3]. First generation: Cellulose acetate derived membranes, which were developed to desalinate seawater. They were susceptible to microorganisms and disinfectants as well as sensitive to pH (3-8) and (maximum 50^0C) temperature.[4] Second generation: Developed from synthetic polymers like Polysulfone or polyolefin derivatives), these are better than first generation as having better resistant towards hydrolysis, pH and temperatures, but have lower resistance to mechanical compacting [5]. Third generation: Mineral membranes consisting ceramic material based on zirconium or alumina oxide are usually deposited on a graphite surface. These membranes have great mechanical strength, are chemically inert and can be operated on high pressures, wide pH range (0-14) and temperatures greater than 400^0C. The main demerit of these membranes is their cost (expensive than other membrane materials), but the same is compensated by their long operational life [6]. Fourth generation: Hybrid process i.e. combination of conventional Electro dialysis and different pore sizes membranes (E.D.+MF/UF/NF) [1].

IV APPLICATION OF MEMBRANE TECHNOLOGY IN FOOD INDUSTRY

The application of membrane technology in food industry is growing gradually in both international and domestic market since 1960s. Advanced characteristics such as high separation precision, better selectivity, operation at room temperature, no high temperature or chemical damage, high automation, easy operation, economic energy, reduced cost, comprehensive utilization of resource and reduced pollution are the main advantages of the membrane technology in this field of application.

MF, UF, RO and NF are today frequently used in the food industry. The main applications include: removal of microorganism from food, purification or concentration of water, fruit juice, vegetable juice, whey, vinegar, soy, wine and beer; concentration or separation-purification of proteins, polypeptides, fats, sugars, mucus, starch, scour and lysozyme; purification of oil, discoloration of oil and wastewater treatment.

V REMOVAL OF BACTERIA AND SPORES FROM MILK

The removal of bacteria and spores from milk to extend its shelf-life by MF is an alternative way to ultra-pasteurization. In this approach, the organoleptic and chemical properties of the milk are unaltered. The first commercial system of this so- called Bactocatch was developed by Alfa Laval [7] and marketed by Tetra Pak under the name Tetra Al cross_ Bactocatch. In this process, the raw milk is separated into skim milk and cream. The resulting skim milk is micro filtered using ceramic membranes with a pore size of 1.4 µm at constant Trans membrane pressure (TMP). Thus, the retentate contains nearly all the bacteria and spores, while the bacterial concentration in permeate is less than 0.5 % of the original value in milk. The retentate is then mixed with a standardized quantity of cream. Subsequently, this mix is subjected to a conventional high heat treatment at 130 °C for 4 s and reintroduced into the permeate, and the mixture is then pasteurized. Since less than 10 % of the milk is heat treated at the high temperature, the sensory quality of the milk is significantly improved. MF for the removal of bacteria and spores can be further applied in the production of other dairy products. In the production of cheese, the use of low bacterial milk improves also the keeping quality of cheese due to the removal of spores, thus eliminating the need of additives (e.g., nitrate). While in the production of whey protein concentrates (WPC) and isolates (WPI), this MF concept is used to remove bacteria and spores giving a high quality product. It is shown in figure 1.

Milk Protein Standardization, Concentration and Fractionation

The protein content of milk is subjected to natural variations during the year. Standardization of milk by UF offers the possibility of increasing or decreasing the protein content in milk without the need of adding milk powders, casein and whey protein concentrates. Skim milk and 1%milk with increased protein content have an improved appearance (whiter milk) and higher viscosity. The sensory quality of increased protein milk is therefore more similar to that of higher fat milks resulting in an improved consumer appeal. Another application of UF is the standardization of protein and total solids in milk for use in fermented dairy products, such as cream cheeses, yoghurt and cottage cheeses. The resulting dairy products have superior quality and sensory characteristics compared to those produced from milk concentrated by conventional methods. Concentration of milk, which conventionally is done by evaporation techniques, can also be achieved by RO. The concentrated milk has its greatest potential in ice-cream manufacturing, since all the solids are retained in the concentrate and 70% of the water is removed. MF and/or UF are used in the production of milk protein concentrates (MPC), which are products containing 50–58 % of protein. These products are used as food additives and it is therefore extremely important to maintain the functionality of the proteins. By using UF membranes in combination with MF and/or dia filtration (DF) with the corrected adjustments of pH, temperature and filtration conditions, it is possible to produce the desirable MPC for a specific food application. The most promising MF application in the dairy industry is the fractionation of milk protein. The Separation of micellar casein from the whey proteins can be achieved by ceramic membranes with a pore size of 0.2µm at a constant TMP. The resulting retentate has a high concentration of native calcium phosphor caseinate that can be used for cheese making. Native casein has an excellent rennet-coagulation ability that will make calcium phosphor caseinate an exceptional enrichment for cheese-milk. The permeate can be further processed by UF to produce high-quality WPC. These protein concentrates can be further separated into lactoferrin, β-lactoglobulin and α-lactalbumin via ion-exchange chromatography. Both β-lactoglobulin and α-lactalbumin have great potential markets. β-lactoglobulin can be used as a gelling agent and α-lactalbumin, which is very rich in tryptophan, can be used in the production of peptideswithphysiologicalproperties.Anotherapplicationcanbetheproductionof infant milk. The fractionation of milk proteins using membrane technology enables the recovery of value-added protein ingredients. Further, the casein and whey proteins are separated without the need of heat or enzymes. The potential applications of membrane separation in milk processing are shown in Figure 2.

Application of Membrane in Vegetable Oil Processing

Traditional oil refining methods have several demerits like nutrient loss, needs higher amount of energy, water and chemicals; greater losses of neutral oil as well as the generation of more effluent. Vegetable oil refining employing membranes has been not only reported as an easier/simpler process but also the same offers different advantages like better nutrient retention, reduced demand of energy and added chemicals, milder process parameters and cleaner production . Several researchers have been used membrane processes for the recovery of solvents from the micelle, degumming, bleaching, deacidification as well as hydrolysis of fats and oils [3].

Application of Membrane Technology in Gluten Production

MF, UF and RO technology can all be applied in gluten production. The clarification technique after decomposition can be realized by MF to replace diatomite. The permeate can be concentrated by UF, while RO system is used in reclaim of waste and water recycle. Beijing Food Institute concentrates Xanthan Gum by UF removing most part of proteic components and pigments [8].

Table 1: Applications of MF, UF, NF, and RO dairy and oil industries

Application	Membrane processes
Concentration of whole and skim milk	RO
Partly de mineralized WPC (baby food, special WPC products)	NF/UF
Production of whey protein concentrates and isolates	UF
Concentration of chicken blood plasma	MF/UF
Filtration of extra-virgin olive oil	MF/UF
Dry degumming of vegetable oil	UF/NF

Application of Membrane in Fruit Juices Processing

The general production flow in the fruit juice industry starts with grinding or crushing of the fruits into an optimal and uniform size of particles and then pressing out the fruit mash. The traditional fining process consists of long retention time in tanks followed by kieselguhr filtration and requires large amounts of enzymes, gelatin and other chemicals. After clarification/fining, the fruit juice is concentrated to reduce costs for transportation and storage. The common approach to concentrate fruit juice is by using an evaporator combined with an aroma-recovery unit concentrating the apple juice from originally 11–12 ^{0}Brix to over 70 ^{0}Brix. The concentrated fruit juice can then be optionally pasteurized before transportation. The general fruit juice production process including membrane processes is shown below in figure 3.

Clarification of Press Water Using UF/NF

Another encouraging route to improve the quality of diffusion juice is to apply membrane filtration for clarification of press water. Press water is a very dilute stream containing about 3-4% of total sugar entering the factory. It is recycled back to a diffusion stage after pulp presses. Membrane filtration can be applied for both press water sterilization and suspended solids removal.

New Applications of Membrane Processes

The development of new applications of the established membrane processes MF, UF, NF and RO will be driven by economic and environmental targets. An additional driver for membrane processes is the high growth rate of the market for functional foods, a segment in which membranes has a high potential. In Table 2 some of the most recent research trends on membrane applications for MF, UF, NF and RO in the food industry are summarized.

Table 2: New applications of MF, UF, NF and RO in the food industry [4, 21, 28-29].

Application		Membrane process
Dairy	Concentration of whole and skim milk	RO
	Partly demineralized WPC (baby food, special WPC products)	NF
	Production of whey protein concentrates and isolates	UF
	Defatting of whey for high protein WPC	MF
	Standardization of the protein content in cheese milk	MF
Sugar industries	Concentration of thin juice	RO
	Purification of raw juice	UF
Fruit juices	Clarification of pulpy tropical fruit juices	MF
	Concentration of tomato juice	MF and RO
Other applications	Concentration of chicken blood plasma	MF/UF
	Dry degumming of vegetable oil	UF/NF

VI CONCLUSION

Application of membrane technology in food processing industries are green technology to prevent pollution, minimizing the usage of chemicals and reduction of waste generation load, which is both better for environment and human health. Membrane separation processes can be used as alternatives to conventional processing methods, in a way that the former assists more economical, save energy consumption, better quality products, minimize the losses of nutrition value during processing**.** Membrane separation processes increases the shelf life of processed food products by better reduction of microorganisms. In dairy, sugar, fruits juice processing, and beverage industries membrane separation and concentration is better methods and promising technology system for future.

Figure 1 Bacteria removal from milk by MF

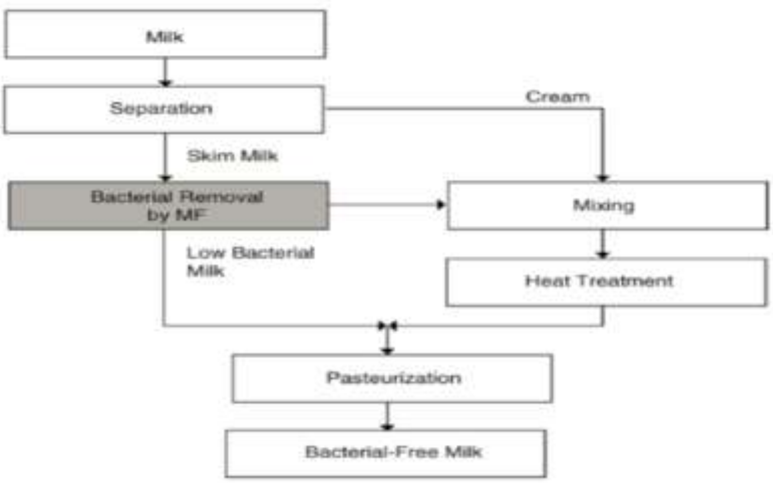


Figure 3 Membrane processes in fruit juice production

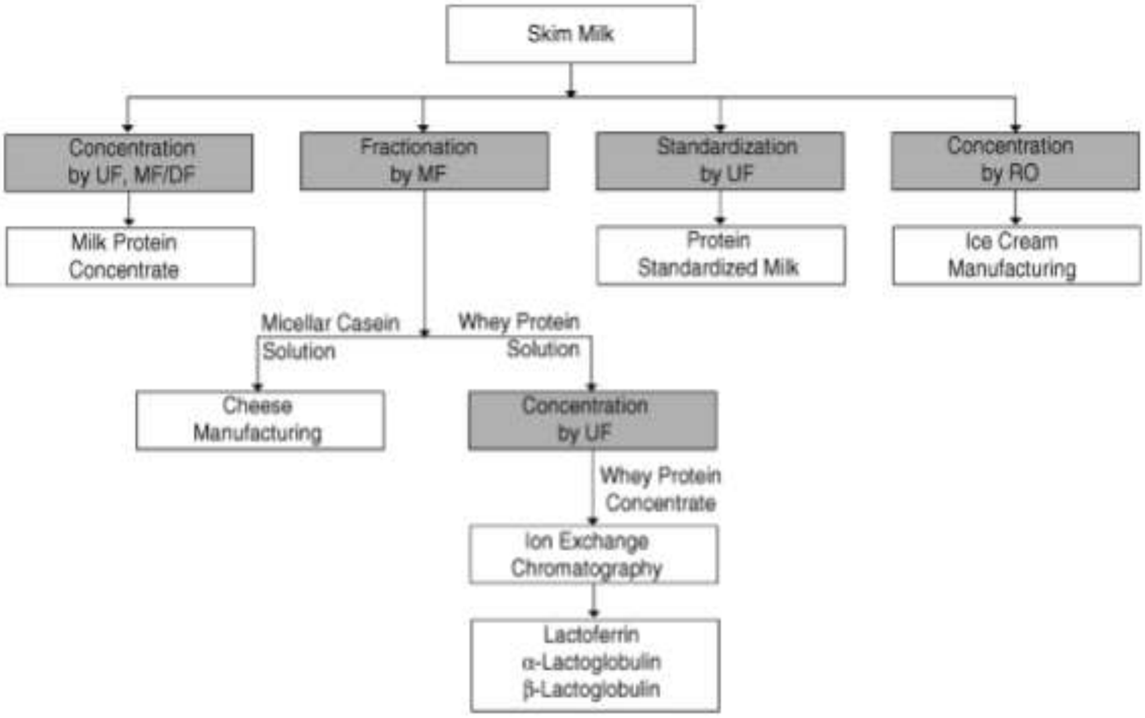


Figure 4 Schematic of press water treatment with RO/NF

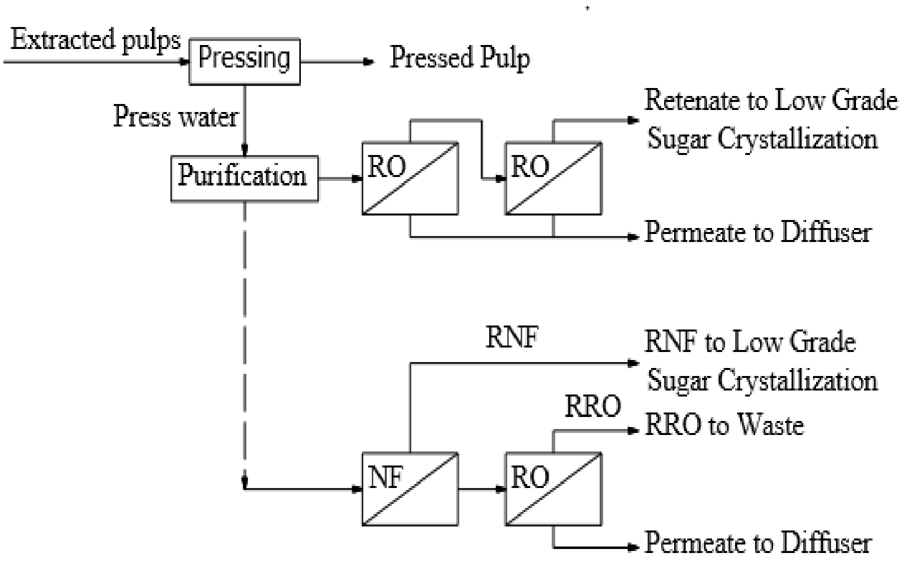
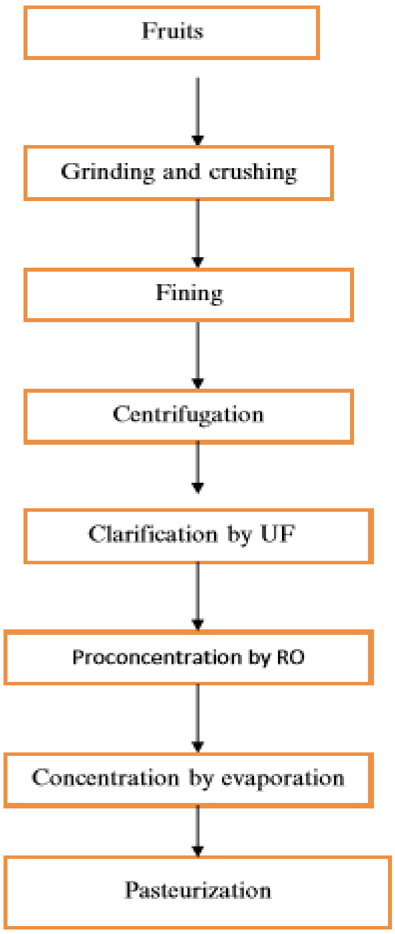


Figure 2 Applications of membrane technology in milk processing



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