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Effect of Pre-treatment on Aggregation, Biochemical Quality and Membrane Clarification of Pineapple Juice

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Abstract: Pineapple (*Ananas comosus* L., Merril) is the most popular tropical non-citrus fruits, mainly because of their attractive aroma, refreshing flavour and Brix/acid ratio. The research was carried out on the physicochemical analysis and membrane clarification of pineapple juice after pretreatment. Pretreatment of pineapple juice was performed using egg albumin with different concentrations and observed that 2 g/L concentration gave effective removal of colloidal substances of pineapple juices. The biochemical analysis of pineapple juice after pretreatment revealed TSS, colour intensity, browning index, turbidity, titrable acidity, pH, viscosity, total antioxidant activity, total phenolic content, total anthocyanin content, reducing sugars, non-reducing sugars, total sugars and colour were 13.255%, 8.254, 6.024, 0.782, 3.357%, 4.813, 2.33cP, 20.202 mg/g, 60.231 (mg of GAE/g of dry material), 0.7744mg/100mL, 7.605%, 1.951%, 9.556% and 8.984, respectively. There were significant differences among all the treatments of pineapple juices. There is a reduction in most of the biochemical constituents due to pretreatment. It is due to aggregation of these components and retention on the membrane. Permeate flux generally declined with time for both MF and UF. However, increase in permeate flux was achieved with increase in TMPs and feed flow rates. The permeate flux was high during MF of pineapple juice than UF. The decrease in pore size and MWCO also decreased the permeate flux. In MF and UF of pineapple juice, the initial fluxes were high but gradually decreased.

Keywords: Membrane clarification, Microfiltration, Ultrafiltration, Egg albumin, Permeate flux, MWCO, Pore size

Pineapple (*Ananas comosus* L., Merril) is the tropical non-citrus fruit, mainly because of its attractive aroma, refreshing flavour and Brix/acid ratio. This juice have been used in fruit based beverages individually, in the form of mixture or combined with other fruit juices. As an ingredient, the concentrated juice from pineapple blends well with other aromas of fruits resulting in a pleasant product with a competitive market price. Pineapple juice is a popular product because of nutritional compounds for human health identified as phytochemicals, such as vitamin C, carotenoid, flavanoid and phenolic compounds (Laorko et al 2010). Due to these characteristics and increasing public awareness about nutritional food, the demand for the pineapple fruit has significantly increased in the last years. Consequently, many industries producing pineapple fruit juice as well as pharmaceutical companies extracting health beneficial compounds from the fruits have been developed. There is a worldwide increasing tendency for the consumption of tropical fruits, juices and fruit drinks due to the interest in ready to consume healthy products. Fruit juices are liquid foods that provide vitamins, sugars, mineral compounds and water. Consumers have individual preferences for specific appearance, consistency and flavor characteristics. Traditional methods of processing fruits limit the possibility to retain freshness as much as possible and its health-beneficial compounds. Similarly, the concentration of fruit juices by thermal evaporation results in color degradation and reduction of most thermally sensitive compounds. Phytochemicals in pineapple juice are reduced during a conventional heating and often leads to detrimental change in the sensorial and nutritional quality. Membrane technology is an alternative to produce a juice with good nutritional characteristics as it does not destroy the vitamins and other nutrients. It is also an alternative because of its operational advantages such as mild temperature, ease of scale-up and simplicity.

Introduction of membrane processing enables production of additive-free juices with high quality and natural fresh like taste. Juice clarification, stabilization, depectinization and concentration are typical steps in which membrane processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) can be potentially utilized. Clarification based on membrane processes, particularly UF and MF, have replaced conventional clarification, resulting in elimination of chemical clarifying agents and simplified process for continuous production. Purpose of the membrane processing is to remove suspended solids as well as haze-inducing and turbidity causing substances to obtain a clear juice after storage. Pineapple juice in its original state have a turbid appearance that makes it hard to preserve during the storage. Since the main problem with juices is stability, there is a need for research to solve this problem besides preservation of color. According to the literature, the present methods used for polyphenol elimination to produce stable juice involve liquid extraction with organic solvents. However, these methods require high temperature to increase the extraction rate and yield, but, may denature the polyphenols leading to undesirable byproducts. Therefore, MF and UF as modern methods are used to reduce juice turbidity. MF and UF are non- thermal and low cost separation technologies for juices emerging in recent years. UF and MF have been applied in vegetal juices, pulps and wine industries, reducing many steps of the conventional clarification. Also, pectinolytic enzymes can be reduced and sometimes can even be eliminated. Keeping in view of the above points, a study was undertaken on membrane processing of pineapple juice after pretreatment with egg albumin. The study also constituted the analysis of physicochemical characteristics of juice and establishing operational parameters to achieve high permeate flux.

MATERIAL AND METHODS

Pineapple (cv. *Simhachalam)* variety was obtained from local market, Bapatla, Guntur dist. Andhra Pradesh and properly sorted to discard fruits of mechanical damage while transportation. Pineapple fruits were properly peeled, cut into slices and used for extraction of juice**.**

Pre-treatment on aggregation and clarification of pineapple juice: The pretreatment was performed using a fining agent called egg albumin. The juice was subjected to four concentration levels *i.e.,* 0.25, 0.5, 1 and 2 g/L and effect of pretreatment was analysed (Table 1). After the collection of juice, the egg albumin powder was added and mixed thoroughly. The juice samples were muslin cloth filtered and centrifuged at 4000 rpm (2147 g) for 5 min (Domingues et al 2011). The supernatant was used for biochemical quality analysis to determine the effect of pretreatment. The concentration of egg albumin which resulted in better clarification was determined by biochemical quality analysis. This concentration was subsequently used for pretreatment of pineapple juice in all the experiments. The pretreatment was performed to remove the colloidal substances present in the juices. Colloids can decrease the permeate flux during filtration of the juice due to presence of pectinases, cellulase, hemicellulase, xylanase, carbohydrase, glucanase or arabinose. Removal of aggregates of these species via pretreatment may increase the permeate flux due to the reduction in the size of the particles and the subsequent decrease in viscosity (Valero et al 2014). The results of the biochemical analysis were expressed statistically with SPSS software.

The pretreated pineapple juice with egg albumin was subjected to physicochemical analysis. Total soluble solids (TSS) of juice were measured by Refractometer (ATAGO make, range 58-90%) and expressed in terms of % Brix. The pH measurement was performed using a digital pH meter (Systronics digital pH meter 355). The colour intensity was measured using a Systronics PC based Double Beam Spectrophotometer at absorbance of 510 nm. Similarly, Browning index was expressed as the ratio of 420 nm to 520 nm using Systronics PC based Double Beam Spectrophotometer (Valero et al 2014). The turbidity and color was also measured using Systronics PC based Double Beam Spectrophotometer at absorbance of 700 nm and 420 nm respectively. The turbidity values of both juices were measured according to the procedure given by Valero et al (2014). Titratable acidity of both juices are determined by the procedure of AOAC (2005). Titratable acidity is expressed as the amount of free acid mainly as anhydrous citric acid present in fruit, conveniently in g acid per 100 g or 100 ml.

$$\%\ \text{acidity} = \frac{a \times b \times c \times d \times 100}{e \times w \times 1000} \qquad (1)$$

where, a = titre value (volume of 0.1N NaOH)

b = Normality of the alkali (0.1N), c = volume made up, d = equivalent weight of the acid, w = weight or volume of sample taken (g or ml) , e = aliquot

Viscosity of the fruit juice was determined by using Digital Viscometer (Brookfield, Model: DV1MLV). Lane and Eynon method (Ranganna, 1986) was used for determination of total, reducing and non-reducing sugars.

$$\text{Reducing sugars\%} = \frac{(\text{Factor}\ (0.052) \times \text{dilution} \times 100)}{(\text{titre} \times \text{wt. of sample})} \qquad (2)$$

$$\text{Total sugars\%} = \frac{(\text{Factor}\ (0.052) \times \text{dilution} \times 100)}{(\text{titre} \times \text{wt. of sample})} \qquad (3)$$

Non-reducing sugars % = Total sugars-reducing sugars (Saeed and Iftikhar et al 2002, Ahmmed et al 2015)

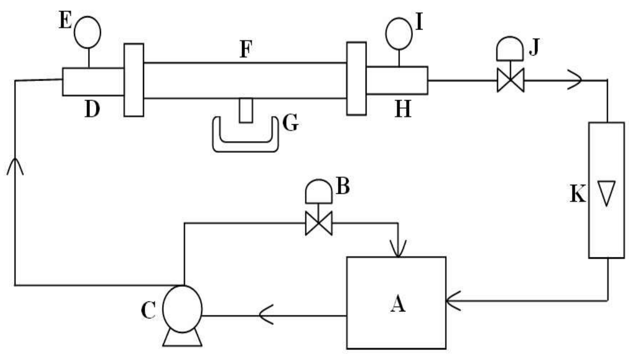
The antioxidant assay was estimated by ferric reducing antioxidant power method using ascorbic acid as standard and total Phenolic content by Folin Ciocalteu's method using gallic acid as standard (Kametkar et al 2014). The total anthocyanin content was determined by the procedure given by Raj et al (2011). Anthocyanins are water soluble phenolic glycosides belonged to flavonoid pigments having C_{15} skeleton of flavones as basic structural unit.

$$\text{Total O.D./100ml} = \frac{\text{O.D.} \times \text{Volume made up} \times 100}{\text{ml of juice taken}} \quad (4)$$

$$\text{Total anthocyanin (mg/100 ml)} = \frac{\text{Total O.D./100 ml}}{87.3} \quad (5)$$

Membrane clarification of pineapple juice: Membrane clarification (MF and UF) of pineapple juice after pretreatment was carried out at Dr. N.T.R. College of Agricultural Engineering, Bapatla in hollow fibre membrane module setup (Model: HFM – 01). The term membrane processing in this thesis is essentially clarification of juices using membranes.

Hollow fibre membrane module setup: The schematic of hollow fiber membrane set up is shown in Figure 1 and Plate 1. The heart of the set up is the hollow fiber module (F). The feed is drawn by the booster pump (C) and fed to the module by 6 mm polyurethane tube via a Perspex flange. Two pressure gauges in the range of 0 to 60 psi (4.1364 bar) are attached to the upstream and downstream of the module. A3/4 inch needle valve (J) of stainless steel has been fitted in the retentate line after the module. This valve is used for fine tuning of pressure and flow rate through the module. A rotameter (K) of range 0 to 50 L/h is attached to the retentate line and the retentate stream is recycled back to the feed tank (A). A bypass line is connected from the pump to the feed tank and a1/2inch stainless steel needle valve (B) is attached to the bypass line. The permeate flows through a 5 mm polyurethane pipe into permeate collector (G). By controlling the bypass valve (B) and retentate valve (J), one can control the flow rate and the transmembrane pressure drop across the module, independently. The transmembrane pressure



A : Feed tank, B : Bypass valve, C : Booster pump, D : Short piece, E : Upstream pressure gauge (0 – 4.21 kg/cm^2 (60 psi)), F : Hollow fibre module, G : Permeate collector, H : Short piece, I : Downstream pressure gauge (0 – 4.21 kg/cm^2(60 psi)), J : Pressure valve (Needle type), K : Rotameter (0 – 50 Lph)

Fig. 1. Schematic diagram of the hollow fibre membrane module setup

Plate 1. Hollow fibre membrane setup

Table 1. Independent and dependent variables for pretreatment on aggregation and clarification of pineapple juice

Independent variables	Dependent variables
Concentrations of egg albumin: 0.25, 0.5, 1 and 2 g/L	Total soluble solids (TSS), pH, Turbidity, Viscosity, Titratable acidity, Colour, Colour intensity, Browning index, Total antioxidant activity (TAA), Total phenolic content (TPC), Total anthocyanin content (TAC), Reducing and non-reducing sugars, Total sugars

drop is the arithmetic average of the readings in the pressure gauges E and I. The physical dimension of the setup is 70 mm in length, 48 mm in width and 65 mm in height. The weight of the setup is approximately 10 kg. One power point of domestic line 220 V is required to run the pump.

Membrane processing of pineapple juice was carried out in the membrane module setup with different hollow fibre cartridges. The container was filled with 250 mL of juice. The operation was done in total recycle mode. The suction, retentate, by-pass lines were kept in feed solution and continuous operation was carried out. The permeate was collected at permeate line separately. The technical specifications of MF and UF membrane were given in Table 2 and 3, respectively. Further, pure water flux data was collected both for MF and UF membranes using distilled water. After each run, the set up was flushed with distilled water and then cleaned with 0.1 N hydrochloric acid (HCl) for 30 mins in total recycle mode according to the washing protocol given by the manufacturer. After thorough washing, the permeability of the cartridges was analysed to measure the change in permeability of the hollow fibres. All the experiments were conducted in triplicate at room temperatures (30±2°C). After every experiment, the membranes were cleaned properly and stored in the 1% formalin solution for future use.

The permeate flux was calculated as

$$J^* = \left(\frac{1}{A}\right) \times \left(\frac{dv}{dt}\right) \qquad (6)$$

Where, J*= Permeate flux (L/h m^2), A= Area of the membrane (m^2), dv= Volume of flow rate (L), dt= Time of flow rate (h)

The permeate collected was stored in glass bottles. The experiments were performed according to the different conditions laid down in the Table 3 and analyzed to obtain high permeate flux.

RESULTS AND DISCUSSIONS

In pineapple juice after the pre-treatment, the 2 g/L concentration level recorded highest removal of colloidal substances. There was a decrease in all the constituents of the juice but not high to lose the essential components of juice. The decrease in complex colloidal components might increase in permeate flux of the juice decreasing the fouling. There was decrease in TSS of pineapple juice. The 2 g/L concentration recorded TSS of 13.255 % for pineapple juice. Similar results were recorded by Valero et al (2014). The decrease of colour intensity was observed for pineapple juice. The colour intensity for pineapple juice was 8.254 at 2 g/L concentration. As the concentration level of egg albumin

Table 2. Technical specifications of MF and UF membranes

Membrane material	Pore size (μm)	Water permeability as claimed by the manufacturer (m / Pa.s)
MF membranes		
Poly acrylonitrile (PAN) (Make : M/s Technoquips seperations equipments Pvt. Ltd., Kharagpur)	0.2	53.4×10^{-11}
Poly acrylonitrile (PAN) (Make : M/s Technoquips seperations equipments Pvt. Ltd., Kharagpur)	0.1	44.5×10^{-11}
UF membranes		
Poly Sulphone (PS) (Make : M/s. Technoquips Seperations Equipments Pvt Ltd., Kharagpur)	120	29.7×10^{-11}
Poly Sulphone (PS) (Make : M/s. Technoquips Seperations Equipments Pvt Ltd., Kharagpur)	70	24.3×10^{-11}
Poly Sulphone (PS) (Make : M/s. Technoquips Seperations Equipments Pvt Ltd., Kharagpur)	44	20.5×10^{-11}
Poly Sulphone (PS) (Make : M/s. Technoquips Seperations Equipments Pvt Ltd., Kharagpur)	10	13.4×10^{-11}

Table 3. Operating variables for microfiltration and ultrafiltration of pineapple juice

Operating variables	
Membrane poresizes	MF - 0.1 and 0.2 μm UF – 120, 70, 44 and 10 kDa
Transmembrane pressures (TMP):	0.3447 bar (5 psi), 0.6894 bar (10 psi), 1.0342 bar (15 psi) and 1.3789 bar (20 psi)
Crossflow velocities/ Feed flow rates	0.024 m/s (20 Lph), 0.037 m/s (30 Lph) and 0.049 m/s (40 Lph)

increased, the clarity in the juice increased, but there was significant decrease in colour intensity of pineapple juice. This was in accordance with Mirsaeedghazi et al (2010). There was significant decrease in all the biochemical attributes as the concentration level of egg albumin increased which enhanced the filtration process while membrane processing by high permeate flux. Valero et al (2014) recorded decrease in pineapple juice upon using egg albumin as pre-treatment. BI values were high prior to the pre-treatment and in non- clarified juice. Similarly, Alper et al (2005) also observed decrease in browning degree for non-clarified juice. The decrease of 49.1% was obtained with gelatine and bentonite combined conventional fining. Browning index being 6.024 for pineapple juice in 2 g/L concentration level of egg albumin. The turbidity values decreased as the concentration level increased. The highest clarity was obtained with 2 g/L egg albumin. The pineapple juice recorded high mean values of turbidity because of fibrous and pectinaeceous present in fruit pulp. Similarly turbidity was also decreased with addition of PVPP and bentonite and increased the clarity of the juices (Vardin and Fenercioglu 2003, Valero et al 2014). The data pertaining to pineapple juice of all the biochemical attributes were also tabulated (Table 4).

Titrable acidity (TA) values decreased as the concentration of egg albumin increased. The pH values increased for pineapple juice. The mean values for TA of pineapple juice was 3.357 expressed as citric acid. Similarly, the mean pH value for pineapple juice was 4.813. The best results were for 2 g/L concentration level of egg albumin. However, there was significant difference among all the concentration levels of egg albumin. Similar, trend was observed by Alighourchi et al (2009). Initially the concentration level 0.25 and 0.5 g/L did not show any significant difference in the values (Molina et al 2009). Viscosity of the pineapple juice decreased with increase of concentration level of egg albumin. The mean value of viscosity of pineapple juice at 2 g/L concentration level was 2.33 cP. There was a significant decrease in viscosity in both the juices at different concentration levels of egg albumin. The antioxidant activity decreased as the concentration level of egg albumin increased. The highest decrease was observed in 2 g/L egg albumin for pineapple juice as 20.202mg/g. The centrifugation and clarification process might aid to the decrease in the antioxidant activity of pineapple juice. Similar results were recorded by Vegara et al (2013) in terms of pomegranate juice. The results pertaining to antioxidant activity obtained in this study were not in accordance to Valero et al (2014) where the antioxidant activity increased upon increase of concentration level of egg albumin. Total phenolic content of pineapple juice also significantly decreased with increase of concentration level of egg albumin. Valero et al (2014) and Pinelo et al (2010) also observed decrease of total phenolic content with 2 g/L egg albumin. The decrease of phenolic content might be due to the changes in the different clarification techniques with egg albumin.

Total anthocyanin content decreased as the

Table 4. Biochemical characteristics of pineapple juice after pretreatment with different concentrations of egg albumin (Mean± SD)

Property	Concentration of egg albumin (g/L)			
	0.25	0.5	1	2
Total soluble solids (%)	15.224±0.010	14.926±0.010	14.325±0.050	13.255±0.050
Colour intensity	8.850±0.050	8.644±0.010	8.454±0.010	8.254±0.010
Browning index	6.433±0.010	6.321±0.050	6.284±0.050	6.024±0.050
Turbidity	0.824±0.010	0.801±0.010	0.791±0.010	0.782±0.050
Titratable acidity (%)	4.204±0.010	3.957±0.010	3.723±0.010	3.357±0.050
pH	3.86±0.010	4.136±0.015	4.57±0.010	4.813±0.050
Viscosity (cP)	5.213±0.057	4.77±0.017	3.55±0.010	2.33±0.01
Total antioxidant activity (mg/g)	22.553±0.040	21.852±0.010	21.198±0.057	20.202±0.058
Total phenolic content (mg of GAE/g of dry material)	81.256±0.010	73.422±0.020	67.584±0.020	60.231±0.050
Total anthocyanin content (mg/100 mL)	0.812±0.050	0.8103±0.010	0.7924±0.010	0.7744±0.030
Reducing sugars (%)	9.325±0.020	9.273±0.050	8.873±0.010	7.605±0.010
Non - reducing sugars (%)	1.82±0.02	1.685±0.010	1.352±0.010	1.951±0.010
Total sugars (%)	11.145±0.050	10.958±0.050	10.225±0.010	9.556±0.010
Colour	9.114±0.02	9.105±0.05	8.996±0.01	8.984±0.02

concentration of egg albumin in clarification increased. There was no significant difference for pineapple juice at 0.25 and 0.5 g/L of egg albumin. The anthocyanin significantly decreased for 1 and 2 g/L egg albumin. Anthocyanin compounds are labile and undergo degradative reactions. There are many variations in the stability of the structure of anthocyanins (Wrolstad 2000, Delgado and Paredes 2002). Anthocyanins remain stable in dried form than in state of high water activity (Wrolstad et al 2005). Reducing sugars significantly decreased for pineapple juice. The highest decrease was at 2 g/L concentration level egg albumin. The mean value of decrease obtained for pineapple juice was 7.605%. Similarly, the decrease was obtained for total sugars and non-reducing sugars. Total sugars significantly decreased for pineapple juice as the concentration level increased. The decrease of total sugars was achieved due to conversion into simpler sugars while hydrolysis in juice.

The colour values significantly decreased for pineapple juice. Anthocyanins are phenolic compounds responsible for colour in juice. As, the phenolic content of the juice was in decreasing trend, the anthocyanins also decreased in juices. This might be the reason for the decrease of colour in juice as anthocyanins decreased. The loss of anthocyanin pigments occurred because of addition of egg albumin as it is sequestering agent it removes the colloidal substances in flocs which might have reduced the pigments in turn aided to decrease in colour in pineapple juice. Vardin and Fenercioglu (2003) recorded the same decrease with the use of gelatine addition and natural sedimentation. The 2 g/L egg albumin was the best concentration level as flocculating agent to remove the colloidal substances and was utilized as pre-treatment prior to membrane processing of pineapple juice to increase permeate flux and reduce fouling.

Membrane processing of pineapple juice and establishing operational parameters to achieve high permeate flux: In membrane processing, both Microfiltration (MF) and Ultrafiltration (UF) hollow fibre cartridges were used for clarification of pineapple juice. The different combinations of membrane pore sizes, transmembrane pressures and flow rates were given in Table 3.

I.MF of pineapple juice: Pineapple juice after pre-treatment with egg albumin was subjected to membrane processing using microfiltration with membrane pore sizes of 0.2 and 0.1 µm. The permeate flux declined with time on both the membranes (Table 5 and 6). The permeate flux of pineapple juice was low because the juice was thick with colloidal pectinaceous substances. The pineapple juice highest flux was 121.191 L/m^2 h for 0.2 µm pore size membrane because of its larger pore size. As pineapple juice is a colloidal solution of highly complex sugars, filtration of juice would have formed a secondary layer of colloids on the membrane surface due to concentration polarization (Blatt et al 1970). The decline in permeate flux was perhaps due to the formation of secondary layer on the membrane surface. The decline in permeate flux during MF was also recorded earlier (Chilukuri et al 2001, Bottino et al 2002, Cassano et al 2003, Onsekizoglu et al 2010). The permeate flux increased as the transmembrane pressures and flow rates increased. The permeate flux was observed to decrease gradually and reach a steady state flux for both the membrane pore sizes. The flux decreases sharply initially due to membrane fouling and gradually thereafter and finally attains a steady state value. Similar results were obtained by Rai et al (2006) for mosambi juice and by Karmakar et al (2017) for coconut water. The difference in steady state values for both the pore sizes was marginal. Similar results were observed during MF of Tomato juice (Bottino et al 2002). It was also observed that as the processing time increased there was a decline in permeate flux probably because of deposition of colloidal substances while clarification on membrane surface. These colloidal substances resist flow of permeate which leads to fouling. Fouling may have occurred due to pore narrowing by smaller particles that may have accumulated on the pore walls (Chilukuri et al 2001) or by pore plugging. High amount of permeate flux was obtained for 0.2 µm pore size probably because of its larger pore size. High fluxes were recorded due to pretreatment with egg albumin at 2 g/L concentration as large flocs of colloidal substances were removed.

UF of pineapple juice: Ultrafiltration (UF) of pineapple juice was carried out with four different hollow fibre membranes with different molecular weight cut off (MWCO) *i.e.,* 120, 70, 44 and 10 kDa, transmembrane pressures 0.3447 bar (5 psi), 0.6894 bar (10 psi), 1.0342 bar (15 psi) and 1.3789 bar (20 psi) and three flow rates 20, 30, 40 Lph. After pre-treatment with egg albumin at 2 g/L concentration, pineapple juice was subjected to membrane processing. It was observed through the biochemical quality analysis that large colloidal substances present in the juice was removed in the form large flocs as egg albumin is a good flocculating agent. The permeability of UF membranes was determined using distilled water at different pressures prior to the ultrafiltration of pineapple juice.

120 kDa MWCO membrane: Membrane processing of pineapple juice was performed with 120 kDa MWCO membrane. The pineapple juice pre-treated with egg albumin was fed to the equipment for membrane processing. The permeate flux was observed to decrease as it was observed for filtration for all other membrane pore sizes (Table 7). The increase of flux with increase in flow rate was observed in the filtration process of pineapple juice. There was decrease in

Table 5. Variation of permeate flux at different transmembrane pressures and feed flow rates in MF of pineapple juice using 0.2 µm pore size membrane (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	98.227±1.87	105.535±1.65	121.191±9.86	87.326±5.22	98.218±2.54	115.758±8.57	85.452±4.16	98.458±7.80	108.041±9.59	84.261±5.64	91.606±2.00	96.458±5.80
20	93.864±1.21	104.009±1.79	112.25±2.37	89.921±1.27	93.686±1.85	103.675±2.37	80.489±1.33	82.505±1.91	91.755±2.37	73.525±1.39	80.123±1.96	82.238±2.37
30	84.709±1.33	96.653±1.91	108.325±2.48	81.518±1.33	84.376±1.91	96.32±2.48	78.517±1.39	73.419±1.96	86.724±2.42	69.489±1.33	73.452±1.91	77.917±2.42
40	79.982±1.04	86.201±1.44	97.573±2.54	78.688±1.44	79.415±2.02	85.701±2.31	71.942±1.56	67.323±2.14	76.089±2.54	65.193±1.44	67.523±1.79	72.625±2.31
50	62.352±0.87	81.779±1.45	87.25±2.60	64.582±1.44	73.006±2.02	81.119±2.60	52.595±1.44	56.291±2.02	70.661±2.71	52.528±1.56	56.391±1.85	69.343±2.42
60	61.185±1.15	77.889±1.73	82.272±2.31	47.701±1.15	66.741±1.73	77.555±2.31	44.561±1.15	49.224±1.73	64.2152.31	44.561±1.15	49.224±1.73	59.548±2.31
70	41.635±1.21	44.095±1.79	66.375±2.37	37.129±1.27	41.148±1.85	61.23±2.37	30.96±1.33	44.775±1.91	51.089±2.37	27.653±1.39	28.879±1.96	44.509±2.37
80	33.689±1.27	37.581±1.85	56.480±2.42	33.488±1.27	36.795±1.85	52.407±2.42	27.720±1.27	37.949±1.85	39.588±2.42	26.091±1.27	14.385±1.85	37.616±2.42
90	30.817±1.33	38.344±1.91	52.374±2.48	33.454±1.33	38.344±1.91	44.189±2.48	26.057±1.33	33.199±1.91	34.881±2.48	13.905±1.33	15.811±1.91	30.294±2.48
100	22.658±1.39	35.138±1.96	35.834±2.54	24.945±1.39	31.022±1.96	34.805±2.54	20.637±1.39	25.455±1.96	25.973±2.54	10.658±1.39	11.359±1.96	23.400±2.54
110	20.152±1.21	31.432±1.79	31.975±2.54	21.445±1.21	23.079±1.79	28.217±2.37	19.184±1.21	23.834±1.79	25.928±2.37	9.523±1.21	10.629±1.79	16.984±2.37
120	19.846±1.27	29.358±1.85	30.327±2.42	19.119±1.27	21.398±1.85	24.284±2.42	16.922±1.27	23.038±1.85	20.722±2.42	8.825±1.27	10.161±1.85	14.035±2.42

Table 6. Variation of permeate flux at different transmembrane pressures and feed flow rates in MF of pineapple juice using 0.1 µm pore size (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	89.979±1.21	97.419±1.79	110.106±2.37	84.743±1.27	89.612±1.85	98.316±2.37	73.785±1.33	87.024±1.91	89.312±2.37	73.752±1.39	77.322±1.96	80.094±2.37
20	83.234±1.39	91.388±1.85	107.434±2.54	79.749±1.44	82.867±2.02	93.252±2.60	67.689±1.50	76.356±2.08	82.500±2.66	67.656±1.56	74.189±2.14	76.893±2.71
30	78.122±1.33	86.125±1.91	104.037±2.48	69.976±1.33	77.789±1.91	89.889±2.48	56.658±1.39	71.095±1.96	77.489±2.42	56.691±1.33	62.114±1.91	69.343±2.42
40	71.529±0.87	75.615±1.45	93.252±2.60	62.621±1.44	70.862±2.02	77.389±2.60	49.391±1.44	64.381±2.02	70.462±2.71	49.324±1.56	57.566±1.85	62.054±2.42
50	48.920±1.04	71.291±1.44	81.709±2.54	45.900±1.44	68.718±2.02	73.697±2.31	33.399±1.56	51.223±2.14	68.418±2.54	47.690±1.44	54.395±1.79	58.991±2.31
60	44.428±1.21	57.529±1.79	77.951±2.37	41.482±1.27	50.382±1.85	59.515±2.37	31.689±1.33	39.631±1.91	50.082±2.37	44.824±1.39	41.080±1.96	39.364±2.37
70	37.981±1.15	47.156±1.73	69.709±2.31	37.195±1.15	44.622±1.73	48.186±2.31	25.058±1.15	36.301±1.73	45.400±2.31	36.634±1.15	38.218±1.73	38.911±2.31
80	36.748±1.33	37.024±1.91	61.163±2.48	31.388±1.33	36.415±1.91	39.726±2.48	21.658±1.33	33.414±1.91	36.082±2.48	24.721±1.33	30.535±1.91	33.080±2.48
90	31.732±1.27	34.648±1.85	43.918±2.42	23.379±1.27	30.875±1.85	34.314±2.42	21.389±1.27	28.259±1.85	30.541±2.42	19.303±1.27	23.795±1.85	27.926±2.42
100	23.545±1.21	26.191±1.79	38.278±2.54	21.425±1.21	24.651±1.79	29.717±2.37	19.422±1.21	24.379±1.79	26.716±2.37	11.792±1.21	19.379±1.79	24.701±2.37
110	19.345±1.39	24.531±1.96	30.990±2.54	17.621±1.39	22.012±1.96	25.201±2.54	14.424±1.39	21.282±1.96	20.528±2.54	9.756±1.39	14.622±1.96	18.899±2.54
120	19.379±1.27	21.807±1.85	28.865±2.42	17.133±1.27	19.068±1.85	22.352±2.42	13.488±1.27	15.394±1.85	18.314±2.42	7.722±1.27	11.720±1.85	14.081±2.42

permeate flux with increase in time (Bottino et al 2002). Though the constant TMPs were tend to be maintained there was decrease in permeate flux with time, this might be because of fouling as the pineapple juice is higher in its viscosity. Similar results were expressed by Bottino et al (2002) that poor pulp fluidity and high viscosity, the membrane pores clog which in turn increased the pressures and further channel clogging caused the decline in permeate flux.

70 kDa MWCO membrane: The permeate flux declined gradually for all the experiments at different TMPs and flow rates (Table 8). The initial increase in permeate flux was increased with increase in flow rates and TMPs, and then declined. The highest permeate flux obtained at 40 Lph flow rate, 20 psi (1.3789 bar) TMP was 97.244 L/m^2 h and then the lowest flux obtained was 5.512 L/m^2 h at 20 Lph flow rate, 5 psi (0.3447 bar) TMP.

The decline in permeate flux might have occurred because of concentration polarization on the membrane surface. The concentration polarization might have occurred because of some colloids which could not be removed in the pretreatment process of egg albumin. These colloids might adhere to the membrane surface causing plugging of pores. This in turn could have reduced permeate flux of the juice. The fouling might be predominant because of the tighter membrane pore size where easy clogging of membrane would have taken place. Initially high amount of flux rates were achieved because of the high TMPs and flow rates but gradually the permeate flux decreased. The increased flux rates initially might also because clean membrane in which the pores were unclogged.

44 kDa MWCO membrane: The pineapple juice clarification was also performed with 44 kDa MWCO membrane at different trans membrane pressures and flow rates. The membrane permeability of the 44 kDa membrane was verified with different TMPs. The permeate flux declined gradually for all the experiments at different TMPs and flow rates (Table 9). The initial increase in permeate flux was increased with increase in flow rates and TMPs and then declined. The highest permeate flux for 44 kDa MWCO was obtained at 40 Lph flow rate, 20 psi TMP was 90.284 L/m^2 h and then the lowest flux was 4.488 m^2 h at 20 Lph flow rate, 5 psi TMP. Similarly, the highest permeate flux for 10 kDa MWCO membrane was 86.921 L/m^{2}h and the lowest was 3.392 m^{2}h. The decrease in permeate flux was probably due to concentration polarization by sediments of pineapple which could not be removed while aggregation process with egg albumin.

10 kDa MWCO membrane: The membrane permeability of the 10 kDa MWCO membrane was determined as the

Table 7. Variation of permeate flux at different transmembrane pressures and feed flow rates in UF of pineapple juice using 120 kDa MWCO membrane (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	81.519±1.39	91.388±1.85	108.720±2.54	73.768±1.44	81.152±2.02	93.038±2.60	56.591±1.50	71.028±2.08	80.785±2.66	56.558±1.56	61.981±2.14	73.035±2.71
20	73.901±1.21	86.192±1.79	104.533±2.37	71.510±1.27	73.535±1.85	88.241±2.37	49.457±1.33	64.448±1.91	73.235±2.37	49.424±1.39	57.500±1.96	70.877±2.37
30	70.190±1.33	75.355±1.91	99.750±2.48	63.974±1.33	69.857±1.91	83.672±2.48	47.852±1.39	60.477±1.96	69.557±2.42	51.447±1.33	54.328±1.91	63.512±2.42
40	50.206±1.04	71.291±1.44	93.286±2.54	41.382±1.44	64.431±2.02	76.012±2.31	31.556±1.56	53.946±2.14	64.131±2.54	41.380±1.44	47.490±1.79	60.277±2.31
50	44.628±0.87	57.722±1.45	87.679±2.60	37.029±1.44	44.455±2.02	67.956±2.60	24.891±1.44	51.289±2.02	63.174±2.71	38.318±1.56	44.557±1.85	53.779±2.42
60	37.981±1.15	47.156±1.73	67.480±2.31	31.488±1.15	44.875±1.73	49.473±2.31	21.758±1.15	38.016±1.73	44.542±2.31	27.090±1.15	30.635±1.73	37.682±2.31
70	41.960±1.21	37.091±1.79	62.087±2.37	23.379±1.27	41.593±1.85	43.223±2.37	21.355±1.33	29.984±1.91	41.293±2.37	24.062±1.39	24.355±1.96	29.717±2.37
80	31.732±1.27	33.447±1.85	50.907±2.42	21.392±1.27	24.617±1.85	37.273±2.42	19.389±1.27	24.345±1.85	33.114±2.42	11.759±1.27	19.345±1.85	22.181±2.42
90	23.749±1.33	27.468±1.91	43.585±2.48	17.654±1.33	22.045±1.91	33.166±2.48	14.457±1.33	21.315±1.91	25.320±2.48	9.789±1.33	14.655±1.91	20.004±2.48
100	21.425±1.27	26.348±1.85	34.614±2.42	17.133±1.27	19.068±1.85	25.611±2.42	13.488±1.27	17.174±1.85	23.038±2.42	7.722±1.27	14.081±1.85	15.321±2.42
110	17.515±1.21	19.121±1.79	29.660±2.54	14.625±1.21	17.332±1.79	21.785±2.37	13.156±1.21	15.530±1.79	17.498±2.37	6.752±1.21	13.529±1.79	12.353±2.37
120	17.314±1.39	19.035±1.96	21.187±2.54	14.054±1.39	16.755±1.96	17.592±2.54	12.055±1.39	13.539±1.96	14.352±2.54	6.312±1.39	7.323±1.96	13.012±2.54

Table 8. Variation of permeate flux at different transmembrane pressures and feed flow rates in UF of pineapple juice using 70 kDa MWCO membrane (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	77.331±1.21	75.422±1.79	97.244±2.37	69.413±1.27	72.677±1.85	86.097±2.37	47.885±1.33	51.356±1.91	76.665±2.37	47.723±1.39	54.295±1.96	71.520±2.37
20	65.012±1.39	71.057±1.85	92.857±2.54	61.819±1.44	41.048±2.02	80.176±2.60	31.589±1.50	67.570±2.08	67.923±2.66	41.313±1.56	44.391±2.14	67.204±2.71
30	44.361±1.33	57.462±1.91	82.172±2.48	37.881±1.33	32.052±1.91	72.310±2.48	26.652±1.39	64.036±1.96	65.913±2.42	38.451±1.33	39.125±1.91	63.769±2.42
40	38.148±0.87	56.612±1.45	76.531±2.60	36.291±1.44	30.988±2.02	64.312±2.60	21.592±1.44	59.286±2.02	61.459±2.71	24.588±1.56	30.568±1.85	59.053±2.42
50	37.524±1.04	47.323±1.44	70.991±2.54	32.632±1.44	22.945±2.02	60.277±2.31	21.222±1.56	51.073±2.14	55.985±2.54	24.029±1.44	29.041±1.79	50.973±2.31
60	31.765±1.21	40.555±1.79	57.800±2.37	22.783±1.27	21.058±1.85	46.438±2.37	19.355±1.33	24.312±1.91	40.221±2.37	14.955±1.39	19.279±1.96	35.720±2.37
70	23.849±1.15	27.568±1.73	50.545±2.31	20.889±1.15	17.421±1.73	35.753±2.31	14.557±1.15	21.415±1.73	41.541±2.31	11.825±1.15	9.556±1.73	29.107±2.31
80	21.391±1.33	26.315±1.91	42.084±2.48	16.088±1.33	16.766±1.91	27.936±2.48	13.454±1.33	17.141±1.91	29.436±2.48	7.688±1.33	14.048±1.91	24.506±2.48
90	17.482±1.27	19.087±1.85	34.872±2.42	15.821±1.27	14.258±1.85	30.456±2.42	13.123±1.27	15.496±1.85	27.326±2.42	6.719±1.27	13.495±1.85	21.066±2.42
100	17.381±1.27	19.101±1.85	32.042±2.42	14.493±1.27	13.787±1.85	22.181±2.42	12.122±1.27	14.418±1.85	20.809±2.42	6.379±1.27	13.078±1.85	13.863±2.42
110	15.415±1.39	16.430±1.96	26.402±2.54	12.424±1.39	13.761±1.96	17.827±2.54	9.658±1.39	11.723±1.96	16.541±2.54	5.524±1.39	10.083±1.96	11.396±2.54
120	14.925±1.21	16.089±1.79	19.327±2.54	12.414±1.21	14.523±1.79	16.574±2.37	9.412±1.21	10.425±1.79	15.353±2.37	5.512±1.21	6.684±1.79	9.738±2.37

Table 9. Variation of permeate flux at different transmembrane pressures and feed flow rates in UF of pineapple juice using 44 kDa MWCO membrane (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	67.424±1.39	74.385±1.85	90.284±2.54	59.391±1.44	67.291±2.02	83.391±2.60	55.367±1.50	63.025±2.08	73.497±2.66	49.212±1.56	59.351±2.14	69.176±2.71
20	37.424±1.21	64.136±1.79	86.097±2.37	32.732±1.27	23.045±1.85	73.663±2.37	21.658±1.33	66.641±1.91	68.947±2.37	24.062±1.39	28.709±1.96	66.375±2.37
30	31.698±1.33	47.056±1.91	84.744±2.48	22.749±1.33	21.025±1.91	69.309±2.48	21.322±1.39	59.748±1.96	63.769±2.42	14.988±1.33	19.312±1.91	59.481±2.42
40	23.916±1.04	27.735±1.44	71.634±2.54	20.723±1.44	17.254±2.02	64.264±2.31	19.222±1.56	41.331±2.14	61.987±2.54	9.723±1.44	11.459±1.79	57.833±2.31
50	21.658±0.87	26.575±1.45	68.385±2.60	16.022±1.44	16.699±2.02	61.740±2.60	14.391±1.44	21.248±2.02	55.885±2.71	7.555±1.56	14.081±1.85	38.902±2.42
60	17.548±1.15	19.154±1.73	60.406±2.31	15.887±1.15	14.325±1.73	54.489±2.31	13.554±1.15	17.241±1.73	44.542±2.31	6.785±1.15	13.562±1.73	32.537±2.31
70	17.414±1.21	19.135±1.79	56.728±2.37	14.493±1.27	13.787±1.85	50.297±2.37	13.089±1.33	15.463±1.91	34.862±2.37	6.312±1.39	13.012±1.96	27.788±2.367
80	15.482±1.27	16.496±1.85	37.830±2.42	12.491±1.27	13.827±1.85	31.184±2.42	12.122±1.27	14.418±1.85	29.255±2.42	5.591±1.27	15.226±1.85	22.181±2.42
90	14.858±1.33	16.022±1.91	35.138±2.48	12.347±1.33	13.456±1.91	23.648±2.48	9.691±1.33	11.756±1.91	20.218±2.48	5.445±1.33	10.116±1.91	19.123±2.48
100	12.054±1.39	14.155±1.96	30.903±2.54	11.522±1.39	12.992±1.96	17.827±2.54	9.312±1.39	11.325±1.96	16.326±2.54	5.094±1.39	9.193±1.96	10.538±2.54
110	11.856±1.21	12.821±1.79	24.429±2.54	10.864±1.21	12.822±1.79	16.512±2.37	7.954±1.21	9.521±1.79	13.811±2.37	5.052±1.21	7.182±1.79	8.748±2.367
120	11.491±1.27	12.159±1.85	15.964±2.42	9.521±1.27	12.047±1.85	14.320±2.42	7.521±1.27	8.366±1.85	11.055±2.42	4.488±1.27	4.936±1.85	7.904±2.42

Table 10. Variation of permeate flux at different transmembrane pressures and feed flow rates in UF of pineapple juice using 10 kDa MWCO membrane (Mean± SD)

Time (min)	Permeate flux (L/m^2 h)											
	TMP 1.37890 bar (20 psi)			TMP 1.0342 bar (15 psi)			TMP 0.6894 bar (10 psi)			TMP 0.3447 bar (5 psi)		
	20 Lph, 20 psi	30 Lph, 20 psi	40 Lph, 20 psi	20 Lph, 15 psi	30 Lph, 15 psi	40 Lph, 15 psi	20 Lph, 10 psi	30 Lph, 10 psi	40 Lph, 10 psi	20 Lph, 5 psi	30 Lph, 5 psi	40 Lph, 5 psi
0	0	0	0	0	0	0	0	0	0	0	0	0
10	55.501±1.27	64.288±1.79	86.921±2.42	49.885±1.33	59.135±1.91	77.060±2.42	47.424±1.39	57.521±1.96	71.915±2.42	44.295±1.44	54.057±2.02	67.166±2.48
20	23.716±1.39	27.501±1.85	77.851±2.54	20.723±1.44	17.254±2.02	73.744±2.60	19.255±1.50	41.364±2.08	66.637±2.66	9.656±1.56	21.331±2.14	61.887±2.71
30	21.391±1.33	26.315±1.91	71.453±2.48	16.088±1.33	16.766±1.91	65.879±2.48	14.424±1.39	21.282±1.96	62.483±2.42	7.688±1.33	14.048±1.91	55.408±2.42
40	17.715±0.87	19.314±1.45	64.955±2.60	15.721±1.44	14.158±2.02	59.724±2.60	13.388±1.44	17.074±2.02	53.527±2.71	6.552±1.56	13.495±1.85	47.734±2.42
50	17.514±1.04	19.335±1.44	61.559±2.54	14.393±1.44	13.687±2.02	50.545±2.31	12.956±1.56	15.330±2.14	45.695±2.54	6.279±1.44	13.112±1.79	42.398±2.31
60	15.515±1.21	16.530±1.79	48.796±2.37	12.491±1.27	13.827±1.85	41.936±2.37	12.088±1.33	14.385±1.91	36.363±2.37	5.524±1.39	12.419±1.96	33.147±2.37
70	14.958±1.15	16.122±1.73	40.683±2.31	12.447±1.15	13.556±1.73	35.967±2.31	9.791±1.15	11.856±1.73	32.966±2.31	5.545±1.15	10.216±1.73	28.036±2.31
80	12.087±1.33	14.188±1.91	33.938±2.48	11.555±1.33	13.025±1.91	31.151±2.48	9.345±1.33	11.358±1.91	28.579±2.48	5.127±1.33	9.226±1.91	22.362±2.48
90	11.823±1.27	12.787±1.85	29.469±2.42	10.831±1.27	12.788±1.85	28.183±2.42	7.921±1.27	9.487±1.85	24.325±2.42	5.019±1.27	7.148±1.85	16.864±2.42
100	11.524±1.21	12.081±1.79	24.901±2.54	9.554±1.21	12.193±1.79	24.358±2.37	7.554±1.21	9.090±1.79	20.928±2.37	4.521±1.21	6.515±1.79	15.867±2.37
110	10.435±1.39	11.425±1.96	20.828±2.54	8.756±1.39	9.435±1.96	16.669±2.54	7.056±1.39	7.492±1.96	14.826±2.54	3.424±1.39	5.608±1.96	9.681±2.54
120	10.382±1.27	11.347±1.85	15.964±2.42	8.415±1.27	9.148±1.85	12.320±2.42	6.532±1.27	7.058±1.85	9.319±2.42	3.392±1.27	5.058±1.85	6.317±2.42

membrane was prior used for the membrane filtration of other juice which might clog the pores of membrane. The permeate flux declined gradually for all the experiments at different TMPs and flow rates (Table 10). The initial increase in permeate flux was increased with increase in flow rates and TMPs and then declined. The highest permeate flux recorded for 10 kDa MWCO membrane was obtained at 40 Lph flow rate, 20 psi (1.3789 bar) TMP as 86.921 L/m^{2}h and the lowest recorded was at 20 Lph flow rate, 5 psi (0.3447 bar) TMP as 3.392 L/m^{2}h.

In all the experiments with 70, 44 and 10 kDa MWCO membrane the permeate flux decline was observed. The decline in permeate flux was observed with decrease in membrane pore size. This was observed because of tighter membrane whose pore size was less which could prevent high amounts of permeate to flow through them and moreover the pore narrowing was predominant factor caused by fouling. Mohammadi et al (2002) defined fouling as existence and growth of microorganisms and irreversible collection of materials on the membrane surface which results in a flux decline. The viscosity of pineapple juice can also be considered as one of the constraints for the declining permeate flux. The permeate flux observed initially high because of the removal of pectinolytic substances due to aggregation with egg albumin which was achieved at 2 g/L concentration. Tapre and Jain (2014) observed that pectin enzymes were used in apple juice preparation to facilitate pressing or juice extraction and to aid in the separation of a flocculant precipitate by sedimentation, filtration or centrifugation. The permeate flux gradually decreased though constant TMP and flow rate were maintained because of formation of gel layer on the membrane surface. The gel layer could not be flushed by frequent cleaning in between intervals because the pineapple juice was thicker and high in viscosity.

CONCLUSIONS

Pineapple fruits of high grade variety were selected, cleaned, and juice was extracted. Pretreatment of pineapple juice was performed using egg albumin at different concentrations and observed that 2 g/L concentration gave good results in removal of colloidal substances of both juices. The optimum concentration of flocculant *i.e.,* 2 g/L of egg albumin effectively remove the colloids. Biochemical analysis of pineapple juice after pretreatment with optimum egg albumin concentration revealed the mean values of TSS, colour intensity, browning index, turbidity, titrable acidity, pH, viscosity, total antioxidant activity, total phenolic content, total anthocyanin content, reducing sugars, non-reducing sugars, total sugars and colour. The characteristics were analyzed in triplicate and found that they were in permissible limits. Permeate flux declined with time in both MF and UF. However, increase in permeate flux was achieved with increase in TMPs and feed flow rates. The permeate flux was high for MF than UF. The decrease in pore size also decreased the steady state permeate flux.

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