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Membrane Separations

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ABSTRACT

Membrane technology is widely utilised in industries for separation, concentration, filtering, and extraction operations. Membrane technology carries out various applications by utilising simple and specially designed semi-permeable membranes. It uses little energy and is thus considered a green technology. Ultrafiltration (UF), Microfiltration (MF), Nano-filtration (NF), and Reverse osmosis (RO) are membrane filtration methods that have a major influence on the organoleptic and nutritional qualities of juice. The adoption of a membrane method linked with enzymatic hydrolysis resulted in clarified and concentrated fruit juices with good sensory and nutritional quality. Membrane fouling is a significant problem of membrane-based separation processes. Membrane procedures powered by pressure, such as MF, UF, NF, and RO, allow for the separation of components with a wide variety of particle sizes. Because of this, they have a wide range of uses in the food processing business.

Keywords: *Membrane technology, Ultrafiltration, Microfiltration, Reverse osmosis*

INTRODUCTION

Membrane processes (MP) are increasingly being used in the food, beverage, and nutraceutical sectors (Daufin 2001; Drioli 2009; Pabby 2009; Drioli, Giorno 2010; Echavarria 2011; Carstensen, Apel 2012; Mohammad 2012; Akin 2012; Lin 2012). Lower pressure membrane processes, microfiltration (MF, 20-400 kPa), ultrafiltration (UF, 200-1400 kPa), and nano filtration are examples of membrane filtration applications (NF, 1-4 MPa). Because it is being used in the food industry and biotechnologies, reverse osmosis (RO) as a high pressure driven MP (2-10 MPa) with a different transport mechanism will be briefly reviewed as well. Membrane separation techniques include the separation of chemical species by a difference in transport rates across the membrane interphase. The driving power, mobility, and concentration of the particular component inside the interphase all influence the transport rate. The important elements for successful separation of chemical components are solute molecular size, membrane morphological structure, and chemical affinity. Membrane separation efficiency is determined by the type and module. (Sonune, 2004).

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Membrane filtration may be a very efficient and cost-effective method of separating components that are suspended or dissolved in a liquid. The membrane is a physical barrier that permits specific chemicals to flow through based on their physical and/or chemical qualities. Membranes are typically made up of a porous support layer with a thin dense layer on top that forms the actual membrane.(Munir, 2006). Because membrane controls the permeation of certain components, the membrane is the "heart" of every membrane separation process. The membrane characteristics influence the membrane process choices. Membrane materials can significantly impact the features and characteristics of the membrane, such as hydrophobicity and surface charge, modifying the membrane's separation characteristic. The majority of membranes are made of cellulose or non-cellulose organic polymers like poly ethersulfone (PES), poly sulfone (PSF), polyvinyl di fluoride (PVDF), and polypropylene. These polymeric membranes, however, are not appropriate for severe environments. As a result, inorganic ceramic membranes for treating highly polluted wastewaters such as oily water and high turbidity water have been proposed.(Othman et.al.,2021)

Membrane may be described as an insufficient barrier between two fluids, implying that not all components in touch with the membrane are carried through it at the same pace and separation is possible. Trans membrane pressure differential is the driving factor in membrane filtration (TMP). Membrane separation is based on two factors: sieving effect and physical or chemical interactions of separated components with membrane. Separation of rejected species (ions, molecules, colloid particles, or microparticles) according to size is discussed under the sieving effect. The separation effect is dominant in MF and UF. Electrostatic repulsion between charged species such as divalent ions, aminoacids, or charged colloids is one type of physical interaction that plays a key role in NF or UF separations when fixed charge membranes are utilised. Differences in sorption or solubility are critical in the solution-diffusion transport mechanism of RO and other MP. Chemical interactions, such as the creation of complexes carried via membranes or catalytic solute splitting, serve as the foundation for separation and transport in other MP.(Teixeira, 2014) For almost 25 years, membrane processes have been important instruments in food preparation.The food business contributes significantly to the global turnover of the membrane manufacturing industry. The dairy industry (whey protein concentration, milk protein standardization, etc.) is the most common application for membrane operations, followed by beverages (wine, beer, fruit juices, etc.) and egg products. Among the many industrial applications, a few of the main separations that represent the most recent advances in food processing are reported. Clarification of fruit, vegetable, and sugar juices through microfiltration or ultrafiltration allows flow sheets to be simplified, processes to be made cleaner, and product quality to be enhanced.(Daufin 2001)

One effective approach as a low-cost separation technique for the concentration and purification of bio actives from diverse feed streams is industrial membrane technology. Many microfiltration (MF), ultrafiltration (UF), Nano filtration (NF), and reverse osmosis (RO) are significant practises in the food industry for concentration. Their inherent characteristics (low working industries have come to accept cross flow filtration as a standard technology for clarification or concentration over the years, including microfiltration (MF), ultra filtration (UF), Nano filtration (NF), and reverse osmosis (RO). To achieve the desired performance, more than one type of membrane process may be used in series in some cases. These membrane filtration procedures employ the notion of cross-flow, in which the solution to be filtered flows across the membrane surface at a constant velocity while the filtrate passes through the membrane. (Akin 2012). Over the previous two decades, the global market for membrane technology in the food sector has grown to over 800–850 million dollars (Peinemann. K et al, 2011). Purification enzyme membrane reactors (EMRs), temperature, no specific chemicals required, no phase changes necessary, easy scaleup in addition to modularity, simple operation, and automation possibilities) make them a viable alternative to standard liquid food treatment procedures. Furthermore, potential power savings from membrane process application in the food and beverage sector might be calculated at 50% (Eichhammer, 1995).

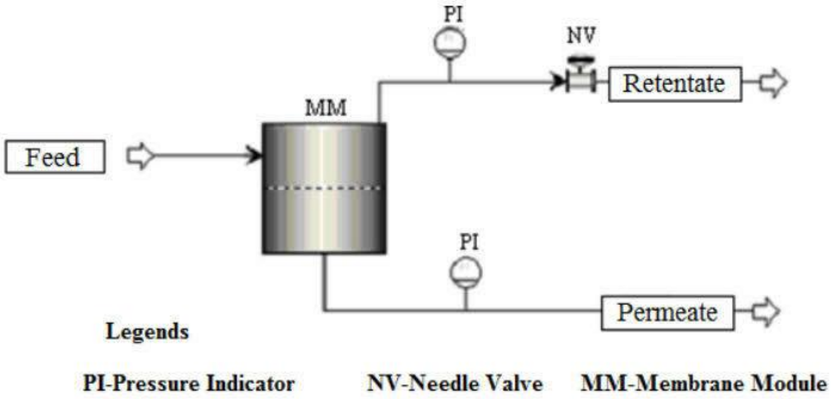

Fig 1. Membrane Separation Process

1. MODULES & FEATURES OF MEMBRANE IN MEMBRANE SEPARATIONS

2.1 MEMBRANE MODULES

The term 'module' refers to the arrangement or packing of membranes. Membrane modules are classified into four types: plate-and-frame, tubular, spiral-wound, hollow-fiber, and membrane cassette. The packing density, potential uses, and pricing of various types of modules vary. Membranes are attached in membrane modules with correct feed channel design and adequate support of membranes, which are often not mechanically robust enough. Membrane modules are classified into four types: planar, tubular, tubule (capillary), and hollow fibre. Spiral wound modules with a planar membrane wound along with a support layer and a feed channel spacer on the module's central collecting tube are crucial (Pabby 2009; Drioli, Giorno 2010).The packed membrane area per unit volume is greatest in the hollow-fiber and spiral-wound modules. Plate-and-frame and tube modules have the lowest packing density, implying the biggest expenditure per unit of membrane surface area. Tubular modules (ceramic membranes) are frequently utilised in skim milk MF. The feed channel is broad with this sort of module. As a result, the feed may be pumped at high CF velocities, reducing the development of concentration polarisation and external membrane fouling and therefore improving permeate flow and allowing for high retentate concentration.(Baker,2004)

2.2 MEMBRANE FEATURES

The choice of a proper membrane is critical in deciding the success of that specific application. Filtering membranes can be formed of organic polymeric or inorganic materials. Organic membranes are often available in a wide variety of pore diameters, are less expensive, and have a high packing density (a large membrane surface area per unit of space volume). One issue is that organic membranes, depending on the material, can only operate in specific temperature, pH, and TMP ranges. Organic membranes are also more susceptible to detergents.(Cheryan,1998). They contribute to the simplicity of flow sheets (replacement of two or more stages) and the enhancement of process performance (clarification, etc.) and food quality (low temperature operation, etc.) in the production of traditional food items. In terms of the environment, membrane separations are viewed as clean processes: a substitute for the use of polluting materials (diatomaceous earth in clarity of wine, beer, fruit juices, etc.); frequently co-fractions may be provided extra value (fractionation of protein containing fluids, etc.); extremely well fitted to the treatment of effluents (evaporation condensates, ultra filtrates, nano filtrates, osmo sates. (Daufi et.al,2001). Pressure, temperature, viscosity and density of the feed fluid, and tangential velocity are the primary physical operating factors that influence permeate flow rate (Scott, 2003). The rate of permeate flow is related to the applied pressure and inversely proportional to the viscosity. Two elements can influence viscosity: solids content in the feed and temperature (Hwang and Kammermeyer, 1998). As feed concentration rises, the viscosity, density, and diffusivity of the feed solution change, resulting in a drop in permeate flow rate (Satyanarayana et al., 2007). An increase in pressure causes a greater convective rate for the transport of solute to the membrane surface, increasing its concentration at the interface and causing an increase in diffusivity of the solute in the opposite direction to that of the process pressure, resulting in a decrease in permeate flow rate (Field et al., 1995)

3. TYPES OF FLOW IN MEMEBRANE SEPARATIONS

3.1DEAD-END SEPARATION

Dead-end filtration is the most fundamental type of filtering. The entire feed flow is forced through the membrane, and the filtered matter accumulates on the membrane's surface. Because collected debris on the filter reduces filtering capacity owing to clogging, dead-end filtration is a batch procedure. A subsequent process step is necessary to remove the accumulated materials. Dead-end filtering can be a highly effective approach for concentrating chemicals.

The flow of water in a dead end filtration system is perpendicular to the membrane surface. Water is pushed through the membrane by pressure. There is no rejected water because all of the water introduced into the dead-end cell passes through as permeate. Retained particles accumulate over time on the membrane surface or within the membrane in dead end filtration. In either scenario, particle buildup increases filtration resistance and causes permeate flux to decrease; as a result, dead end filtration necessitates interrupting filtration to clean or replace the membrane; hence, this form of filtration is also known as batch filtration.[21]

3.2 CROSS FLOW SEPARATION

A continual turbulent flow along the membrane surface prevents matter from accumulating on the membrane surface in cross-flow filtration. Membranes utilised in this technique are typically tubes having a membrane layer on the interior wall. The feed flow through the membrane tube has a high flow speed to create turbulent conditions and an elevated pressure as a driving force for the filtration process. Because the feed flow and filtration flow directions are at a 90-degree angle, the process is known as "cross-flow."Cross-flow filtration is an effective method for filtering liquids with a high concentration of filterable materials. (Munir,2006)

4. TYPES OF MEMBRANE SEPARATIONS

4.1 MICRO FILTRATION (MF)

Microfiltration is a pressure-driven, microporous membrane method used to retain materials as small as 0.2 m in size, but more often 0.1-10 m in size. Large colloids, tiny and solid particles, blood cells, yeast, bacteria, and soluble macromolecules are all examples of matter.The membrane structure for MF includes screen filters that gather retained matter on the surface and depth filters that trap particles at constrictions within the membranes (Zeman and Zydney, 1996).Microfiltration is the technique of separating big molecules as well as microorganisms from fluids. It is possible to remove suspended particles and carry out the procedure efficiently by combining ultrafiltration and microfiltration. (Cheryan, 1998; Farheen, (2020). Unlike centrifugation, MF utilising 0.2 m-rated membranes produces a particle-free harvest solution that does not require extra clarifying before subsequent purification. Many processes, however, now use bigger pore size membranes to boost product output and throughput, with the filtrate subsequently passing through a standard flow filter for ultimate clarifying. To optimise product output and throughput, current MF systems are often operated at constant flux rather than constant transmembrane pressure (van Reis et. al., 1991; Kwon, 2000; Li H,2000). The major objective of MF in the fruit juice processing business is clarifying to remove suspended particles (SS), fat, and high molecular weight (HMW) proteins. In the dairy sector, MF is used to clarify cheese whey, as well as to defat and decrease the microbial burden of milk (Merin. 1984). Microfiltration can also be used to separate fruit juices into a fibrous concentrated pulp and a clarified fraction devoid of spoiling microorganisms. The fruit juice processing sector extensively use MF for juice clarifying. (de Oliviera et al. 2012; Vaillant et al. 2001).

4.2 ULTRA FILTRATION

It is a method of separation and filtering. The membrane pore size is bigger in this procedure than in RO, allowing some chosen solute particles to flow through the membrane with water. This method is used in the dairy sector to ultrafilter skim milk. It enables minerals and lactose through while retaining proteins and lipids. The filtering procedure is also carried out using external pressure. Polysulfone membranes are commonly employed in this application. Polysulfone, polyethersulfone, and regenerated cellulose are the most often used polymers in UF membranes for biopharmaceutical applications (Zydney & Kuriyel, 2000).This technique is carried out at temperatures ranging from 50 to 70 ºC with cutoffs of 40 psig and 10,000 MW. Diafiltration is a form of ultrafiltration that is more sophisticated. (Echavarria et.al., 2011; Farheen,2020). Ultrafiltration (UF) has essentially replaced size-exclusion chromatography in these applications (Kurnik et.al. 1995).Recent research has shown shown that UF may be used to purify plasmid DNA (Kahn et.al. 2000) and virus-like particles(Cruz et.al., 2000). For example, UF may be used to fractionate milk for cheese production, with the retentate component including proteins, fat, and some insoluble and binding salts, and the permeate part containing lactose and solvent salts (Brans et al. 2004). The use of UF to concentrate skimmed milk results in a product with a high calcium and protein content (Vyas et al. 2003), which is one of its key uses in the dairy sector. Depending on the MWCO, the fruit juice business also employs UF for clarifying and concentration. (Mohammad et al. 2012).

4.3 NANO FILTRATION

The nano filtration (NF) membrane was initially introduced in the late 1980s. It possesses features similar to both RO and UF membranes (Waite et.al.2005). A molecular mixture is transported to the surface of a membrane via hydrostatic pressure in this procedure. The solvent and some low molecular weight solutes pass through the membrane, while other components are trapped. It is sufficient to eliminate ions that significantly increase osmotic pressure and so necessitate lower operating pressures. Although soluble fractions cannot be eliminated by NF, highly polluted fluids require effective pretreatment. The membranes are affected by free chlorine in the feed water. NF membranes are made of cellulose acetate blends or polyamide composites, or they can be modified variants of UF membranes such as sulfonated polysulfone. (Bolong et.al.2009). Divalent salts, microorganisms, proteins, and other substances with molecular weights larger than 1 kDa can also be concentrated using NF. In addition to concentration, NF can be used for demineralization. NF is a relatively recent method in the dairy industry for demineralizing whey (Pan et al. 2011). NF can be used in the juice processing business to concentrate valuable bioactive chemicals from fruit juices, such as lycopene in watermelon juice (Arriola et al. 2014).

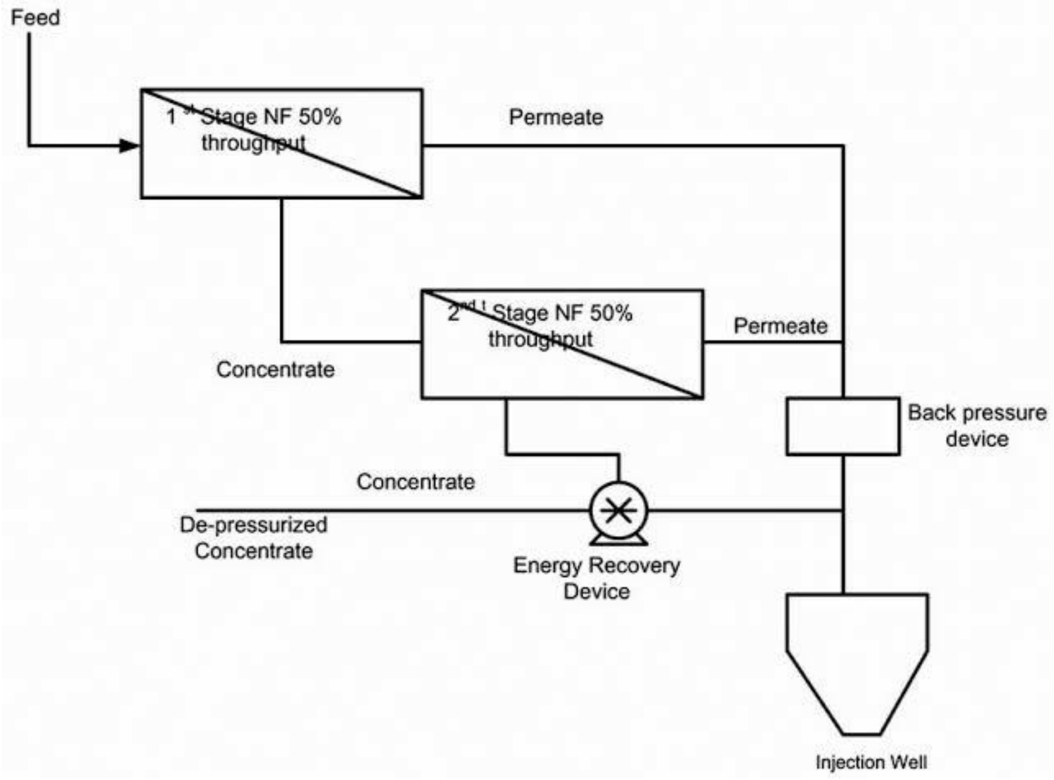

Fig 2. Nano Separation Process

4.4 REVERSE OSMOSIS

RO is a pressure driven method that is only permeable to water molecules and is used to remove dissolved chemicals and smaller particles. The pressure provided to RO must be adequate to allow water to pass the osmotic pressure. Higher penetrability, selectivity, and fouling resistance often improve RO membrane efficiency. It is one of the most advanced membrane separation methods available. The water is pushed under pressure and squeezed through a membrane, which filters out minerals and nitrate. RO retains almost all molecules except water, and the needed osmotic pressure is substantially higher than for MF due to the size of the pores. RO is a high pressure driven technique that desalts salt water. The disadvantages include the utilisation of high pressure, the high cost of RO membranes in comparison to other membrane processes, and their vulnerability to fouling. In some cases, a thorough preparation is required (Srinivasan et.al.2015). At relatively high pressures, reverse osmosis (RO) separates salts and small molecules from low molecular weight solutes (usually fewer than 100 daltons) utilising membranes with NMWLs of 1 kDa or below. The retention of sodium chloride is generally used to rate RO membranes, whereas the molecular weight of retained solutes is used to grade ultrafiltration membranes. Millipore water purification systems use both reverse osmosis and ultrafiltration membranes (Munir, 2006). In the food processing industry, the major application of RO is to concentrate, filter, and recover important components. RO may be used with other membrane separation technologies like as MF and UF. Because of evaporation, or even the absence of this stage, RO needs less operational expense (Hedrick, 1983; Merson et al. 1980). RO has been demonstrated to have much lower energy consumption than mechanical vapour compression. RO may also be used to pre concentrate fruit juices. Instead of high temperatures, this approach can be employed. As a result, the quality deterioration of the product caused by heat exposure is greatly decreased, and the procedure is less expensive (Kotsanopoulus et al. 2015).

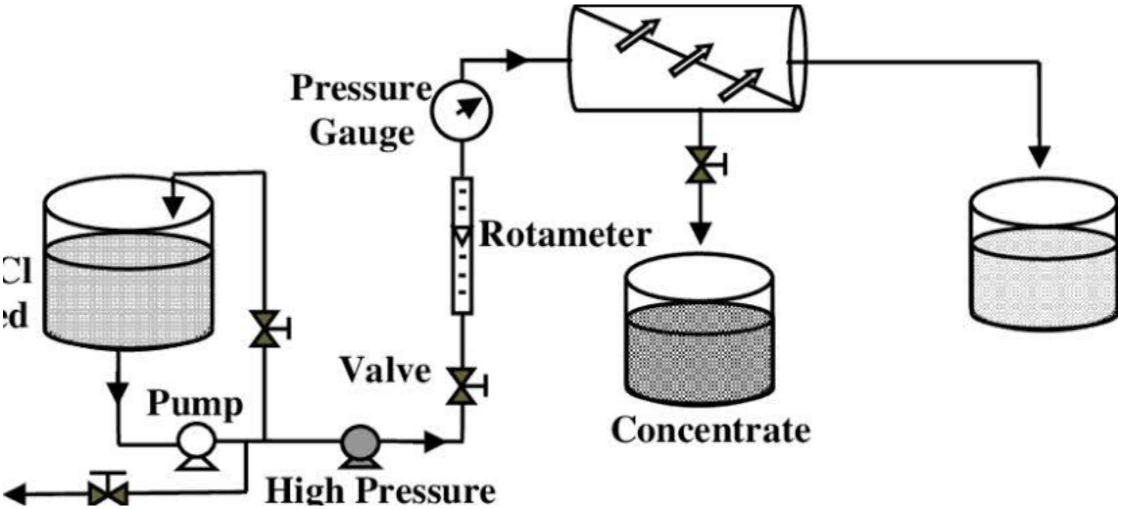

Fig 3. Reverse Osmosis Process

5. MEMBRANE FOULING

One of the most serious issues with utilising membrane to clear liquids is the deterioration of permeate flow, which is produced by the phenomenon known as fouling (Cassano et al., 2007; Barros et al., 2003; Ushikubo et al., 2007). To be a viable technology, the membrane process must reach acceptable permeate flux levels. Given that the principal foulants are insoluble pectic, cellulosic materials, and polygalacturonase, studies show that enzymatic treatment aids in increasing permeate flow. (Vaillant et al., 2001, 1999; Campos et al., 2002; Matta et al., 2000; Oliveira et al., 2010; Rai et al., 2007; Watanabe et al., 2006). Concentration polarisation (CP) causes fouling, such as cake layer development or organic pore clogging CP is a process that occurs when there is an increase in rejected component at the boundary layer near the membrane surface (Koseoglu et.al. 2018).

This can induce membrane degradation, resulting in a reduction in permeate flow and product water quality. Membrane scaling, on the other hand, happens when dissolved chemicals precipitate from the solution and aggregate on the membranes surface or lodge in its pores. Organic molecules larger than the pores of the membrane can produce adsorption on the surface, resulting in a blockage at the membrane's entry. After a time of operation of the membrane system, this obstruction creates a cake layer. This decreases the membrane's cross-sectional area and causes resistance in the membrane process (Vela et.al.2008). When it comes to cake filtration, the molecules are larger than the membrane pores and hence only deposit on the membrane surface. The intermediate blockage is often less restrictive and occurs as a result of the concurrent pore blocking and surface deposit phenomena (Iritani,2013). Humic acid (HA) or fulvic acid (FA) is a prevalent component in surface and saltwater, causing a cake layer to form on the membrane surface. The chemical has the potential to cause significant fouling. In addition to organic materials, inorganic chemicals such as mineral salt ($CaCO_3$, $CaSO_4$, $BaSO_4$, $SrSO_4$) and metal ions may cause fouling and scaling.(Alvarado et.al. 2016).

The TMP increases permeate flow, however the relationship is only linear when the supply is pure water. At higher pressures, the flux becomes independent of pressure, indicating that the system is in the mass-transfer-controlled area. The presence of a limiting flux, according to the gel polarisation model, is connected to the concentration polarisation phenomena that occurs when the feed solution is convected towards the membrane, where the separation of suspended and soluble particles from the bulk solution occurs. The creation of a viscous and gelatinous-type layer, in addition to the membrane, is responsible for an extra barrier to permeate flux (Conidi et.al.2015; Lutz, 2010).

Membrane fouling can also be linked to a decrease in flux caused by an increase in flow resistances, according to the resistance in series model (Jiraratananon & Chanachai, 1996; De Bruijn et.al.2002). The permeate flow (Jp) for is commonly expressed in terms of TMP and total resistance:

$$J = \frac{TMP}{\mu Rt}$$

5.1 FACTOR AFFECTING MEMBRANE FOULING

Membrane fouling is affected by several factors, including feed qualities (pH and ion strength), membrane characteristics (roughness, hydrophobicity, and so on), and processing parameters (crossflow rate, transmembrane pressure, and temperature) (Elimelech et.al. 2010). Several of these variables interact in some way to exacerbate membrane fouling.

5.2 CHARACTERISTICS OF MEMBRANES

Hydrophilic membranes, such as ceramic membranes, are less prone to fouling, whereas hydrophobic membranes, such as polymeric membranes, are more prone to fouling. During the operation, the rough surface creates a groove for colloidal particles to gather on the membrane surface, and fouling increases with increasing surface roughness. The larger the membrane pore size, the greater the likelihood of contaminant blockage and hence fouling (Liao et.al. 2018). Hydrophilicity increases the likelihood of membrane fouling, whereas hydrophobicity increases the likelihood of membrane fouling (Liu & Drews, 2010).

5.3 WORKING CONDITIONS

Higher aeration rates result in reduced membrane fouling rates. Low temperatures increase the likelihood of membrane fouling by releasing more bacterial extracellular polymeric substances (EPS) and increasing the load of filamentous bacteria.

A higher COD/N ratio in the feed reduces membrane fouling, improves membrane efficiency, and extends operating duration (Hila et.al. 2005). However, findings imply that a low COD/N ratio indicates less fouling. Fouling rises when HRT decreases. Excessive HRT, on the other hand, causes fouling agents to clump together (Vrouwenvelder et.al. 2006).

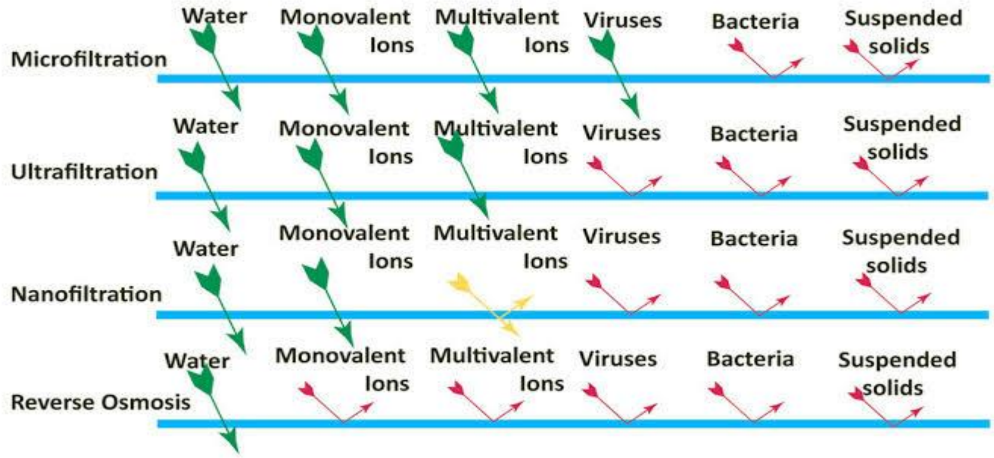

Fig 4. Working Conditions Process

5.4CHARACTERISTICS OF FODDER

Membrane fouling increases as floc size decreases. More membrane fouling is caused by bound EPS released as salt rises. A decrease in pH causes an increase in membrane fouling rates. Fouling is more likely when the EPS concentration in the feed is high. Increased viscosity causes membrane fouling (Chang et.al 2002).

6. METHODS FOR CLEANING MEMBRANES:

Because separating material and impurity might deposit on the membrane's surface, the membrane can get contaminated and clogged. As a result, the system must include a procedure for cleaning the membrane. There are numerous membrane cleaning methods available, including forward flush, reverse flush, and air flush. Effective cleaning is one of the most significant strategies and means of extending the life of a product. Chemical cleaning and manual cleaning are among the cleaning procedures available (Karode et al., 2001).

Cleaning processes, such as cleaning frequency and backwash duration, must thus be adjusted to reduce the negative impacts of cleaning agents on membrane life, the expense of procuring and disposing of cleaning chemicals, the quantities of water consumed and wastewater created, and the disturbance to regular manufacturing activities (D’souza & Mawson AJ,2005; Madaeni & Mansourpanah, 2004). The cleaning operation must remove fouling deposits while also restoring the equipment's normal capacity (typically measured as demineralized water flow) and separation characteristics (Madaeni et.al. 2010).

Sequestering compounds (e.g., EDTA, polyphosphates) can be added to low-quality water to improve the solubility of metal ions such as calcium, magnesium, manganese, and iron [202]. When the above-mentioned cleaning procedures are ineffective in restoring the flux to an acceptable level, the membranes must be chemically cleaned. Membranes are bathed in a solution of strong acids and bases, such as hydrogen chloride (HC1) or sodium hydroxide (NaOH), or disinfectants, such as hypochlorous acid, during chemical cleaning (HOC1). Effective chemical cleaning restores the original flow, allowing the membrane to be used again (Kuzmenko et.al.2004, 2005).

7. APPLICATION OF MEMBRANE TECHNOLOGY IN JUICE INDUSTRY

Conventional methods of fruit juice clarity entail several procedures such as enzymatic treatment (depectinization), chilling, flocculation (gelatin, silica sol, bentonite, and diatomaceous earth), decantation, and filtering, all of which are labor-intensive and time-consuming. Furthermore, these approaches rely on the use of large volumes of coadjuvants and additives, which has a number of disadvantages, including the danger of dust inhalation with subsequent health concerns caused by handling and disposal, environmental issues, and high expenditures (Vaillant et.al.1999).

The viscosity of the raw juice, the retention of certain chemicals, the sterilising ability, and the membrane investment costs should all be considered when selecting UF and MF membranes for fruit juice clarification. For pulpy juices with high particles content and viscosity, vibrating membrane systems, plate and frame modules with large spacers, or large-bore tubular modules are preferred. However, the tubular form is linked with poor packing density and high membrane replacement costs. In contrast to other membrane arrangements, hollow fibre membranes have the benefit of a high membrane area per volume unit of module, low production costs, and simple handling. This leads into space reductions, increased productivity, and cost savings associated with maintenance, as these modules may be back-flushed (Chung et.al. 2000).

Because the separation process does not require heat or the use of chemical agents, MF and UF are very effective at preserving juice freshness, aroma, and nutritional value while producing high-quality, natural, freshtasting, and additive-free products (Qaid et.al.2017). The juice is separated into a fibrous concentrated pulp (retentate) and a clarified fraction that is free of spoilage microorganisms and completely stable in these processes (permeate). These membranes enable low molecular weight solutes (sucrose, acids, salts, fragrance and taste chemicals) to pass through while retaining large molecular weight molecules (pectin or proteins).

The use of membrane technology in the manufacturing of fruit juices fits well with the current sustainable food processing (SFP) methods, which are focused on the use of low energy and low impact environmental processing schemes. Furthermore, because of the moderate operating temperatures, membrane treatment does not degrade product quality as much as standard heat processing .The world market for membrane technology for food and beverage processing is expected to reach $8.26 billion by 2024, rising at a CAGR of 6.8 percent during the projected timeline.(Samborska et.al.2018)

The benefits of adopting membrane technology in the beverage sector include economics, working conditions, the environment, and product quality (Koseoglu et al., 1990; Hagg, 1998). The juice is mostly processed following enzymatic pulping. This pre-treatment of juices prior to membrane layer filtration is typically required to increase filtering overall performance. In particular, enzyme combinations known as pectinases are utilised to hydrolyze pectin directly into poly-d-galacturonic acidity fragments, lowering the viscosity of the juice with relatively low pulp and leading in an increase in penetration fluxes as well as yield recovery (Alvarez et al ., 1998).

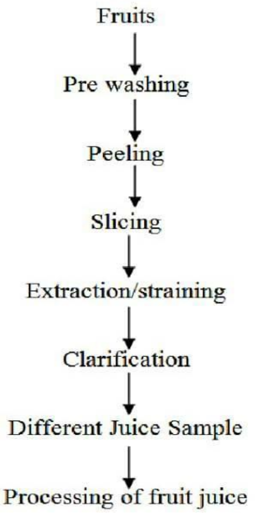

Fig 5. Juice Separation flow chart

CONCLUSION

Since the introduction of membrane technology into the food processing business four decades ago, the number of applications and membrane surface area has grown rapidly. Among the causes for this tendency are:

i) Membrane separation processes can be used as alternatives to traditional processing methods, allowing for more economical production and higher quality products in terms of both technological functionality and nutritional value.

ii) Membrane techniques can be used to create products and ingredients with desirable properties that conventional techniques cannot provide.

iii) Membrane methods enable the recovery of valuable components from diluted effluents, byproducts, and wastewater. These applications provide additional benefits to manufacturers.

iv) Membrane filtration are an excellent wastewater treatment method, particularly because penetrated water from some membrane filtrations may be reused in manufacturing processes.

Membranes are causing significant changes in the juice business, and future advances will decide if such membrane-based processes can achieve the requisite product quality, purity, yield, and throughput while staying economically viable for the fruit juice sector.

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Conflict of Interest:

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Author Contribution

All author contributed equally to establishing the research and design experiment topic.

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