

DEHYDRATION OF ALOE VERA JUICE BY MEMBRANE DISTILLATION**¹S.K. Dershmukh*, ²Dr. V.S. Sapkal, ³Dr. R.S. Sapkal**

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Aloe vera polysaccharides have traditionally been used in Asian cultures as medicinal plants to enhance immunity and reduce oxidative injury. The current investigation was conducted to examine the effects of temperature on A. vera polysaccharides and its retention during concentration process. This paper objective is to realize DCMD experimental tools and to study the effect of following operating parameters, feed temperature, feed flow rate, feed concentration, and membrane materials. The flux of 14- 18 Kg/m² hr was achieved and polysaccharide retention was greater than 68 % with flat sheet PTFE membranes of 0.2 μm pore size for Aloe Vera juice. Flux decline over time was observed, but it was more significant at high concentration.

Key Words: Direct Contact Membrane Distillation, Aloe Vera Juice, polysaccharides, Flux Decline.

1. INTRODUCTION

Since 1986 *Aloe vera* has been used as a traditional medicine and as an ingredient in many cosmetics products. It has gained high importance for its diverse therapeutic properties. The plant, being a succulent plant, contains 99.5 per cent water and the remaining solid material contains over 75 different ingredients including vitamins, minerals, enzymes, sugars, anthraquinones or phenolic compounds, lignin, tannic acids, polysaccharide, glycoproteins, saponins, sterols, amino acids and salicylic acid. The advantages of the concentration of the liquid foodstuffs include the reduction in packaging, storage, transport cost and prevention of deterioration by microorganisms. Now, the processing of aloe vera gel, derived from the leaf pulp of the plant, has become a big industry worldwide due to the application in the food industry. It has been utilized as a resource of functional food, especially for the preparation of health drinks which contain aloe vera gel and which have no laxative effects. It is also used in other food products, for example, milk, ice cream, confectionery, and so on. However, aloe vera gel juice was not very popular due to their laxative effect and majority of them contained absolutely no active mucilaginous polysaccharides or acemannan in China. Although color changes have little relation to the therapeutic effectiveness of stabilized gel, they are rarely acceptable psychologically to the user. The color change is totally unacceptable in some products. It therefore becomes imperative that a simple but efficient processing technique needs to be developed, especially in the aloe beverage industry, to improve product quality, to preserve and maintain almost all of the bioactive chemical entities naturally present in the plant during processing.

For these reasons, many concentration techniques have been developed and used for the food industries. They include evaporative concentration, freeze concentration, and membrane processes such as reverse osmosis (RO) and ultrafiltration (UF).

Nevertheless, when concentration is carried out by traditional multi step vacuum evaporation, a severe loss of the important components occurs as well as a partial degradation of polysaccharides and natural antioxidants, accompanied by a certain discoloration and a consequent qualitative decline. These effects are mainly attributable to heat transfer to the juice during evaporation. In order to overcome some of these problems and to better preserve the properties of the fresh fruits, several new “mild” technological processes have been proposed in the last years for juice production. Membrane Distillation has many significant advantages, such as high system compactness, possibility to operate at low temperatures (30–90 °C) which makes it amenable for use with low temperature heat sources, including waste or solar heat, and, when compared with say reverse osmosis or electrodialysis, the simplicity of the membrane which allows it to be manufactured from a wide choice of chemically and thermally resistant materials, and much larger pores than of reverse osmosis membranes (and typically larger than in ultrafiltration membranes, that aren't nearly as sensitive to fouling).

2. EXPERIMENTAL

2.1 Module Development: The membrane module design for this work is unique in that it can use flat-sheet membranes without support. Additionally, the membrane module and associated apparatus were designed to achieve relative high feed and permeate Reynolds numbers within the module. Cross flow module of hydrophobic PTFE 0.2μm has been developed with the help of viton gasket, polyester mesh and adhesive. Module has length

11.5cm, breadth 10 cm and hydraulic diameter 2.28 mm is supported with stainless steel holding device. Module has effective membrane area 0.0115m².

2.2 Experimental set up: Concentration of feed solution by DCMD was carried out using a flat-sheet membrane cell with an effective membrane area 0.0115 m². The membrane cell was made of stainless steel and was placed in a vertical configuration. The system to be studied consists of a porous hydrophobic membrane, which is held between two symmetric channels. Hot feed is circulated through one of the channels and cold permeate through the other one. The hot and cold fluids counter-flow tangentially to the membrane surface in a flat membrane module. In our experiments, the membrane is sandwiched between two equal stainless steel manifolds. Microporous hydrophobic membrane of 0.2 µm pore size and thickness 160 - 200 µm was placed between polyester mesh (0.28mm), polyviton gasket (3 mm) on both side which create the two identical flow channels, the membrane and the manifolds create spacer-filled flow channels for hot feed and cold permeate liquids.

Feed tank with thermostat, peristaltic pump and temperature and flow indicator is arrange in feed side, where as peristaltic pump, and temperature and flow indicator is arrange in permeate side. Module is supported with stainless steel holding device. The schematic arrangement is shown in Fig.2.1 juice as feed solution and distilled water as receiving phase were contained in two jacketed reservoirs and were circulated through the membrane cell by one two-channel peristaltic pump. The feed and distillate streams flow counter currently from the bottom to the upper part of the membrane cell. Different experiments were carried out for fixed temperatures in the membrane module. The average feed temperature T_f varied for the different experiments from 40 to 70°C and permeates temperature T_p varied for the different experiments from 20 to 30°C. The linear velocity feed and permeate was also varied. Different experiments were carried out applying different recirculation rates.

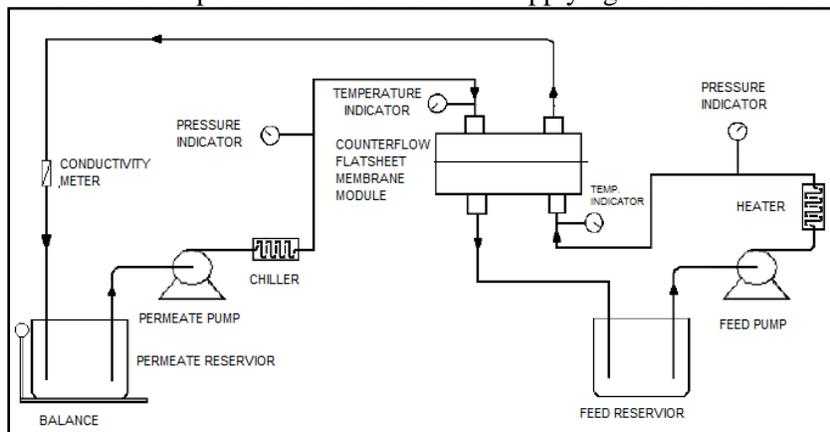


Figure 2.1 Flow Diagram of Direct Contact Membrane Distillation

3. RESULT AND DISCUSSION

3.1 Feed solutions: Aloe vera for the experiments was available for this investigation at the Botanical Garden, Rajasthan. Fresh whole leaves, of between 30 and 50 cm length corresponding to 3-yr old plant, were washed and sliced to separate the epidermis or skin from the parenchyma filet. The filets, were cut into cubes and blended in food processor at low speed and squeezed through a 200-mesh screen. Aloe vera gel juice was then centrifuged at 4800 rpm (Universal Centrifuge DL-5, Shanghai, China) for 10 min to discard the callus and foam. Fresh Aloe vera gel juice was used for experiment having concentration 4.4 Brix and polysaccharide content 2.7 mg/ml. Fresh Aloe vera juice (*A. barbadensis* Miller) for the experiments was used as the raw material in all experiments.

3.2 Effect of temperature on polysaccharide content in Aloe vera juice: Capped flask (200 ml) with approximately 120 ml Aloe vera gel juice was immersed in a SC-15 thermostatic water bath and heated at 50 °C, 60 °C, 70 °C, 80 °C and 90 °C, respectively. Fractions (10 ml) were taken at different time intervals and then centrifuged at 4800 rpm for 10 min. Aliquots (2 ml) of the supernatant were assayed for polysaccharide. Five different temperature treatments were used, 50 °C, 60 °C, 70 °C, 80 °C and 90 °C. The changes, which affected the polysaccharides of gel juice from Aloe vera during heat processing, were evaluated. Sample was taken after 2 h, the relation between the polysaccharide content and time at different heating temperature of the Aloe vera gel juice has been represented in Figure 3.1.

Polysaccharide content was estimated by a colorimetric analysis. 100 mL of Aloe vera Juice were taken in a beaker and the samples were vacuum filtered. The filtrate was diluted to 100mL in a beaker according to the

methodology suggested by Hu et al. (2003). Two milliliters of the solution and 10mL of absolute ethanol were added in plastic tubes; samples were centrifuged at $2500\times g$ for 30 min, and the supernatant was removed; the precipitate was dissolved in a final volume of 50mL water. One milliliter of the filtered solution, 1mL of phenol at 5 g/100 mL, and 5mL of concentrated sulphuric acid were added to the tops of the tubes. It was allowed to settle for 30 min. Sample absorbance was determined at 490nm (Spectronic 20 GenesysTM, IL, USA). Total polysaccharide content was estimated by comparison with a standard curve generated from d-+-glucose analysis.

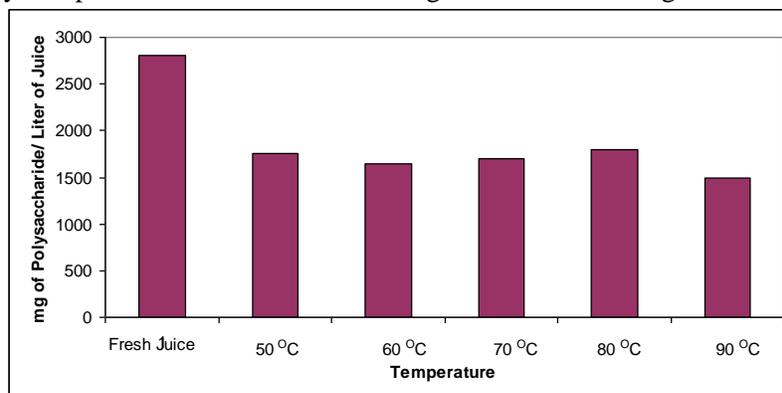


Figure 3.1: Effect of temperature on polysaccharide content in Aloe vera juice.

3.3 Experimental Results: Within an MD process, water flux is known to be proportional to the vapour pressure difference on either side of the membrane, which is imposed by a temperature difference in DCMD. Membrane hydrophobicity and physical characteristics, along with flow rate through the membrane module and input temperatures are key parameters of MD performance. With these parameters in mind, the following series of experiments sought to explore the limitation of the new membranes with respect to overall water flux. The effect of various process parameters such as feed flow rate, permeate flow rate, feed temperature, permeate temperature, temperature difference and concentration on transmembrane flux has been experimentally studied and discussed in the following section.

3.3.1 Effect of Feed Velocity: Effect of feed flow rate on transmembrane flux for Aloe Vera juice is estimated and presented in Figure 3.2. During experiments, the feed side flow rate is varied between 60 to 120 L/hr and permeate side flow rate (30L/hr), Feed temperature (40 °C), Permeate temperature (20 °C), temperature difference ($\Delta T = 20$ °C), and concentration was maintained constant (4.4 °Bx). The transmembrane flux increases with increase in flow rate. The increase is mainly due to the reduction in temperature polarization and fouling phenomenon. Figure 8.8 shows as the permeate flux increase when the recirculation rate increases. The effect of high recirculation rate is to increase the heat transfer coefficient and thus reduce the effect of temperature polarization. This means that the temperature at the membrane surface more closely approximated to the bulk temperature, and thus the transmembrane temperature difference is greater. This produces greater driving force and consequently enhanced the flux.

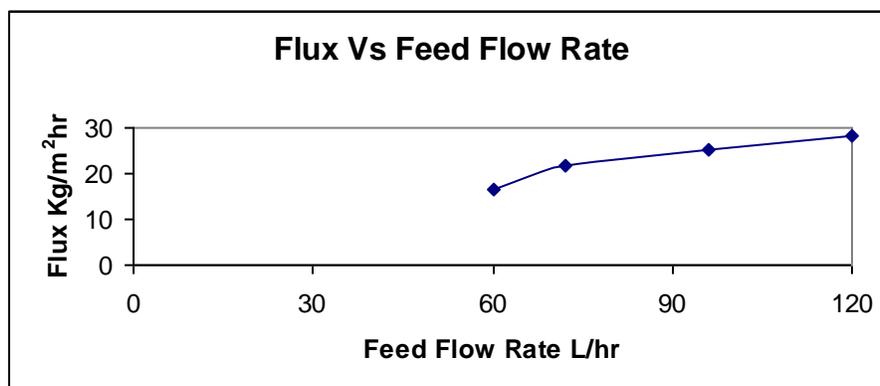


Figure 3.2: Effect of feed velocity on transmembrane flux using PTFE membrane (Permeate flow rate 30L/hr, Feed temperature 40 °C, permeate temperature 20 °C and 4.4 °Brix)

3.3.2 Effect of feed temperature: The effect of the feed temperature on permeate flux has been investigated in the DCMD configuration. The feed temperature has been varied from 30 to 45 °C (below the boiling point of the feed solution) maintaining all other MD parameters constant. Figure 3.3 shows that in DCMD configuration there is an exponential increase of the MD flux with the increase of the feed temperature. This is due to the exponential increase of the vapor pressure of the feed solution with temperature, which increases the transmembrane vapor pressure (i.e. the driving force) as all the other involved MD parameters are maintained invariables. It was stated that it is better to work under high feed temperature as the internal evaporation efficiency, defined as the ratio of the heat that contributes to evaporation and the total heat exchanged from the feed to the permeate side is high although the temperature polarization effect increases with the feed temperature.

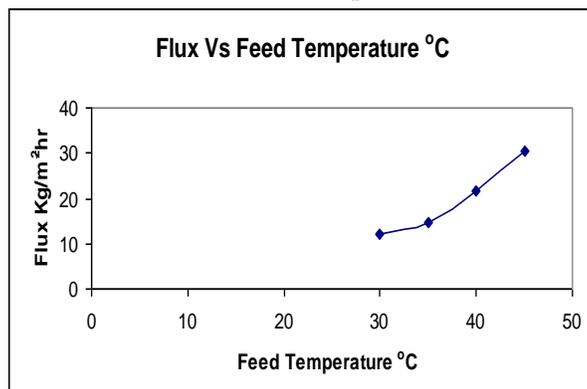


Figure 3.3 : Effect of feed temperature on transmembrane flux using PTFE membrane (Feed flow rate 72 L/hr, Permeate flow rate 30L/hr, permeate temperature 20 °C and 11.5 °Brix).

3.3.3 Effect of Feed concentration: The concentration of Aloe Vera juice was varied over 4.4 – 8.4 °Brix. During the experiments the feed flow rate (72L/hr), permeate flow rate (30L/hr), feed temperature (40 °C), permeate temperature (20 °C) and temperature difference (20 °C) are maintained constant. The values of transmembrane flux observed at different concentration of feed solution and are shown in Fig. 3.4. The transmembrane flux decreases with increase in concentration. This is due to increase in concentration and temperature polarization and thus decrease the driving force. Accordingly, concentration polarization may be significant at high concentration, high temperature and low feed velocity. In other words, the evaporation rate of water at the membrane surface decreases with increase in concentration Flux decline with time was observed, but it was more significant at a high concentration.

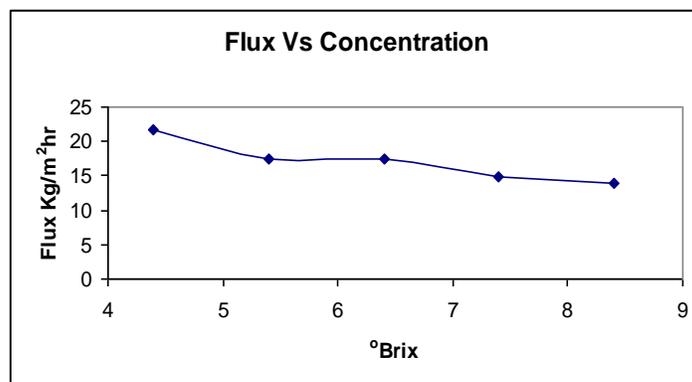


Figure 3.4: Effect of feed concentration on transmembrane flux using PTFE membrane (Feed flow rate 72 L/hr, Permeate flow rate 30L/hr, permeate temperature 20 °C and feed temperature 40°C)

3.3.4 Effect of temperature difference: Fig.3.5. show the results obtained at four constant temperatures of juice in the hot cell (30°C, 35°C, 40°C and 45°C) with constant cold cell temperatures (20°C). During experiments the feed (72L/hr) and permeate velocity (30L/hr) were maintained constant. The flux increased exponentially with temperature. The temperature difference creates vapor pressure difference and thus the membrane distillation flux rises. This leads to water vapor diffusion through the membrane.

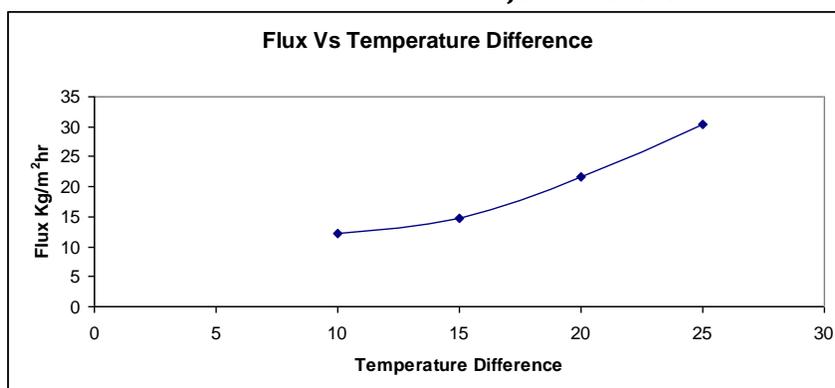


Figure 3.5: Effect of Temperature Difference on transmembrane flux using PTFE membrane (Feed flow rate 72 L/hr, Permeate flow rate 30L/hr, permeate temperature 20 °C and 4.4 °Brix)

3.3.5 Flux Declining Rate: In addition to above experiments, another experiment was performed to study flux decline rate with respect to time. With feed at flow rate 72 L/hr, permeate flow rate 30L/hr, Temperature difference 20 °C, feed temperature 40 °C and permeate temperature 20 °C. The aim of these experiments was to study the flux decay in membrane distillation. The result indicates that it was possible to consistently remove water at steady value of approximately 14- 18 Kg/m² h. Flux decline over time was observed, but it was more significant at high concentration. This suggests a possible effect of both concentration and temperature polarization. Accordingly, concentration polarization may be significant at high concentration, high temperature and low feed velocity. The flux was found around 16 Kg/m² h and has not decreased significantly for first 24 hours. It value started to drop when the juice concentration has reached 8 °Brix levels during the measurement due to the significant viscosity increase.

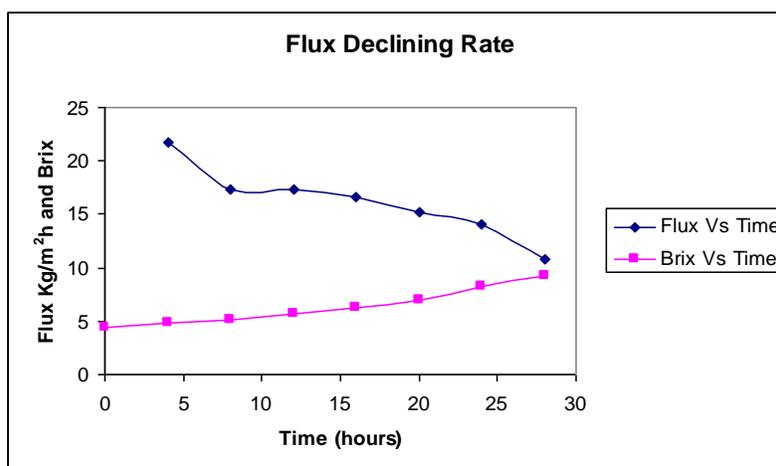


Figure 3.6: Flux Decline Rate.

4. Conclusion: Experimental studies have been carried out and the effects of the involved parameter on the flux have been investigated. Membrane distillation experiments shows that transmembrane flux gradually increases with increase of feed juice temperature at constant flow rate and constant permeate temperature. At lower temperature difference across the membrane, the transmembrane flux decreases as expected due to lower vapor pressure difference between feed and permeate. The increase in feed flow rate could increase the transmembrane flux in the membrane distillation process, reducing concentration polarization and fouling phenomenon. The transmembrane flux decrease with an increase in juice concentration. The flux decay observed at high concentration is related mainly to the significant increase in juice viscosity. Performance testing found that at feed temperature of 40°C and permeate cycle temperature of 20°C, water flux of 15 – 20 L/m²hr and polysaccharide retention was greater than 68 % were achieved with flat sheet PTFE and PVDF membranes of 0.2 µm.

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