Pilot Plant Membrane Filtration Opportunities for the Food Processing Industry

The Food Processing Center

University of Nebraska-Lincoln

Steven L. Stephens, Food Process Engineer

In the food and beverage industries, the precise separation of particles is increasingly important in the production of juices, beer, wine, and numerous dairy products. The Food Processing Center's (FPC) pilot membrane filtration system (**Figure 1**) offers food processors the capability to explore membrane processing of food products and recovering valuable by-products from waste streams on-site or at the FPC's pilot plant facility. The pilot membrane filtration system can purify, concentrate and clarify food products, as well as recover proteins, starches, and sugars from food processing waste streams. Applications include, but are not limited to the following:

- Removal of suspended solids (haze) from juices and wines to improve clarity
- Concentration of milk proteins to enhance the texture and nutrition of dairy products
- Recovery of dairy proteins from whey waste streams
- Reclamation of residual potato starch from wash water after peeling and cutting

In short, membrane filtration has vast applications in enhancing food products and in by-product utilization which can turn a food plant's waste stream into a viable revenue stream.

In addition to the common food and beverage processing applications, recent developments in membrane filtration technology are being used to concentrate nutraceuticals and functional food ingredients to enhance the quality of food products. Examples include the concentration of soy isoflavones from water extracts of soybeans and concentration of green tea leaf extracts (Kumar, 2006). The advantage of membrane-based processing is that flavors and functional food components are preserved because the separation is achieved without thermal processing. Heat can alter flavors and damage functional food properties.

To help convey the capabilities of the FPC's pilot plant membrane filtration system, the principles of membrane filtration and the use of the pilot membrane filtration system for Feta cheese processing at the FPC's dairy pilot plant follows.

Figure 1: The pilot plant membrane filtration system (GEA Model R) is a flexible unit able to perform pilot plant studies on the full range of membrane filtration technologies under a wide range of operating conditions.

Principles of Membrane Filtration

Membrane filtration is a technique that uses a porous membrane to separate particles in a fluid. Particles are separated on the basis of their size and shape with use of pressure and specially designed membranes with different pore sizes. Although there are different membrane filtration methods (reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF)), all aim to separate or concentrate substances in a liquid.

Compared to thermal processes (e.g., evaporation), membrane filtration is an energy efficient method of clarifying, concentrating and purifying food processing streams. Membrane separation can be performed at ambient or low temperatures, thus preventing temperature-sensitive ingredients from damage. Membrane filtration improves product quality by retaining flavors, vitamins, and minimizing protein denaturation (Sharma et al., 2000).

Membrane filtration can separate a range of molecular weights and particle sizes based on membrane pore size. As shown in **Figure 2**, components smaller than the membrane pore size passes through the membrane while larger components are retained. Retentate is the portion that does not cross membrane (large molecules). Permeate is the portion that crosses the membrane (smaller molecules). **Figure 3** shows the fractionation of various components in milk by MF, UF, NF, and RO membranes.

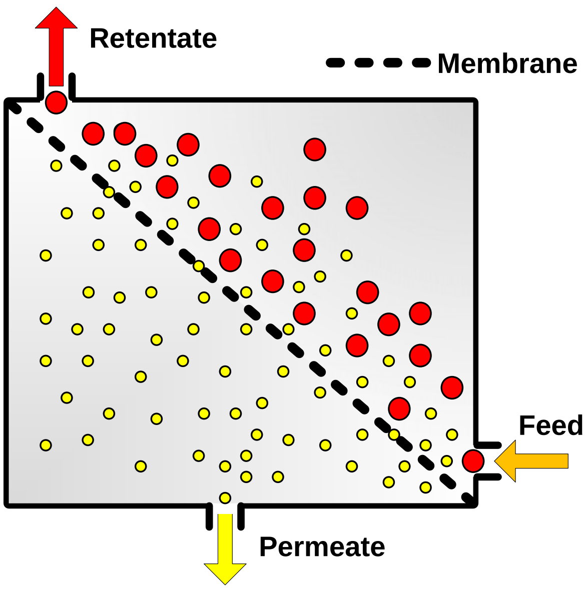

Figure 2: Schematic diagram depicting the principle of membrane filtration.

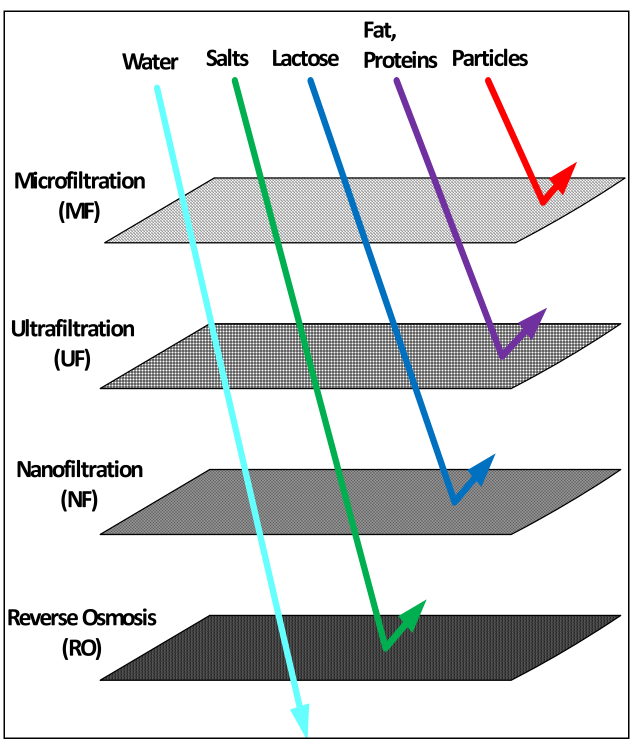

Figure 3: Separation of milk components by MF, UF, NF, and RO membranes (Adapted from Saboya and Maubois, 2000).

An example of a mass balance for the fractionation of whole milk by ultrafiltration and reverse osmosis is shown in **Figure 4**. The protein and fat content is concentrated to about three times to that of whole milk using ultrafiltration and lactose can be separated from the permeate by reverse osmosis. The solids in the UF permeate stream can be recovered and used in the food processing and animal feed industries. The permeate stream from the RO process can be routed to the drain, or it can be polished by a separate RO membrane and used for wash and rinse processes with the exception for final rinse water (DMI, 2000).

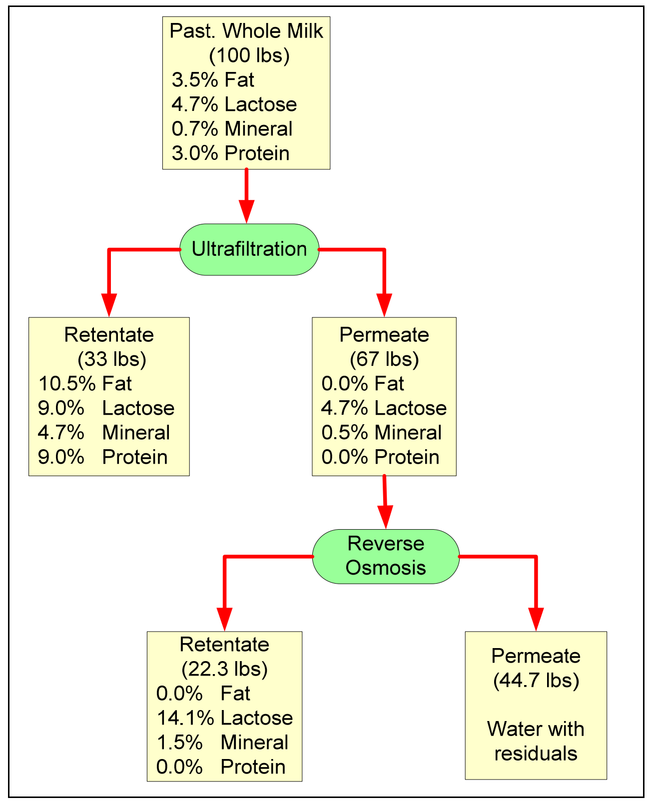

Figure 4: Example of mass balance of membrane filtration of fluid milk (Adapted from DMI, 2000).

Pilot Plant Membrane Filtration System

The FPC's pilot membrane filtration system can operate in batch, continuous, or recycle modes as shown in the schematic diagram in **Figure 5**. The system consists of pumps, a heat exchanger, and process control instrumentation, process indicators such as flow rate meters, thermocouples, and pressure gauges. Low or high pressure variable-speed pumps provide the driving force for moving the liquid along the membrane. A recirculation pump creates a continuous cross-flow to prevent the membrane from plugging with solids. The heat exchanger can be used to cool temperature-sensitive food products to inhibit bacterial growth. Operating parameters such as flow rate, temperature,

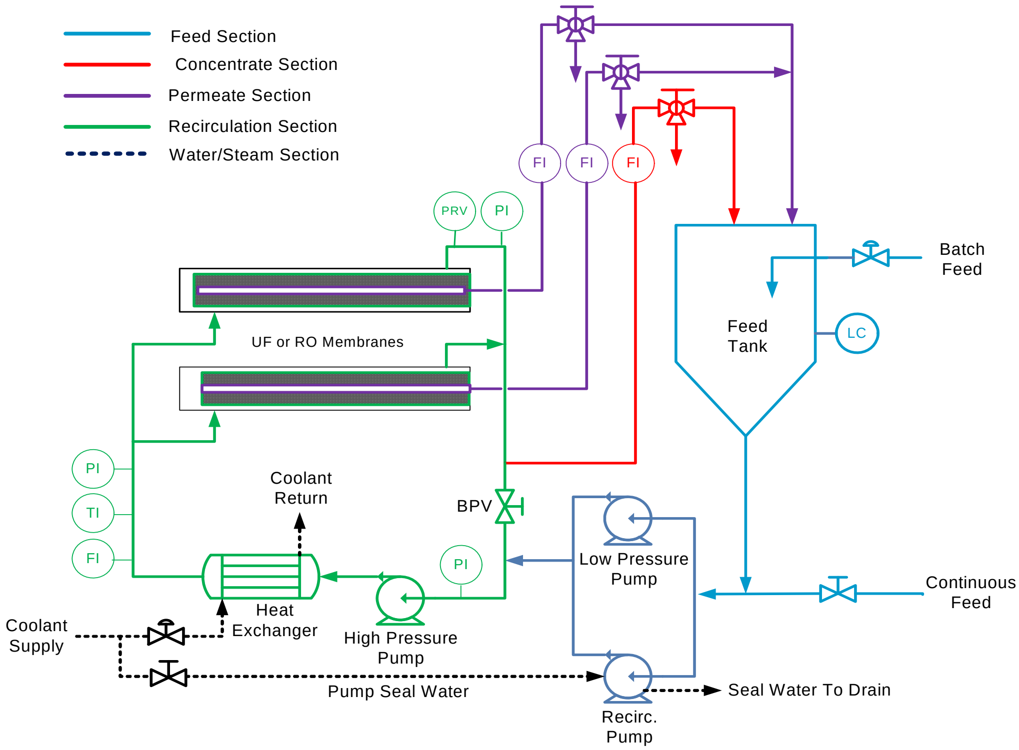

Figure 5: Schematic drawing of pilot membrane filtration system (Adapted from GEA).

and pressure can be monitored throughout the process and used for production scale- up. The design features and operating parameters of the pilot membrane filtration system are as follow:

Pilot Plant Membrane Filtration System Features

Two, sanitary, spiral membrane housings

- one membrane element per housing
- 3.8" diameter, sanitary design elements

One, single element, ceramic or stainless steel module

15 gallon tank with 10 gallons for liquid hold-up

Control loops

- temperature
- tank level
- feed pump
- recirculation pump

Pumps

- variable speed drive for feed pump (5 hp)
- variable speed drive for recirc. pump (3 hp)

Flow indicators

- two, permeate rotameters
- one, concentrate rotameter
- recirculation magnetic flow meter

High pressure shut down and pressure relief valve

Skid Dimensions: 7' L x 6' W x 6.5' H

Utilities

- Electrical: 10 Amps/460 V, 3 phase, 60 Hz
- Cooling Water: 10 gpm, 60 ˚F
- Seal water for recirculation pump: 1 gpm
- Clean-In-Place Steam (30 psig)

Membrane Capacity (Permeate)

- UF or RO Spiral Membrane: 20 - 50 gal/hr
- Ceramic membrane: 10 - 50 gal/hr
- Operating Temperature Range: 50 - 200 °F

The pilot membrane filtration system is designed to test several membranes (spiral (see **Figure 6**), ceramic, hollow fiber, stainless steel, and tubular polymeric) to meet a wide range of separations. The parameters for each membrane follow:

Reverse Osmosis (RO)

- Rejection of: salts, glucose, and amino acids
- Membrane pore size: <0.002 µm
- Operating pressure: 200 to 1,000 psig
- Membrane Selection: spiral or tubular

Ultrafiltration (UF)

- Rejection of: proteins, fat, and polysaccharides
- Pore size: 0.2 – 0.02 µm
- Operating pressure: 20 to 200 psig
- Membrane Selection: spiral, tubular, hollow fiber, or ceramic

Nanofiltration (NF)

- Rejection of: mon-, di- and oligosaccharides, polyvalent negative ions
- Membrane pore size: <0.002 µm
- Operating pressure: 100 to 500 psig
- Membrane Selection: spiral or tubular

Microfiltration (MF)

- Rejection of: large particles (e.g., pulp from juices)

- Pore size: 4 – 0.02 µm
- Operating pressure: 10 – 50 psig
- Membrane Selection: stainless steel or ceramic

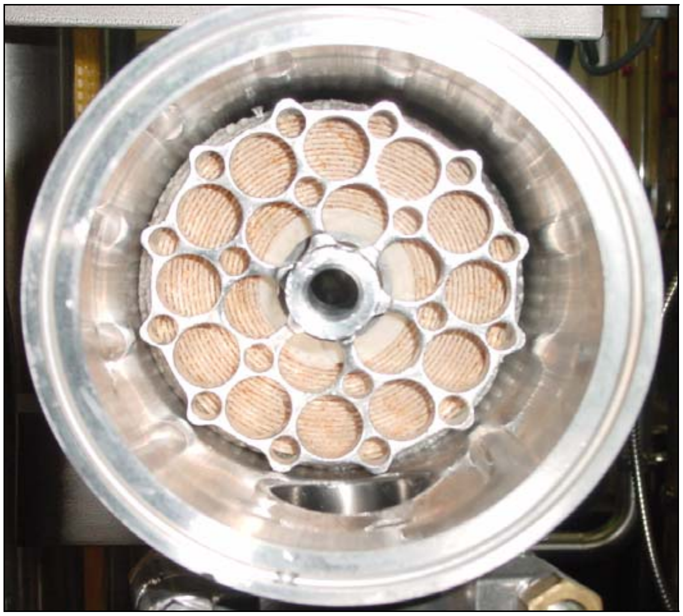

Figure 6: Spiral membrane in housing vessel.

FPC Application – UF Feta Cheesemaking

The FPC Dairy Pilot Plant manufactures Feta cheese using traditional and ultrafiltration methods. In the UF process, the fat and protein in whole milk are concentrated about 2.5 times, and the finished product known as structured Feta is similar to traditional Feta, except for the inclusion of the whey proteins. The inclusion of the whey proteins makes the cheese smoother in texture than traditional Feta. The FPC's UF Feta cheese manufacturing process is shown in **Figure 7**. The cheese yield was 11% based on the weight of feed to UF and pressed cheese curds. This yield closely agrees with the UF Feta cheese yields observed by Cheryan (1988).

FPC Staff Contact

To have your membrane filtration application tested at The FPC's pilot plant or request to have the system tested at your facility, please contact Steve Stephens by email at sstephens2@unl.edu or by phone at 402-472-2901.

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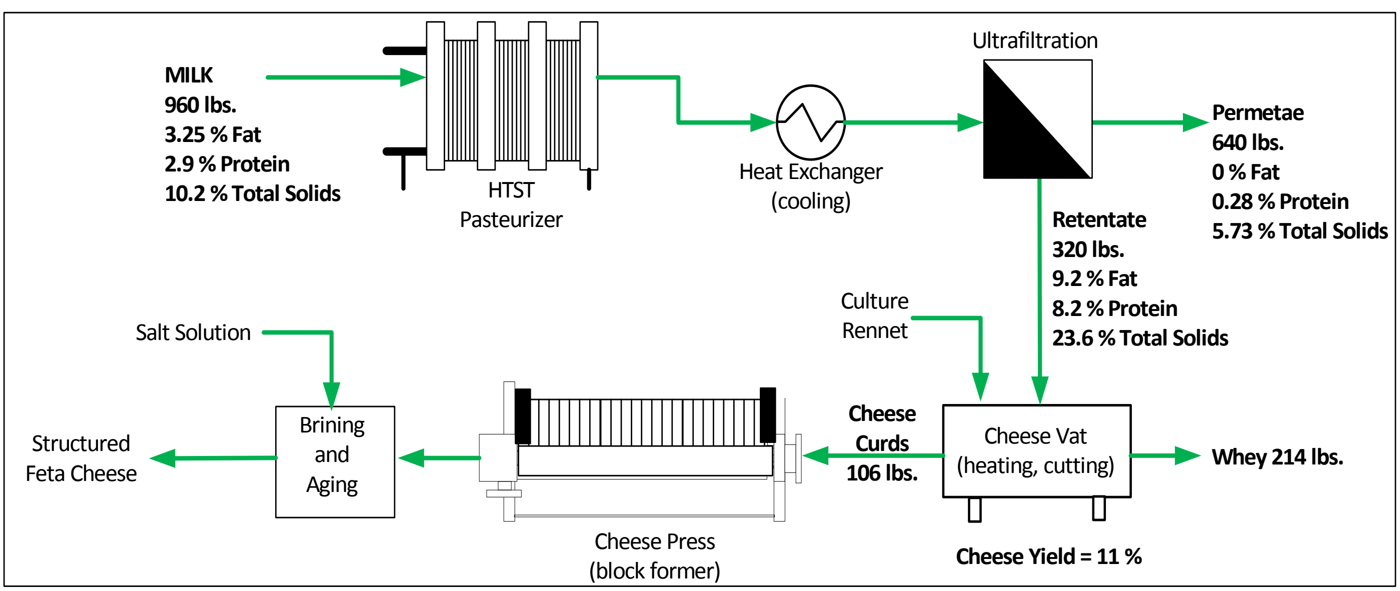

Figure 7: FPC Feta cheese manufacturing process using ultrafiltration.