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# Membrane separation in the sugar industry

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**ABSTRACT**

*As we know, the sugar technologists are being under pressure to eliminate the industrial pollution, upgrading the quality of sugar with optimizing the energy consumption. This requires modification of the conventional production process using new techniques such as membrane technology. Membrane technology is currently a standard process in food and dairy industry, water purification, treatment of liquid effluent streams, and in the corn refining industry. In the few last years, researches have proven that the membrane technology could hold great promise in reducing energy usage, reduction, or elimination of chemical clarification and improved final product quality. This paper reviews the potential application of membrane filtration to the sugar technology.*

**Key words:** sugar industry, membrane separation, Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), Reverse Osmosis (RO), Electrodialysis (ED)

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## INTRODUCTION

Sugar processing, which is one of the most energy intensive processes in the food industry, is a challenge for membrane separation processes like Microfiltration (MF), Ultrafiltration (UF), Nanofiltration(NF), Reverse Osmosis (RO) or Electrodialysis (ED). Moreover, due to high volumes pumped, high viscosity, and high osmotic pressure of sugar juices some limitations exist, and inhibit the extension of membrane separation methods to sugar production [1].

The sugar industry has long maintained an interest in the application of membrane filtration for both quality improvements and as a pre-treatment for processes to produce value-added products. Since the early work of Madsen (1973), sugar industry research organizations, commercial manufacturing and membrane supplying companies and sugar milling companies have been actively involved in the assessment of the benefits of membrane filtration systems and the installation and development of pilot plants into sugar factories [2].

Steindl (2001) provided a summary of data available from investigations undertaken at several sites around the world. Those investigations concluded that membranes would remove polysaccharides, turbidity and colloidal impurities and result in lower viscosity syrups and molasses, provide higher growth rates and improve exhaustion. The consensus from previous investigations proved that membrane filtration was not economically viable due to high capital and operating costs. However, any economic analysis has to be based on the economic environment under which a particular factory is operating and the reasons why the installation of a membrane plant is being considered [2-3].

The purpose of this paper is to review possible applications for membrane technology in sugar industry based on the sugar processing technology and recent experimental results.

### II. Process of beet sugar

The major steps in the traditional sugar beet processing are (Poel Van der et al., 1998):

- **Pre treatment**: Washing and slicing of the sugar-beets into cosettes are the initial Operations.
- **Extraction:** The sugar is counter-currently extracted from beet cosettes to obtain raw juice and beet pulp. The raw juice is thermally unstable at temperatures above 85°C. The beet pulp can be used as cattle feed or can be modified to obtain fibers for human feed.
- **Beet juice purification**: Milk of lime and carbonation gas $CO_2$, both produced in a separate facility, are applied. Coke and limestone are used for the production of CaO and $CO_2$. The lime usage of the conventional process is about 2%/beet. Classical juice

Purification consists of liming, carbonation, sludge separation and sulphitation. However, this process removes only a part of non-sugars from the sugar juice (proteins, pectins, inorganic salts and coloring substances).

- **Beet juice concentration**: By multi-effect evaporation the thin juice with a dry substance content of 14-16% is concentrated to thick juice with 60 – 75% of dry matter.
- **Crystallization**: Further evaporation of water leads to crystallization and growth of crystals. Sugar crystals are separated by centrifugation from the syrup. The separation occurs in three stages. The molasses is the by-product from which the crystallization is not possible [4].

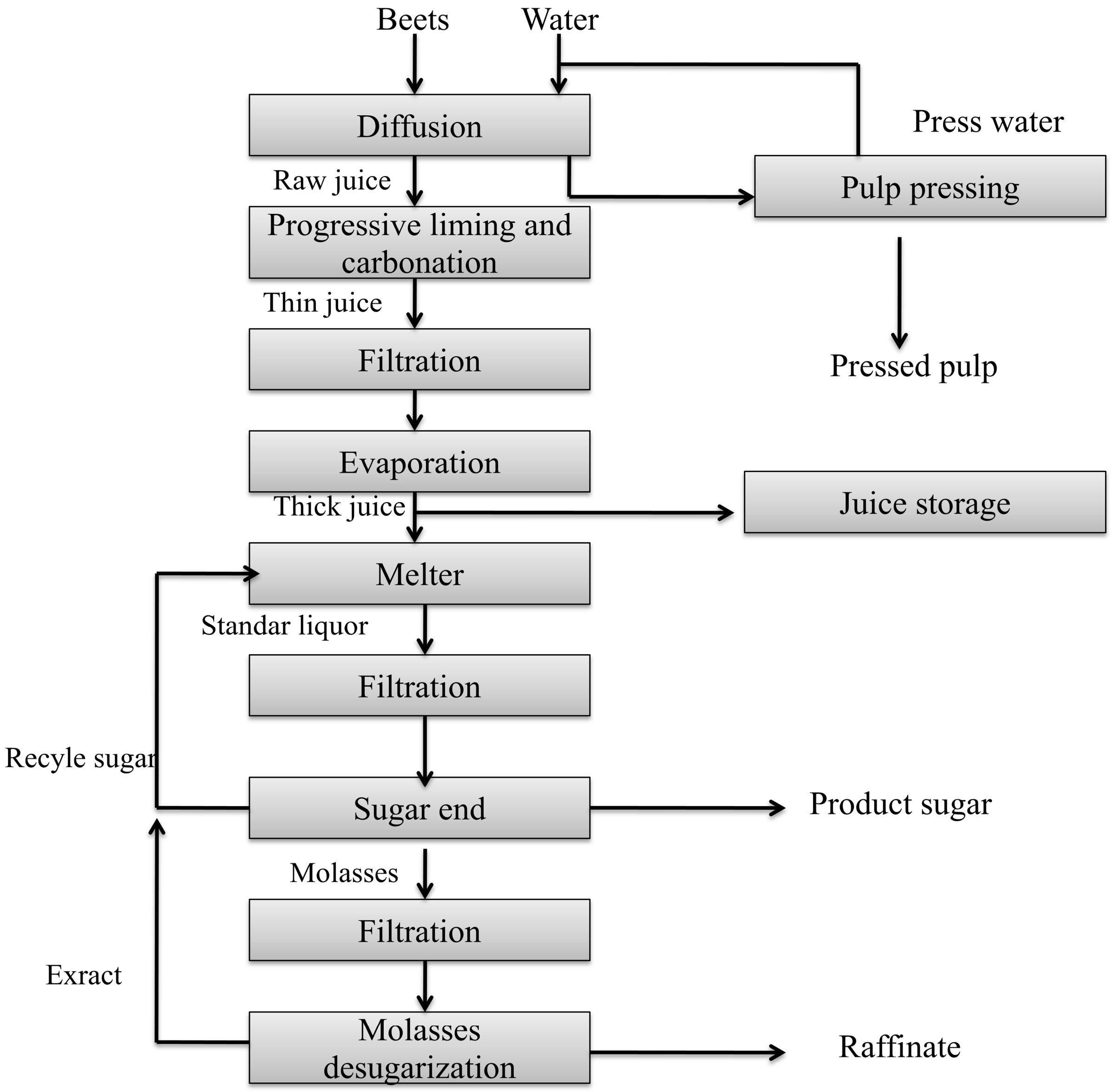


**Fig 1: Block diagram of Beet Sugar Process [5]**

**♦ Specific features of sugar industry applications**

Applications in the sugar industry impose specific requirements on membrane characteristics. The parameters affecting membrane performance and durability are discussed below.

**Table 1: Parameters affecting membrane performance [5]**

| Parameters | Characteristics |
|---|---|
| **Temperature** | Most sugar solutions should be filtered at the highest possible temperature to reduce viscosity and prevent bacterial growth on the feed side of the membrane, 85-95°C. |
| **Suspended Solids** | The concentration of suspended solids in the beet juice depending on the pretreatment may be up to 1-2 % wt. |
| **Abrasive particles** | In the pretreated raw beet juice the concentration of acid insoluble material may reach as high as 20-30% of total suspended solids. |
| **Sugar losses** | High concentration factors are required to minimize sugar losses in the retentate streams. It is not uncommon to operate a membrane system at concentration factors of 50 to 100 and use diafiltration or other desugarizing process on the remaining stream. |
| **High Flux** | Fluxes ranging from 50 to 400 (liters/$m^2$/hour) are reported for various membranes and concentration factors. |
| **Composition of feed** | Composition of the solution and suspended solids content in the feed material may vary significantly during the operating season. The content and quality of suspended solids also changes depending on efficiency of pretreatment operations. |
| **Unstable feed material** | It is important to realize that industrial sugar solutions are quite unstable. Significant sugar losses may be experienced if solutions are stored for more than one or two hours due to bacterial or other mechanisms of degradation. Potential color formation is another factor that is related to excessive storage. |

## ♦ Membrane process filtration

The membrane processes have been involved with major revolutions in industry branches such as petroleum, gas, pharmacy, biotechnology, water, wastewater, food processing and medicine.

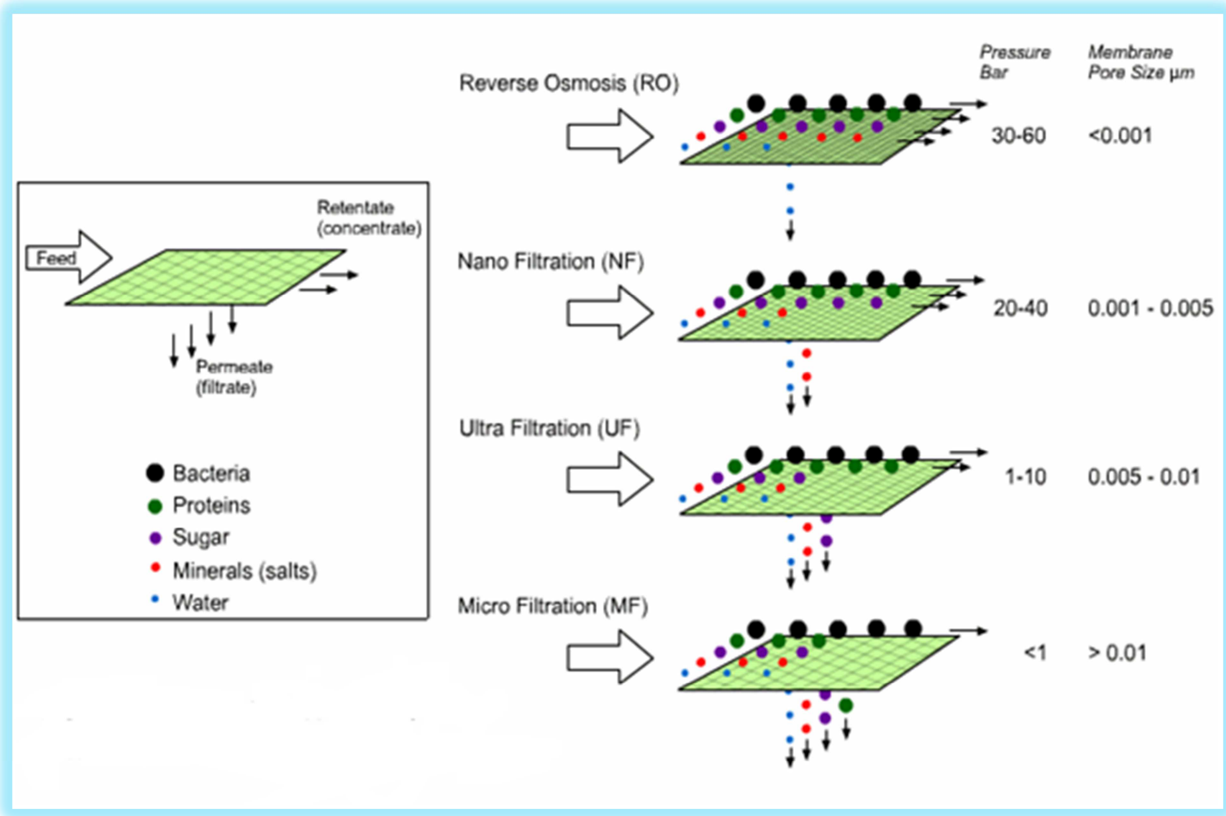


**Fig 2: Nominal Molecular weight cut off of different Membrane types**

Sugar industry is one of the most energy-intensive processes in the food chemical industries; therefore, membrane scientists have extensively investigated it in the last decade.

A review of the pioneering studies on the application of the membrane systems in sugar industry was compiled by Nielsen et al. [6], Kishihara et al. [7], Gekas et al. [8] and Cartier et al.[9]. Several areas of application of the membrane systems were identified in these studies. These include treatment of juice after liming by UF; treatment of thick juice after evaporation by UF; treatment of molasses by ED or UF;treatmentof raw juice by UF.

**III. Integration of membrane Separation**

- **Reverse Osmosis (RO)**

Reverse osmosis (RO) is a membrane-technology filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. RO filtration membranes are used in sugar industry.

In a research carried out by Bichseland al., sugar syrup was concentrated from 13 to 30 percent using PA300 and FT30 RO membranes. These membranes can be used at high temperatures (50 to 90°C) with two advantages: firstly, microorganisms cannot grow at high temperatures and secondly, the outlet flux of the membranes is higher at high temperatures. . In a patent by Tsukamoto, the RO method has been applied to concentrate a water-glucose solution from 110 g/l to 200 g/l. As studied by Kulkarni et al. concentrating a solution containing sucrose is a feasible application of membranes in the sugar industry.

- **Microfiltration (MF)**

Microfiltration is defined as the filtration of a suspension with colloidal or other fine particles having a linear dimension of roughly 0.02 μm to 10 μm. Microfiltration is a pressure-driven process in which a membrane is applied to separate particles from an aqueous solution. Typical operating pressure for microfiltration is relatively low, lying between 0.02 MPa and 0.5 MPa.MF membranes can be used to remove non-sucrose compounds, or to fractionate the retentate rich in colorants.

In the study by B.Farmani and al (2008), the MF process is found to be effective on turbidity and color reduction of clarified sugarcane juice. Continued experiments showed optimum conditions of 70°C and 1.5 bars for the MF of clarified sugarcane juice. Experiments in 70°C and 1.5 bars reduced turbidity, viscosity and color by56.25%, 16.67% and 6.49%, respectively, and increased purity to about 0.87 units. Removing turbidity, viscosity and color were possible with a ceramic MF process (0.2 μm) without addition any chemical substances.

- **Electrodialysis (ED)**

Electrodialysis is an electrochemical membrane separation technique for ionic solutions that have been used in industry for several decades. It can be used in the separation and concentration of salts, acids, and bases from aqueous solutions, the separation of monovalent ions from multivalent ions, and the separation of ionic compounds from uncharged molecules. It can be used for either electrolyte reduction in feed streams or recovery of ions from dilute streams. [12]

Electrodialysis (ED) represents a modern progressive electromembrane separation technology gaining recently an increasing attention in various branches of industry, like sugar industry.

In a research carried out by A. Elmidaoui and al.(2002) an electrodialysis operation using an improved stack with new anion-exchange membranes was conducted on Moroccan beet sugar syrup to remove melassigenic ions especially $Na^+$, $K^+$ and $Ca^{2+}$. The demineralization was operated at a relatively high Brix up to 55 Bx and high temperature up to 60°C. The alkali resistance and behavior of the AXE01 membrane in the sugar syrup were controlled. The electrodialysis is a promising process to reduce the melassigenic ions for the sugar industry.

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- **Ultrafiltration (UF)**

Ultrafiltration (UF) is a membrane separation technique used to separate extremely small particles and dissolved molecules in fluids. The primary basis for separation is molecular size, although other factors such as molecule shape and charge can also play a role. Molecules larger than the membrane pores will be retained at the surface of the membrane (not in the polymer matrix as they are retained in microporous membranes) and concentrated during the ultrafiltration process. UF can be applied to concentrate the relevant juices in sugar industry and to remove non-sucrose compounds.

P.K. Bhattacharya and al, were using three different membranes of UF (Spectra Por 10 K (M1) and 20 K (M3); commercial diffused cut-off 15K (M2) membranes). The filtration studies were carried out in order to retain selectively the solids and not the sugar compounds, present in juice as well as maximizing the flux. Permeate flux and retention of sugars as well as total dissolved solids in permeate stream were measured. Performances of these membranes were evaluated in terms of permeate flux and its quality. It was observed that the permeate flux obtained using M1 membrane was higher than M2 and M3 for most of the operating conditions. However, the retention of sugars was minimum for M3 membrane, which is desirable. A modified resistance-in-series model has been used to analyze both short and long term flux decline behavior under various operating conditions.

- **Nanofiltration (NF)**

Nanofiltration is a filtration process in which a fluid is encouraged to pass over a membrane, which acts almost like a sieve to separate out impurities. The membrane blocks impurities in the fluid, allowing only the fluid and certain monovalent ions to pass through while trapping undesirable materials on the other side.

Nanofiltration membranes have selective permeability for minerals and some small organic and inorganic molecules and NF is used predominantly for concentration and pre-demineralization of juices and waste water in sugar industry.

S.M. Mousavi and al. used ultra and nano membranes (UF10kDa, UF5kDa, N30F) in molasses. The results show that both the ultra and nano membranes have clarified the permeate solution but the rejection for N30F membrane was the greatest, around 0.8 and after that UF5kDa membrane had higher rejection than UF10kDa membrane. For N30F membrane, Brix, viscosity and sucrose concentration in permeate flow decreased. So by evaluating used membranes on separation of sugar from molasses, it was resulted that N30F membrane is the more appropriate.

## CONCLUSION

Membrane separation is applied in food and chemical industry for several decades but its application in the sugar industry is still under investigations, Aware of the fact that membrane separations have a great potential, many scientists are dealing with their adjustment to the requirements of sugar-industry.

This publication provides a review of the results on the purification of sugar beet juices and sugar cane juice by membrane separation, mainly at laboratory level. Despite the encouraging nature of these results, very few large-scale membrane separation processes have been applied in the sugar industry in the world. One of the biggest weaknesses is a progressive decrease in the permeate flux through the membrane caused by the precipitation of macromolecules released on the surface of the membrane. Of all the hydrodynamic methods used to improve mass transfer in membrane filtration, an increase of the flow velocity is the easiest way to create turbulence and reduce membrane fouling; such an increase may be obtained by applying - static turbulence promoters- static mixers.

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