Novel Technologies for Food Processing and Shelf Life Extension
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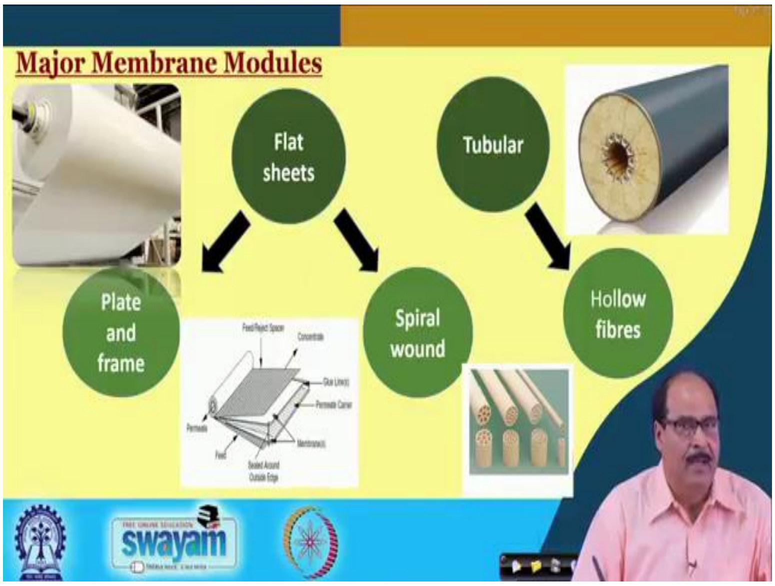
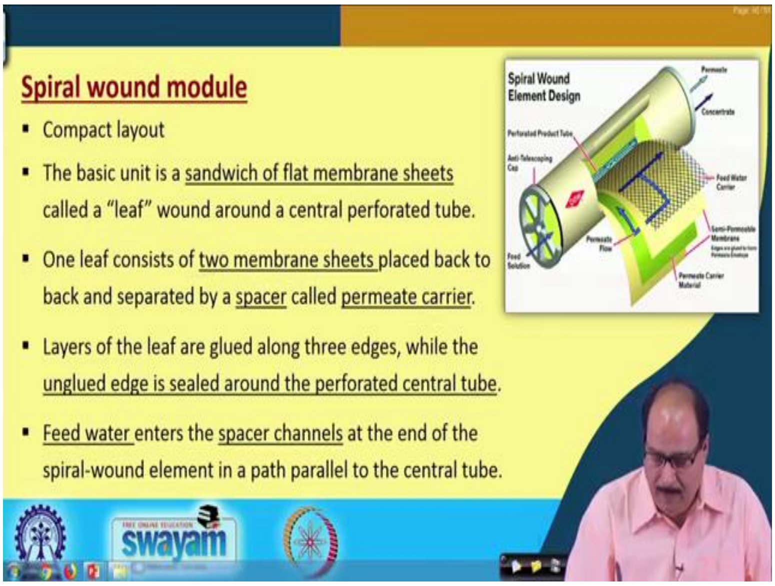
Lecture – 14
Membrane Technology – Part 2

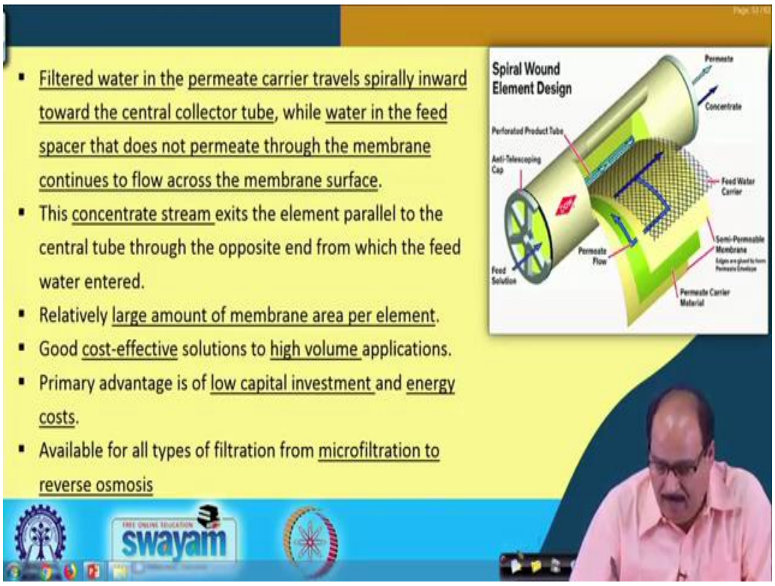
In this lecture, 2nd part of the membrane technology will be studied in which the different types of modules and applications of membrane processes in the food industry will be taken up.



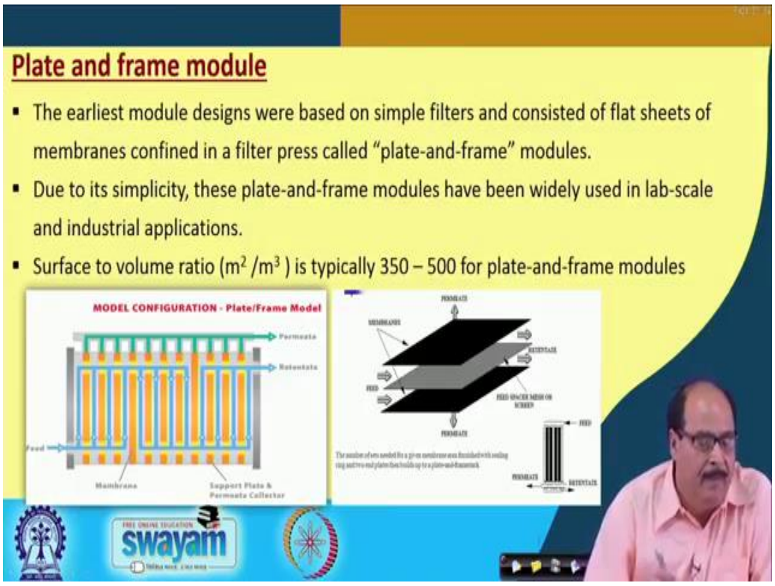
The membrane modules are majorly of flat sheets geometry or tubular membranes. The flat sheet membranes are plate and frame module or spiral wound module and the tubular module may be the hollow fiber.



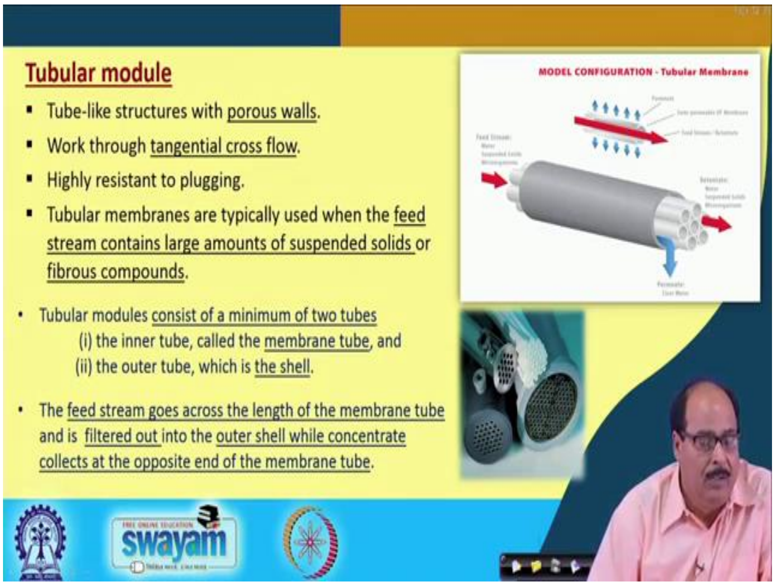
The spiral wound modules are of compact layout. The basic unit is a sandwich of flat membrane sheets, which is called a leaf. And this leaf is wound around a central perforated tube. One leaf consists of two membrane sheets placed back to back and are separated by a spacer called permeate carrier. Layers of the leaf are glued along three edges, while the unglued edge is sealed around the perforated central tube. Feed water enters the spacer channel at the end of the spiral-wound element in a path parallel to the central tube.



The filtered water in the permeate carrier travels spirally inward towards the central collector tube, while water in the feed spacer that does not permeate through the membrane continues to flow across the membrane surface. The concentrate stream exits the element parallel to the central tube through the opposite end from which the feed water enters. Relatively, large membrane area can be provided here per element. And it is considered to be a good cost-effective solution for high volume applications. Primary advantage of this type of module is low capital investment and energy saving. It is available for all types of filtration processes starting from even microfiltration to reverse osmosis, they can be applied for all types of membrane.

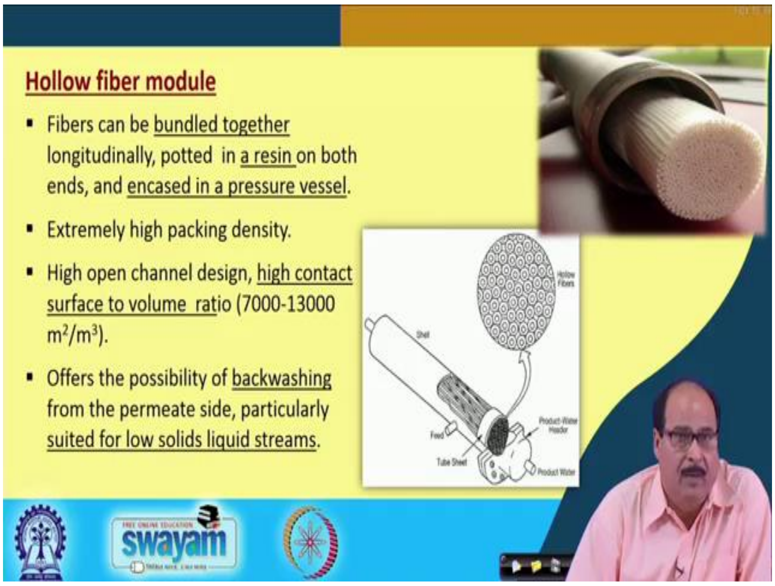


The plate and frame module was the earliest module design based on the simple filters and consisted of flat sheets of membrane confined in a filter press called plate-and-frame module. Due to its simplicity, these plate-and-frame modules had been widely used in lab-scale as well as in industrial applications. Here surface to volume ratio is typically 300 to 500 m^2/m^3 for these modules.

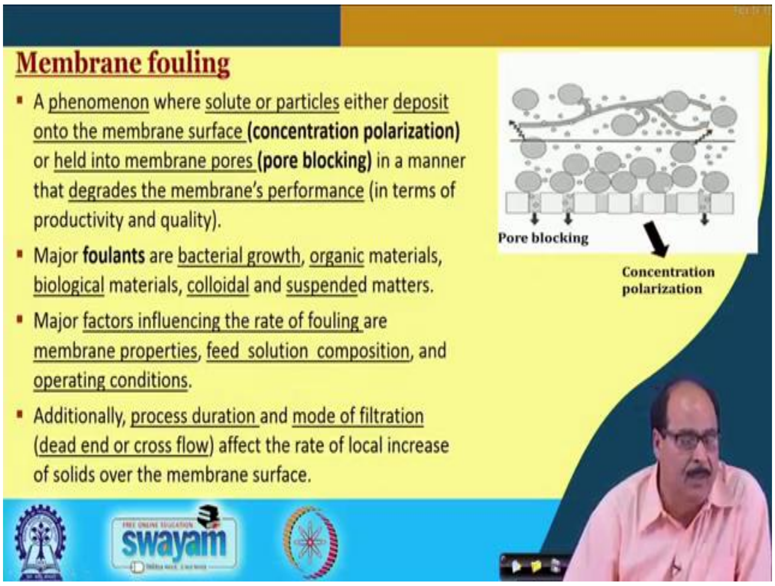


Tubular modules have tube-like structures with porous walls. They work through tangential cross flow and they are highly resistant to plugging. These tubular membranes are typically used when the feed stream contains large amount of suspended solids or fibrous compounds.

The tubular module consists of a minimum of two tubes. There is an inner tube inside, called the membrane tube. And other is the outer tube, which is called the shell. The feed stream goes across the length and enters the membrane tube, and then gets filtered out into the outer shell while concentrate collects at the opposite end of the membrane.



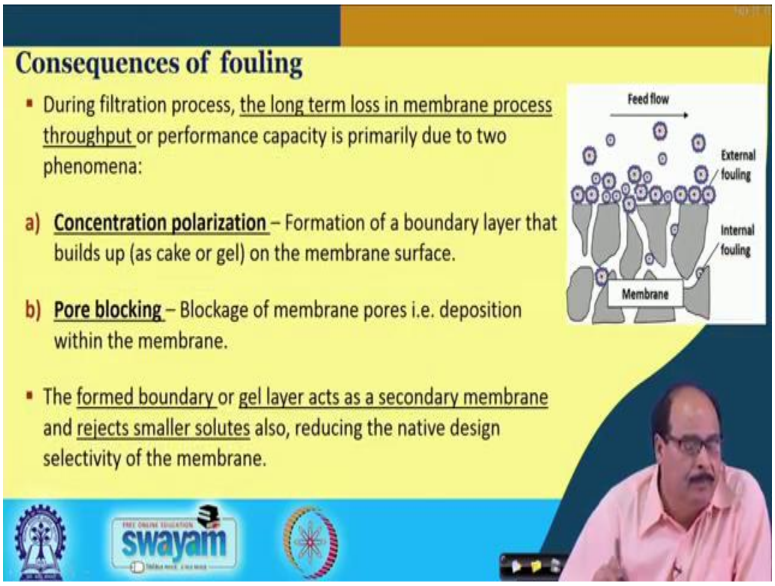
The most common frequently used module is the hollow fiber module. In this, several fibers are bundled together longitudinally, they are potted in a resin on both ends and encased in a pressure vessel. They have extremely high packing density, high open channel design, they provide high contact surface to volume ratio may be 7000 to 13000 m^2/m^3. They offer the possibility of backwashing from the permeate side, particularly suited for low solid liquid stream.



The fouling is basically a phenomenon where solute or particles either get deposited on the membrane surface, which is called concentration polarization or they are accumulated within the membrane pores, called pore blocking. Both of them degrade the membranes' performance in terms of productivity and quality.

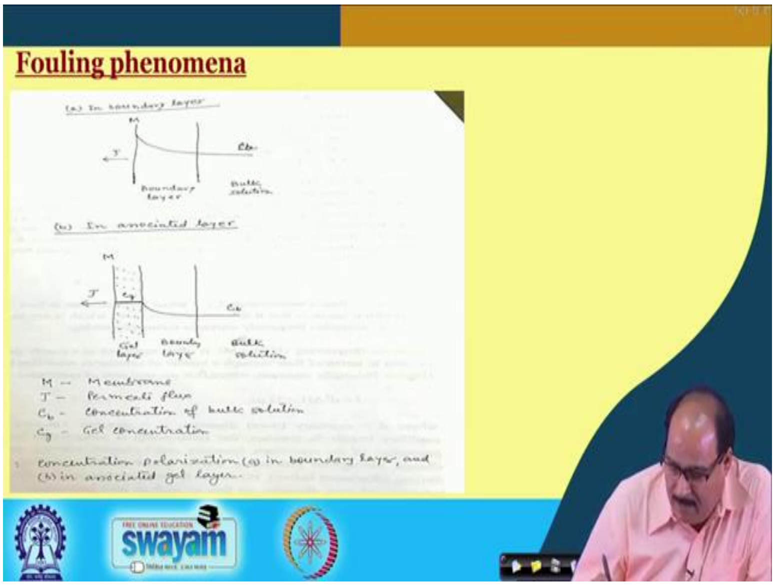
Major types of foulants may be the bacterial growth, suppose if the cleaning of the membrane is not proper and some bacterial cell remains adhered, so after sometimes it will grow, multiply, may grow in size, and it will choke the membrane pores, building up a gel layer. Even organic materials, biological materials, colloidal particles or suspended matters all these may cause this problem of fouling and concentration polarization.

Major factors that influence the rate of fouling are membrane properties, feed solution composition and operating conditions like pressure, temperature etc. Additionally, the process duration and the mode of filtration affect the fouling, e.g. dead end flow causes more blocking or more concentration polarization than that of the cross flow. So, these also affect the rate of local increase of solids over the membrane surface and therefore, problem of fouling.

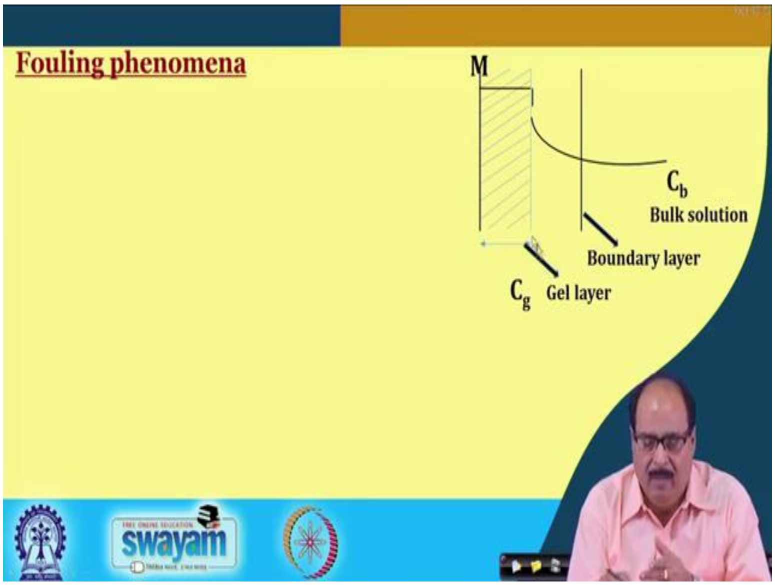


Consequences of the fouling: During filtration process, the long term loss of membrane process throughput or performance capacity results because of this concentration polarization or pore blocking.

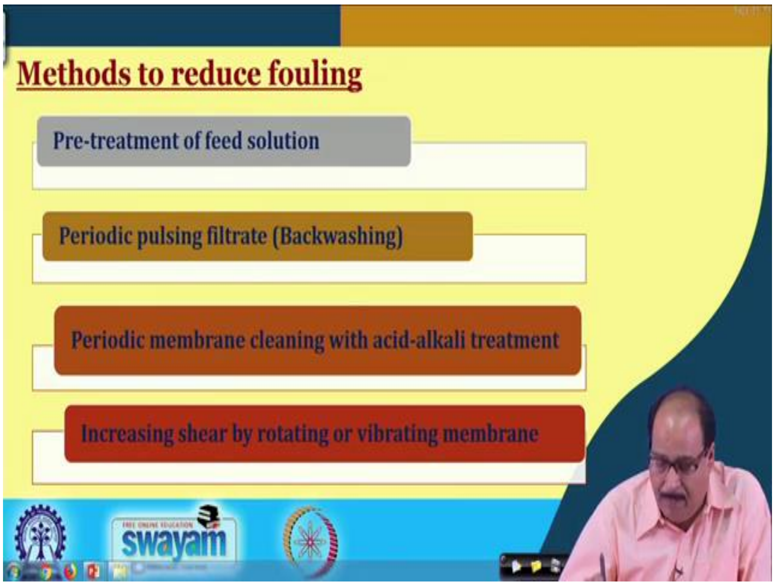
In the long run, the solutes get deposited over the surface forming a gel layer or boundary layer. It may act as a secondary membrane and may cause the rejection of some solutes that are even intended to pass, reducing the native design selectivity of the membrane.



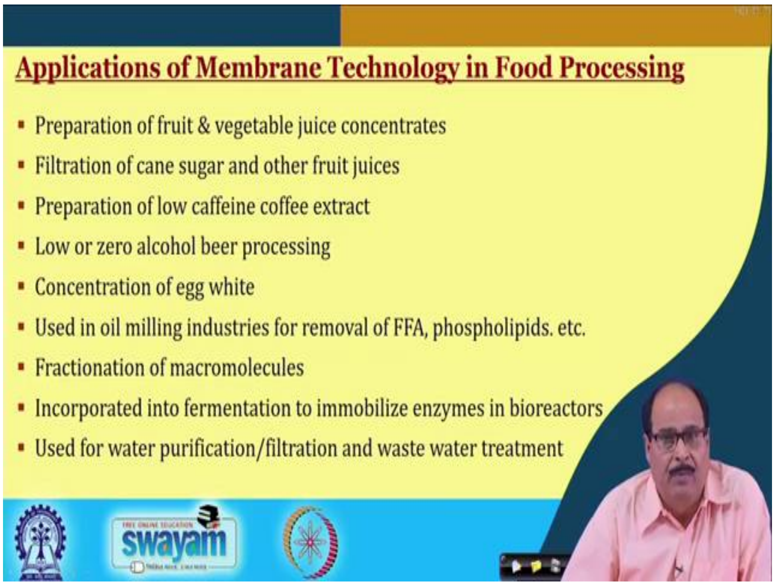
In figure, C_b is the concentration of the bulk solution. When pressure is applied, slowly and slowly that is a boundary layer formed; here the concentration of the solute in the boundary layer will be obviously more than that of the concentration of the solute in the bulk solution. In further long time, these solutes may get even more compact and form a concentrated gel layer (C_g). So, here the concentration of solute is much more than that of the solutes concentration in the boundary layer or in the bulk solution. So, obviously when the concentration layer is formed, the flux gets reduced.



The same thing is shown here in this figure i.e. the concentrated solution, boundary layer, and gel layer.



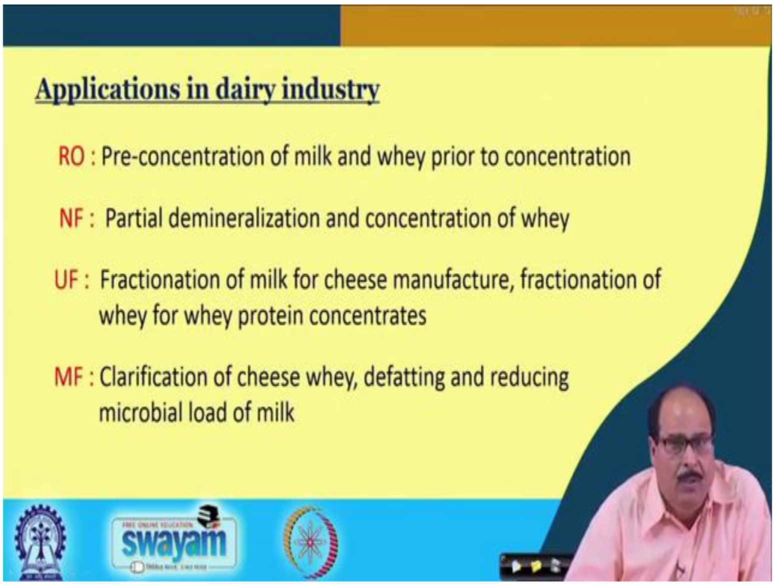
Methods to reduce fouling: In order to get proper filtration for process efficiency, fouling and concentration polarization phenomena should be kept as low as possible. The pre-treatment of the feed solution is one important way; feed can be given some pre-treatment or pre-filtered etc. in the normal filtration process to remove suspended solids at an earlier stage. Periodic pulsing of the filtrate like backwashing and periodic membrane cleaning with acid-alkali treatment, and increasing shear by rotating or vibrating the membrane are other important methods that can be followed. So, these are the ways by which one can reduce the fouling problem in a membrane process.



Membrane technology has a great potential and a wide ranging application in food processing like in concentration of fruit juices, vegetable juices, etc.

Filtration of cane sugar and other fruit juices; particularly in the cane sugar, the characteristic flavor of the sugarcane juice is lost, if it is given heat treatment. Membrane technology can be applied to clarify the cane sugar juice as well as to remove bacteria and enzymes etc. from it. And therefore, its shelf life can be extended without any involvement of heat in the process.

Also this membrane technology can be used for preparation of low caffeine coffee extracts, for production of low or zero alcohol beer, and concentration of egg white. It is also used in oil milling industries for removal of free fatty acids from the oil or for removal of phospholipids, etc. For the fractionation of macromolecules, it is incorporated in fermentation to immobilize enzymes in bioreactors. The use of RO membranes in water purification, filtration and waste water treatment plants is a known application of this technology.



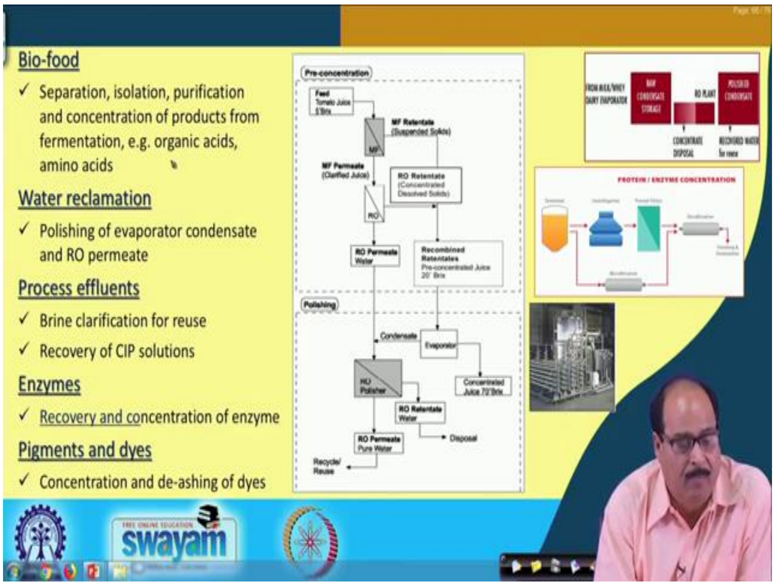
In dairy or milk processing industries, RO can be used for pre-concentration of milk and whey prior to their concentration. Also the nanofiltration can be used for partial demineralization and concentration of the whey, this is obtained after the cheese making. Some colloidally dispersed suspended salts can be removed. Ultrafiltration technology can be used in milk and dairy industry for fractionation of milk for cheese manufacture, for fractionation of whey for whey protein concentrate preparation and so on. Microfiltration can be used for clarification of cheese whey, defatting and reducing microbial load of milk and so on. So, it can be used as a low temperature or non-thermal pasteurization or even sometime sterilization of the milk.

Similarly, in other food and beverage industry for the vegetable products processing, it can be used for clarification and concentration of fruit and vegetable juices, because these fruit and vegetable juices contain many bioactive compounds which are sensitive to heat. When heat thermal processes are used for concentration or evaporation of such products, health components or bio components may get destroyed, and their health benefits are lost. So, the membrane technology can be used for retention of health components in the material. It can be used for clarification, de-colorization, and concentration of beet and cane sugar juice.

It has a great potential in grain processing industries, for the production of soy isolate, wheat proteins, in preparation of plant extracts like concentration of coffee i.e. the de-caffeination of coffee, concentration of tea and preparation of other herbal extracts, etc. It is widely used in clarification and concentration of corn syrup like glucose and fructose, recovery of ion exchange regeneration effluent. So, even in the vegetable processing industries, grain processing industries, in the plant extract preparations this process has a very good use.

In the beverage industries and alcoholic drink manufacturing industries, it can be used for de-alcohalization of beer and wine, even the beer recovery from bottom of the tank, to clear the malt beverage, for clarification of the malt extract, wort etc. RO unit can be used for preparation of alcohol-free beer as can be seen in the picture.

Similarly, in the organic solvent recovery, it has a great potential for animal products. It can be used for concentration and de-ashing of blood plasma. It can be used for concentration and de-ashing of pork, beef, fish gelatin, etc. Concentration of egg white or even clarification and fractionation of protein hydrolisates all these are possible using membrane technology. In the fish and sea food products, concentration of fish proteins, extraction of proteins and their concentration using membrane technology can be possible.



In the bio-food preparation; like in processes like separation, isolation, purification concentration of products from fermentation, even the separation of organic acids, amino acids all are possible using appropriate type of membrane separation process and using proper processing conditions.

Like in the water reclamation, polishing of evaporator condensate and RO permeate can be used. Further process effluents like brine clarification for reuse, recovery of CIP solution etc., even in the enzyme processing industry, recovery and concentration of enzymes or pigment and dyes concentration and de-ashing of dyes, all these can be done by using these processes.

In figure, feed (tomato juice) of 5 ^{0}Brix is passed through a microfiltration membrane. So, the microfiltration retentate is then passed through another RO membrane. The combined MF and RO retentate obtained is the pre-concentrated juice which can be sent to the evaporator. The condensate is sent to RO filter for further use. The tomato juice thus can be concentrated from 5 °Brix to 70 °Brix by the combination of these two processes. Otherwise, in the normal concentration processes such as evaporation etc., even in vacuum also, it is difficult to get such high concentrated juice.

The protein and enzyme concentration from the fermenter medium are passed through centrifuge and pre-coat filters and then they are sent to the ultrafiltration where the finishing and formulation can be obtained. So, these two centrifugation and pre-coat filtration processes can be avoided by having one simple microfiltration. The fermenter output can be passed through microfiltration and then ultrafiltration to get the desired product.

So, the membrane technology has a vast potential for application in processing industry. It being a non-thermal process is a novel technology particularly for the preparation of health foods, for concentration process, for the extension of shelf life of the material, because the causative or deteriorative agents like micro-organisms, enzymes etc. can be separated. Also, some useful components which are separated can be further used as ingredients for preparing value added products.