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ULTRAFILTRATION IN FOOD INDUSTRY

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ABSTRACT

Ultrafiltration (UF) is a pressure-driven operation in which porous membranes are used for fractionation of solutes, most often in aqueous solutions. It has several advantages, such as unique separation properties, concurrent fractionation and concentration, product quality improvement, low energy consumption, and sometimes, increased yield. Today, UF is an established technology in some areas of the food industry for purification and concentration of different types of liquid foods. The annual growth is considerable, and the number of applications are also likely to increase as new needs arise and equipment is developed. Ultrafiltration process has been applied widely in food processing industry for the last 20 years due to its advantages over conventional separation processes such as gentle product treatment, high selectivity, and lower energy consumption. Ultrafiltration becomes an essential part in food technology as a tool for separation and concentration. However, membrane fouling compromises the benefits of ultrafiltration as fouling significantly reduces the performance and hence increases the cost of ultrafiltration. Recent advances in this area show the various intensive studies carried out to improve ultrafiltration, focusing on membrane fouling control and cleaning of fouled membranes.

Key words : *Ultrafiltration, dairy poducts, food processing, fruit juice, sugar.*

In UF, components of a fluid are predominantly fractionated according to size and shape differences, even if other factors, e.g., electrical charge or type of active groups (hydrophilic, hydrophobic) in the molecules of the components, could play a role as well (The European Society of Membrane Science and Technology, 1995). The membranes used in UF are characterized by pore diameters in the range 5–50 nm, thus UF is very suitable for concentrating high molecular weight compounds, e.g., proteins, while low molecular weight compounds such as sugar and salts pass through the membrane. In this way, large molecules are concentrated and purified in one step. The driving force is a pressure gradient across the membrane, and the pressure on the feed side must be higher than the osmotic pressure of the components to be retained. As the osmotic pressure of macromolecules is quite low, the applied pressure is generally in the range of 0.1–1 MPa in UF.

Terminology : The stream passing through the membrane is named permeate, the stream that is retained is named retentate. The capacity of a membrane is expressed as flux, the flow through the membrane per unit membrane area. Most often, volume fluxes are given ($L\ m^{-2}\ hr^{-1}$). The retention of a component is defined as the ability of a membrane to hinder the component from passing through it. Factors, such as temperature, pressure, fluid velocity, pH, concentration effect flux and retention. Fouling, the deposition of suspended or dissolved substances on the membrane surface, at pore openings, or within the porous networks in the membrane leads to a decrease in flux and sometimes changes in the separation properties. Many factors effect fouling and it is important to consider the properties of both feed and membrane, as well as the process conditions, in order to minimize fouling.

The term membrane configuration describes the spatial arrangement of the membrane. For food processing, particularly in the dairy industry, the use of spiral wound membrane modules has increased rapidly and is now standard configuration whenever possible because of the low cost compared to other configurations. Plants with thousands of square meters of membrane area have been installed. For liquids containing suspended material, a tubular configuration is preferred.

Development in the Dairy Industry : In the mid-1960s, UF membranes with reasonable flux became available and the first applications were mentioned. The dairy industry was the first one to develop and use the technology, seeing the potential for recovery and purification of proteins from whey and to incorporate whey proteins into dairy products, thus increasing the yield. A major breakthrough was the commercialization of polysulfone UF membranes in the mid-1970s. This membrane material has much better resistance to pH, heat, and chemicals than the cellulose acetate membranes used earlier, making it possible to operate at higher temperatures and improve cleaning technology although the higher hydrophobicity meant more fouling problems.

Technology for producing yogurt, various types of soft cheese, feta cheese, etc. from UF retentates was developed. In the 1980s, there was an expansion in this area, and technology for producing cheddar cheese from UF retentates was developed in Australia. In addition, the standardization of the protein content of cheese milk was developed. In the 1990s, the use of cheese milk standardization spread around the world, the standardization of protein for milk powder started, and market milk got increased attention (Horton, 1997).

About 220,000 m^2 membrane area had been installed world wide as of 1997 for UF in the dairy industry, of which about 150,000 m^2 is for whey and 60,000 m^2 for milk treatment (Timmer et al., 1998).

Some reasons for this increase are lower prices for membrane systems, increased processing capacity, development of new markets, and replacement of old equipment and technology (Timmer et al., 1998). A general trend in whey processing is that the operating temperature is lowered to 10^0C because operating at this temperature overcomes problems of calcium phosphate precipitation occurring at higher temperatures.

The whey plants are used for production of whey protein concentrates (WPC) with varying protein contents, including very high ones for specific purposes. For milk, a major area is standardization of the milk protein content. The protein content of milk varies during the year and UF of the milk results in a more homogeneous and constant quality. In cheese making, the capacity of existing equipment can be doubled if the milk proteins are preconcentrated by UF. This, however, does not increase the yield substantially. UF is also used to obtain total solids content, equal or almost equal to the concentration in the final cheese. This technology is used for several types of cheese with moderate total solids content. So far, the use of UF for the production of semihard and hard cheese is very limited, and the production of hard cheese of cheddar type from UF retentate developed in Australia has stopped (Horton, 1997). In many cases, the traditional process technology must be modified when UF concentrates are used instead of milk. It is, for instance, very important to carefully adjust the mineral balance in order to obtain the correct rheological properties and taste in the final product.

Other Proteinaceous Materials : There are also applications of purifying and concentrating proteins from sources other than milk. In the meat industry, animal blood is collected and the blood serum proteins are widely used in various food products in a concentrated form. These proteins are very heat sensitive and need gentle treatment to avoid coagulation. They can be successfully concentrated by UF, and commercial plants have been in operation for many years (Cheyan, 1998 and Mohr *et al.,* 1989).

Gelatin is one of the most important by-products from the meat processing industry and is widely used in food products as well as in the pharmaceutical and photographic industries. Different qualities are available. UF is commercially used for simultaneous concentration and desalting of gelatin solutions; sometimes, diafiltration is also used to obtain the right composition. A third example of established applications in this field is the purification and concentration of enzymes, e.g., standardization of rennet used in cheese-making.

Fruit Juice and Wine Industry : In juice processing, compounds such as pectins, cellulose, hemicellulose, starch, and proteins cause undesired turbidity during storage and the juice thus has to be clarified. Since the late 1970s, UF has been applied commercially for the clarification of different types of fruit juices. Most UF plants have been installed for apple juice clarification, but commercial systems are also in operation for other types of juices. There are several advantages of using UF over traditional clarification technology, such as increased yield (96–98%recovery), elimination of filter aid and filter presses, better product quality (less haze), and reduced enzyme usage (Cheyan, 1998).

UF is also an accepted technology within the wine industry. Several wineries are using UF to clarify, stabilize, and enhance their wines. UF is used to remove thermally unstable proteins, tannins, color components, yeast, carbohydrate gums, and oxidized phenolics (Mohr et al., 1989).

Sugar Industry : Membrane applications in the sugar industry are still in its infancy, but progressing. For sweeteners (glucose, fructose), membranes are widely used to obtain higher purity, e.g., by removing suspended solids. Many thousands of square meter are reported to be installed worldwide. Concerning purification of sucrose from sugar cane and sugar beet processing, pilot plants have been installed. Potential applications are clarification of juice, syrups, etc. This involves more difficult separation problems and more fouling problems than with sweeteners (Hlavacek, 1999).

CONCLUSIONS

Ultrafiltration is a low-pressure membrane process used to separate high molecular weight compounds from a feed stream. Ultrafiltration has larger pores than nanofiltration and reverse osmosis and is therefore the least costly of the three to operate. Generally speaking, purification represents the most costly step within food production and biotechnological processes. Membrane-based processes, such as ultrafiltration (pore size from 10 to 1000 Å) are widely used on an industrial scale. Membrane-based processes are aligned to green chemistry concepts, that is, they are environmentally-friendly, do not generate harmful residues, show a low consumption of energy and an easy scale-up, among others. The food industry applies ultrafiltration to a wide range of fields. For instance (i) dairy - milk treatment, production of ice cream, etc. As an alternative to pasteurization of milk, ultrafiltration can be used also as pretreatment of milk for cheese production, in which large molecular weight compounds such as caseins, whey proteins, etc., are in the retentate, whereas low molecular weight compounds such as lactose and peptides are in the permeate. Similarly, low lactose yogurts can be produced (ii) beverage - during the juice clarification using membranes, pulp, pectin and essential oils are retained, whereas the juice itself is permeate. Ultrafiltration is also used in the production of clear beer and wine (concentration) (iii) degumming edible oils - (e.g., crude soybean oil, sunflower seed oil), in which phospholipids are removed (retentate) by ultrafiltration as an equivalent first step of the oil refining process (traditionally, carried out by water or dilute acid that leads to precipitation phospholipids) (iv) fish, poultry and gelatin - ultrafiltration is largely used for wastewater treatment processes, in particular for high protein content residues. Nevertheless, over the past few decades, the recovery of bioactive peptides and proteins from these wastewaters has drawn significant attention, that is, doubly advantageous (waste treatment and recovery of high added-value compounds) (v) drinking water treatment - high quality potable water implies the absence of microorganisms (e.g., Giardia), organic matter (e.g., humic substances), inorganic particles, and others hazardous substances. This water quality can be achieved by ultrafiltration, in which the main limitation is related to long-term flux decline (membrane fouling). Thus, membrane materials and membrane filtration operating systems, etc., should be better investigated (vi) recovery of specific molecules - plant proteins, enzymes (e.g., lysosyme) and phenolic compounds can be recovery and purified by ultrafiltration well-defined methodologies. Membrane-based separations, in particular ultrafiltration, are extensively used by food industry. However, improvements are still needed in virtually all applications.

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