The Andhra Agric. J 64 (2): 432-441, 2017

Membrane Processing of Sugarcane Juice

Samreen, Ch V V Satyanarayana, L Edukondalu, P C Vengaiah and M Sandhya
College of Agricultural Engineering, Bapatla 522 101, Andhra Pradesh

ABSTRACT

Sugarcane juice is commonly used as a delicious drink in both urban and rural areas. Sugarcane juice is spoiled quickly due to the pres-ence of simple sugars. Preservation of sugarcane juice was examined to reduce the spoilage and to increase the shelf life by membrane processing. A study was carried out to preserve sugarcane juice by membrane processing and compared with the untreated juice. The results revealed that good quality sugarcane juice of variety CO380 with satisfactory storage stability at refrigeration could be prepared by microfiltration and pasteurization of sugarcane juice with addition of flocculant. The permeate flux of microfiltered and pasteurized sugarcane juice with addition of flocculant decreased from 9.14 to 6.53 L/h m^2. The TSS and pH value of sugarcane juice decreased during storage. The highest pH of 4.65 was recorded for microfiltered and pasteurized juice with addition of flocculant (PAC) on 20th day of storage. The total sugars generally decreased during storage of sugarcane juice in the study. Microfiltered and pasteurized juice with addition of PAC showed reduction of TSS from 17.5 to 14.1%. The reducing sugars increased during storage. The increase of reducing sugars for microfiltered and pasteurized juice was from 1.42 to 2.00%. The turbidity of the sugarcane juice increased during storage as indicated by decrease in the transmittance values. Turbidity was observed to be low from 78.4 to 60 % for microfiltered and pasteurized juice with addition of PAC. The colour values generally decreased in all the treatments. In microbial analysis, Yeast, Mould and total plate count were observed to be less in microfiltered and pasteurised with and without addition of PAC treatments. It can be concluded that membrane processing of sugarcane juice is one of the alternate methods in combination with thermal processing for producing quality juice.

Key words: *Membrane processing, Microfiltration, Poly Aluminium Chloride, Permeate flux, Ultrafiltration*

Sugarcane *(Saccharum officinarum* L.*)* is an important industrial crop cultivated in tropical and subtropical regions of the world. India is the world second largest producer of sugarcane next to Brazil. Sugarcane has been used as a sweetener for millennia and today refined sugar is used in copious quantities to supplement the natural sugar found in fruits and vegetables.

A part of sugarcane juice is consumed as inexpensive and pleasing beverages in India. It possesses therapeutic value. Sugarcane juice is commonly used as a delicious drink in both urban and rural areas. Sugarcane juice of 100 ml provides 40 Kcal of energy, 10 mg of iron and 6 ìg of carotene. Sugarcane juice is rich in enzymes and has many medicinal properties. It contains water (75%-85%), reducing sugar (0.3-3.0%) and non-reducing sugar (10-21%). Sugarcane juice is a great preventive and healing source for sore throat, cold and flu. Even the diabetic can enjoy this sweet drink without worrying about calories. It hydrates the body quickly when exposed to prolonged heat and physical activity. It is an excellent substitute for aerated drinks and colas; it refreshes and energizes the body (Ashish *et al.,* 2012). Due to its commercial importance, it is envisaged that sugarcane juice production can become a profitable business provided efforts are made to preserve its fresh quality during storage (Krishnakumar *et al.,* 2013).

In general sugarcane juice is spoiled quickly due to the pres-ence of simple sugars. Soon after the harvest of sugarcane, endogenous invertase enzyme is activated and acts as a cause of deterioration. These enzymes lead to inversion of sucrose and affect the quality of sugar. The polyphenol oxidase is the major enzyme involved in the discoloration of sugarcane juice which can be improved by heat inactivation of enzyme. The sugarcane juice can be introduced as delicious beverage by preventing the spoilage of juice with appropriate preservation method. One of the

processes used to enable the commercialization of sugar cane juice is the clarification which can be achieved through two methods, one the conventional filtration method and the other membrane separation method.

The membrane separation processes such as Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF) and Reverse osmosis (RO) are promising novel alternative non-thermal and non-chemical methods that are relatively less energy intensive and retain heat labile components. MF and UF offer excellent potential in food industry for clarification and pasteurization to replace conventional techniques. MF is the separation process with membranes similar to classical filtration to retain material that are larger than pore size and permeate as the desired product. UF can be used to produce further clarified juice and also free of microbes as they are larger than molecular weight cutoff of most UF membranes. Therefore, both UF and MF can potentially replace thermal processing and give better quality juice with good sensory attributes. These processes have several advantages such as energy efficiency, selectivity, simplicity of operation, and reduced consumption of chemicals. Therefore, an attempt was made to explore a non-thermal or combination of thermal and membrane filtration process to produce high quality bottled sugarcane juice. Studies were conducted using fresh sugarcane juice with the objective to explore the possibility of replacing preheating operation in thermal treatment using microfiltration and to develop a process technology for preservation of sugarcane juice by membrane processing.

MATERIAL AND METHODS

The raw materials i.e. Sugarcane CO380 variety was obtained from a local farmer of Thoreddu village, East Godavari district, Andhra Pradesh. Sodium Benzoate, Poly Aluminium Chloride (PAC), bottles of 250 ml capacity were procured from the market. Sugarcane stems with good quality and without any pest or disease infestation were selected and peeled for juice extraction. Sugarcane juice crusher, Hot air oven, autoclave, Hollow Fibre Membrane Setup (Model HFM-01, IIT Kharagpur), Crown corking machine, Pocket Refractrometer (ATAGO make, range 0-93%), Systronics µ pH system 362, Hunterlab color flex meter (M/S.Hunterlab, Reston, VA, USA, and Model CFLX-45), Systronics Spectrophotometer 166 were the equipments used in processing of sugarcane juice. The colour was expressed as Chroma value (Lo *et al*., 2007). It can be measured by Chroma = $(a^{*2} + b^{*2})^{1/2}$.

Lane and Eynon method, stated by Ranganna, 1986 was used for estimation of sugars.

Reducing sugars % = (factor (0.052) x dilution x100) / (titre x wt. of sample)

Total sugars % = (factor (0.052) x dilution x100) / (titre x wt. of sample)

The presence of microorganisms in the processed sugar cane juice was determined by performing Total Plate Count method (to enumerate the growth of coliforms and other bacteria), mould count (to enumerate the growth of fungi) and yeast count (to enumerate the growth of yeast).

Sugarcane juice was extracted by power operated two horizontal roller type juice extractor and filtered through the muslin cloth to remove the extraneous matter. The juice formu-lation was done by the addition of ginger extract and lemon extract to sugarcane juice in proper concentration as stated below and the samples were refrigerated. The prepared mixture of ginger extract, lemon juice and sugarcane juice was filtered through muslin cloth and is subsequently used as a raw material for processing. This mixture is referred as sugarcane juice here after. Flocculation was done for T_2 treatment prior to microfiltration shown in Table.1. Membrane processing was carried out in hollow fiber membrane module setup shown in Fig.1.

RESULTS AND DISCUSSION

Variation of permeate flux during microfiltration of sugarcane juice without and with addition of PAC

Permeate flux during microfiltration was recorded for the treatment T_1 (Fig. 2). The permeate flux gradually decreased from 8.57 to 6.34 L /m^2h and reached a steady flux at 6.34 L /m^2h. This flux is within the range observed for typical MF membranes (Katia *et al.* 2014). The decline permeate flux during MF was also reported earlier (Bottino *et al*. 2002; Chilukuri *et al.* 2001 and Capannelli *et al.* 1992). The permeate flux decreased during microfiltration of sugarcane juice

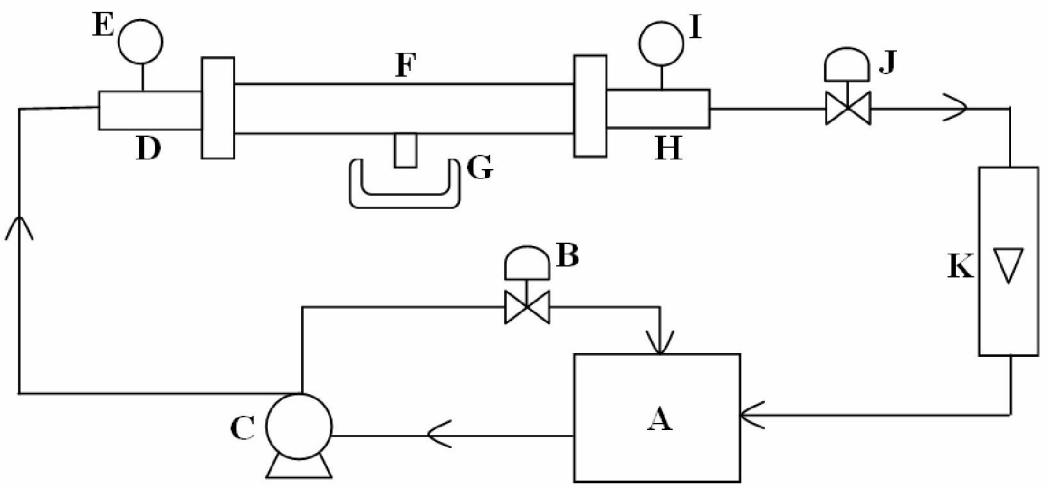

Fig 1. Schematic diagram of the hollow fiber membrane module setup.

Table 1. Different treatments given in sugarcane juice processing.

Treatment code	Treatment	Method	Membrane	Pressure
T_1	Microfiltered and pasteurised juice	Juice was Microfiltered and pasteurised at 80°C for 5 min	0.2µm (PAN)	1.05 kg/cm^2 (15 psi)
T_2	Microfiltered and pasteurised juice with addition of PAC	Addition of PAC before MF to juice, microfiltered and pasteurised at 80°C for 5 min	0.2µm (PAN)	1.05 kg/cm^2 (15 psi)
T_3	Ultrafiltration of microfiltered juice permeate at 2.10 kg/ cm^2 (30 psi)	Ultrafiltration of microfiltered permeate juice, non-thermal, no preservative was added	MF-0.2µm (PAN) UF- 70kDa (PS)	MF-1.05 kg/cm^2 (15 psi)UF-2.10 kg/cm^2 (30 psi)
T_4	Ultrafiltration of microfiltered juice permeate at 3.16 kg/ cm^2 (45 psi)	Ultrafiltration of microfiltered permeate juice, non-thermal, no preservative was added	MF-0.2µm (PAN) UF- 70kDa (PS)	MF-1.05 kg/cm^2 (15 psi)UF-3.16 kg/cm^2 (45 psi)
T_5	Control	No treatment was given	-	-

PAN : Poly Acrylo Nitrile PS : Polysulphone

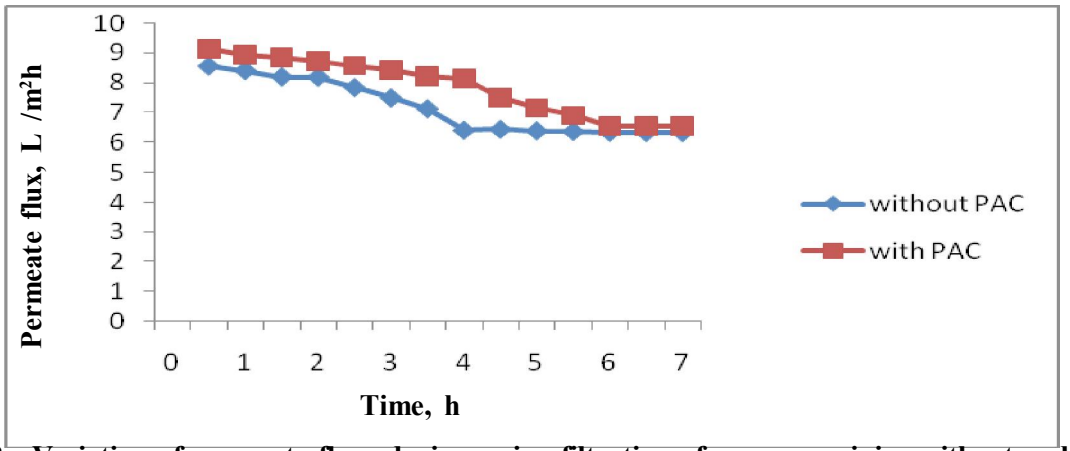

Fig 2. Variation of permeate flux during microfiltration of sugarcane juice without and with addition of PAC.

Table 2. Quality parameters of membrane processed and untreated sugarcane juice.

Treatment code	Storage period ,Days	TSS,% Brix	pH	Total Sugars,%	Reducing Sugars,%	L*	a*	b*	Chroma	Turbid-ity,%	Total Plate count (x 10^6 CFU / 10 ml)	Yeast count (x 10^6 CFU /10 ml)	Mouldcount (x 10^6 CFU/ 10ml)
T_1	0	21	5.48	18.8	1.32	48.8	-1.45	42	42.02	75.1	-	-	-
	4	20	4.99	17.5	1.34	50.5	-1.33	40	40.02	78.0	-	1	1
	8	19	4.75	16.8	1.47	53.6	-0.82	32	32.01	65.3	-	1	1
	12	18.3	4.65	16.2	1.64	59.3	-0.64	27	27.00	56.9	1	1	1
	16	17.5	4.55	15.4	1.71	64.1	-0.53	17	24.00	53.6	1	1	1
	20	17	4.55	15.4	1.73	68.2	-0.32	16	16.00	53.0	2	1	1
T_2	0	18	5.48	17.5	1.42	50.5	-1.35	40	40.00	78.4	1	-	-
	4	17.5	5.15	17.1	1.46	54.3	-1.21	38	38.09	76.1	1	1	1
	8	17	4.98	16.4	1.51	57.8	-0.87	25	28.01	71.0	2	1	1
	12	16.5	4.81	16.2	1.66	61.2	-0.55	18	19.00	64.8	2	1	1
	16	16	4.75	14.7	1.71	63.8	-0.45	14	17.00	60.1	3	1	1
	20	15	4.65	14.1	2.00	65.2	-0.28	12	12.00	60.0	3	1	1
T_3	0	19	6	17.8	1.35	49.5	-1.30	45	45.01	77.0	2	2	-
	4	17	5.55	16.8	1.46	55.8	-1.27	33	33.02	62.2	2	2	1
	8	16.2	5.08	16.6	1.64	63.4	-0.83	21	22.01	55.8	2	2	1
	12	15.5	4.95	15.9	1.68	69.6	-0.61	14	17.01	50.1	4	2	2
	16	15	4.65	14.7	1.80	75.1	-0.48	11	15.01	48.0	4	2	2
	20	15	4.44	14.4	1.80	79.5	-0.26	07	07.00	48.0	4	2	2
T_4	0	19	6.06	17.5	1.32	49.2	-1.17	46	46.01	78.1	2	2	-
	4	18.3	5.65	16.8	1.46	56.7	-1.02	38	38.01	75.0	2	2	2
	8	17.8	5.15	15.4	1.58	68.9	-0.81	27	27.01	71.0	2	2	2
	12	17.1	4.98	15.1	1.66	71.4	-0.65	21	21.09	63.9	2	2	2
	16	16.3	4.67	14.7	1.73	79.2	-0.50	15	15.00	55.3	3	2	2
	20	15.2	4.54	14.7	1.73	81.5	-0.27	09	09.01	55.0	4	2	2
T_5	0	22.9	5.45	23.6	1.46	30.8	-2.50	45	45.11	68.7	3	3	1
	4	21	5.25	20.2	1.54	49.2	-2.20	37	37.09	61.1	3	3	2
	8	20	4.98	18.8	1.58	57.3	-1.80	28	28.05	54.5	3	3	2
	12	18	4.77	16.4	1.62	69.1	-0.85	17	17.02	50.0	4	3	3
	16	17	4.58	14.4	1.78	88.2	-0.71	14.5	14.51	43.2	4	3	3
	20	13	4.37	13.0	2.09	95.4	-0.61	07	07.02	42.0	5	3	3

even after the addition of PAC. The permeate flux gradually decreased slowly from 9.14 to 8.14 L/ m^2h up to 4 h and then steeply declined to 6.53 L / m^2h beyond 4 h of filtration, when PAC was added.

It is generally expected that the addition of flocculants would aid in formation of aggregates which may in turn form a dynamic layer on the membrane surface instead of monomers or simple sugars blocking the MF membrane pores. Interestingly permeate flux declined even after addition of flocculant PAC, but the flux was more sustainable and slightly higher than that occurred without addition of PAC. As sugarcane 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 secondary layer formed with larger aggregates by the addition of flocculant PAC was probably more porous in comparison to MF of juice without addition of PAC. The porous secondary layer would have given slightly higher and more sustainable flux instead of smaller monomers blocking the actual membrane.

Variation of permeate flux during ultrafiltration of microfiltered sugarcane juice permeate at 30 psi and 45 psi

There is general decrease in flux with time even in the case of ultrafiltration of microfiltered juice permeate (Fig.3) at a transmembrane pressure of 2.10 kg/cm^2 (30 psi). The flux declined from 7.71 to 5.35 L/m^2 h. It is surprising to note that flux during UF declined with time inspite of removal of sediments and aggregates during MF. The decline in flux during membrane filtration is due to fouling via concentration polarization of solute particles. Fouling might have occurred due to pore narrowing by smaller particles that might have accumulated on the pore walls (Chilukuri *et al*. 2001) or by pore plugging. Although the overall flux was slightly higher, the decline was similar when UF was performed at a transmembrane pressure of 3.16 kg/cm^2 (45 psi) (Fig.3). The permeate flux increased slightly because of increased driving force when the microfiltered juice was passed through ultrafiltration membrane of molecular weight cutoff (MWCO) 70 kDa, at higher pressure 3.16 kg/ cm^2(45 psi). However, both juice permeates at 2.10 kg/cm^2(30 psi) and 3.16 kg/cm^2(45 psi) pressures during UF almost reached same final flux.

Quality evaluation of membrane processed sugarcane juice

The physico-chemical and microbial characteristics of the membrane processed and untreated sugarcane juice (control T_5) such as %Brix, Total sugars, colour, pH, Reducing sugars, Turbidity, Total Plate Count, Yeast count, Mould count were determined (Table 2).

The TSS of control, T_5 was very high initially and then decreased from 22.9 to 13 % Brix. Microfiltered samples were observed to have slightly low TSS perhaps due to removal of some suspended particles from the juice. It is observed that TSS generally decreased on storage for all the treatments in the study (Table 2 and Fig. 4).

The TSS of sugarcane juice usually consists of sugars, natural flavorings, pigments and other nutrients. The initial TSS of the treatments T_1, T_2, T_3 & T_4 was found to be low because some of the complex sugars and cloud forming solids might have retained in MF because of their higher molecular size. TSS in all treatments decreased during storage because of fermentation process. Similar observation was made by Rosa *et al*. (2012).

The pH of sugarcane juice generally decreased upon storage in the study (Table 2 and Fig.5). Initially pH was high in these treatments because of removal of most of the colloidal particles which might have caused acidity in juice. Then pH decreased during storage due to fermentation process as it was completely non-thermal process. The pH of treatment T_5 decreased from 5.45 to 4.37. It was very low on 20^{th} day compared to all other samples because it was not given any treatment (control) due to which fast fermentation reactions might have occurred. The pH decreased upon storage because of production of lactic acid and acetic acid during fermentation (Lo *et al*. 2007).

The total sugars content decreased upon storage for all the sugarcane juice samples (Table 2 & Fig.6). The total sugars content decreased because of breakdown of total sugars into reducing sugars due to fermentation. Similar observations were made by Krishnakumar *et al*. (2013). Chauhan *et al*. (2002) attributed that the decrease in TSS could be due to hydrolysis of non- reducing sugars to reducing sugars.

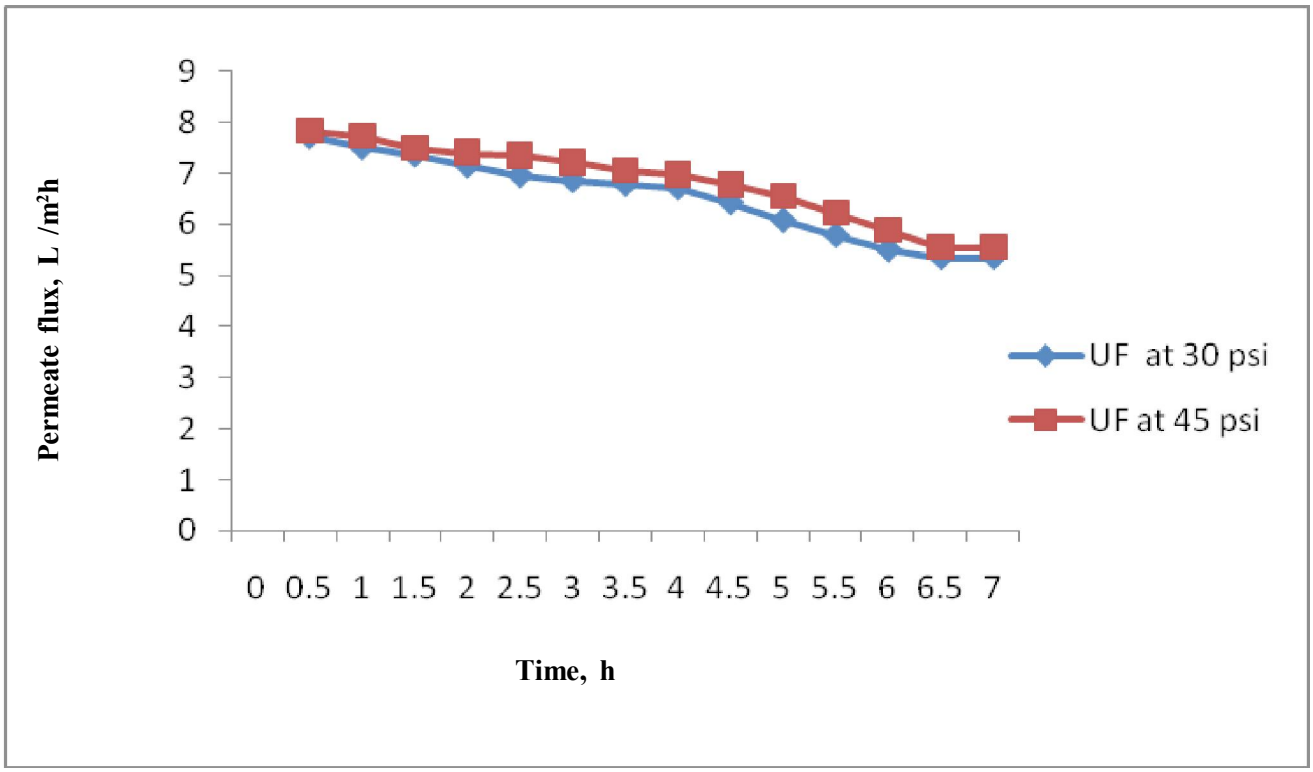

Fig.3. Variation of permeate flux during ultrafiltration of microfiltered sugarcane juice Permeate at 30psi and 45psi

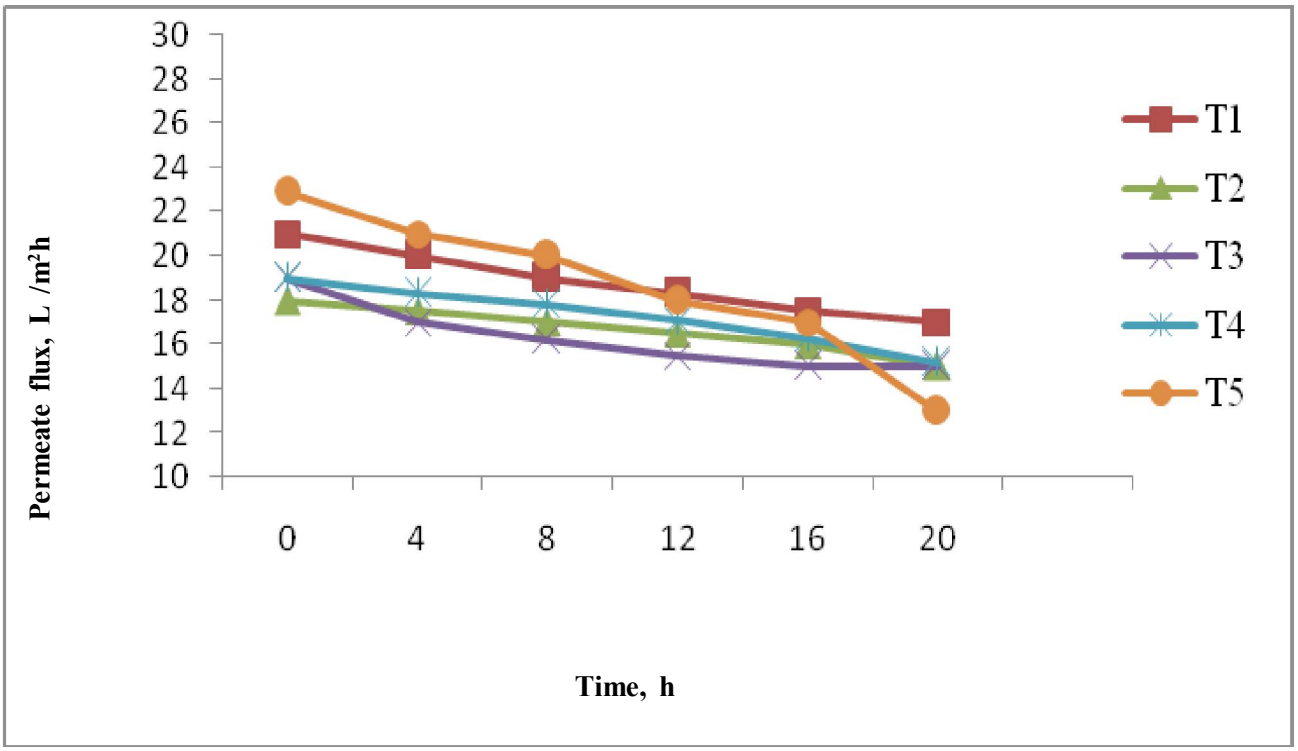

Fig. 4. Variation of TSS of different treatments of sugarcane juice during storage.

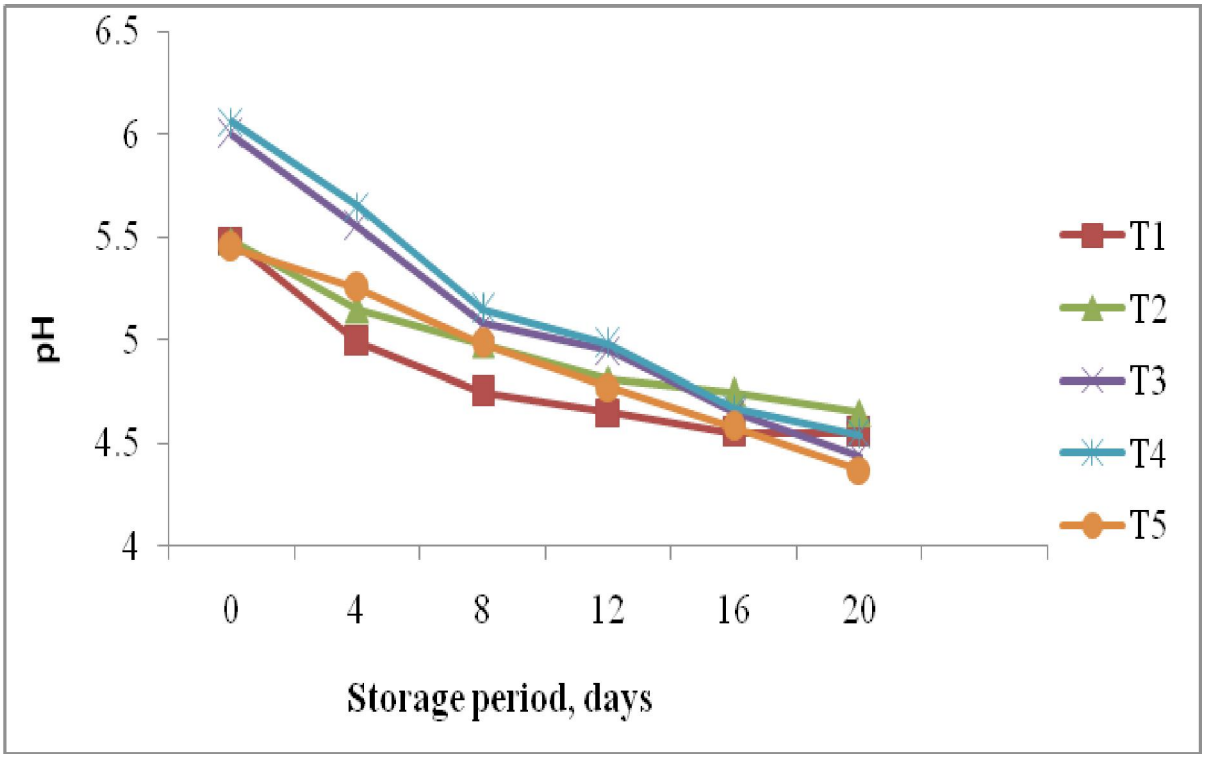

Fig.5. Variation of pH of different treatments of sugarcane juice during storage.

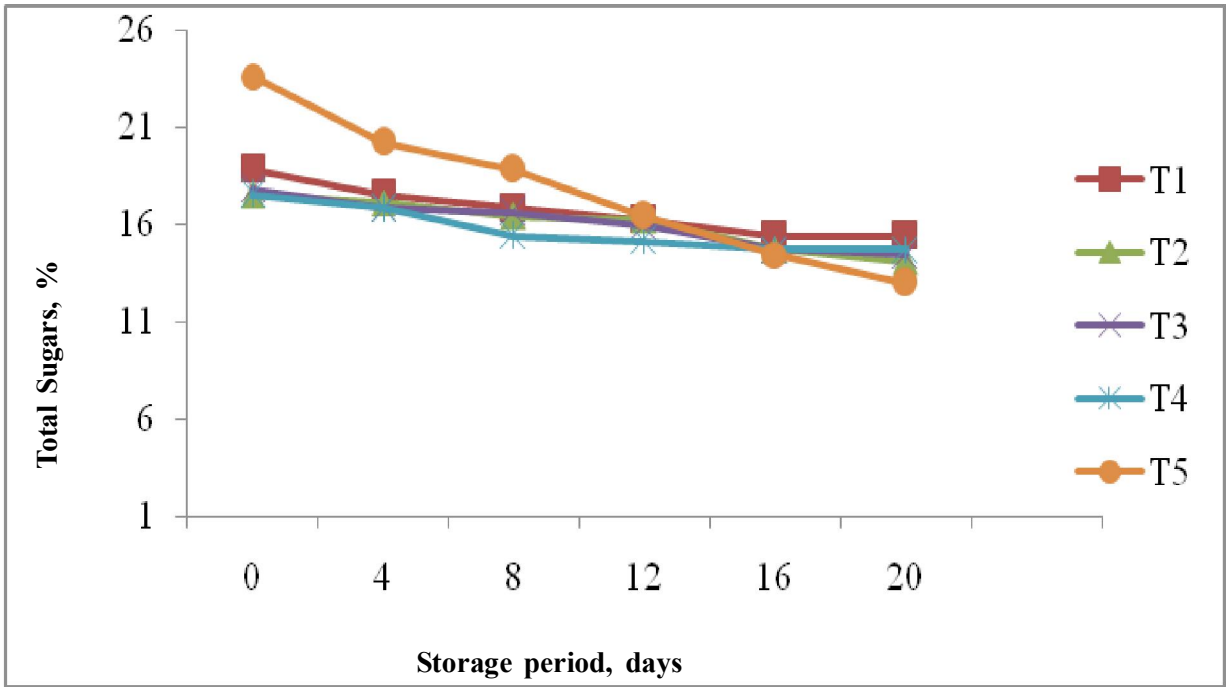

Fig. 6. Variation of total sugars of different treatments of sugarcane juice during storage

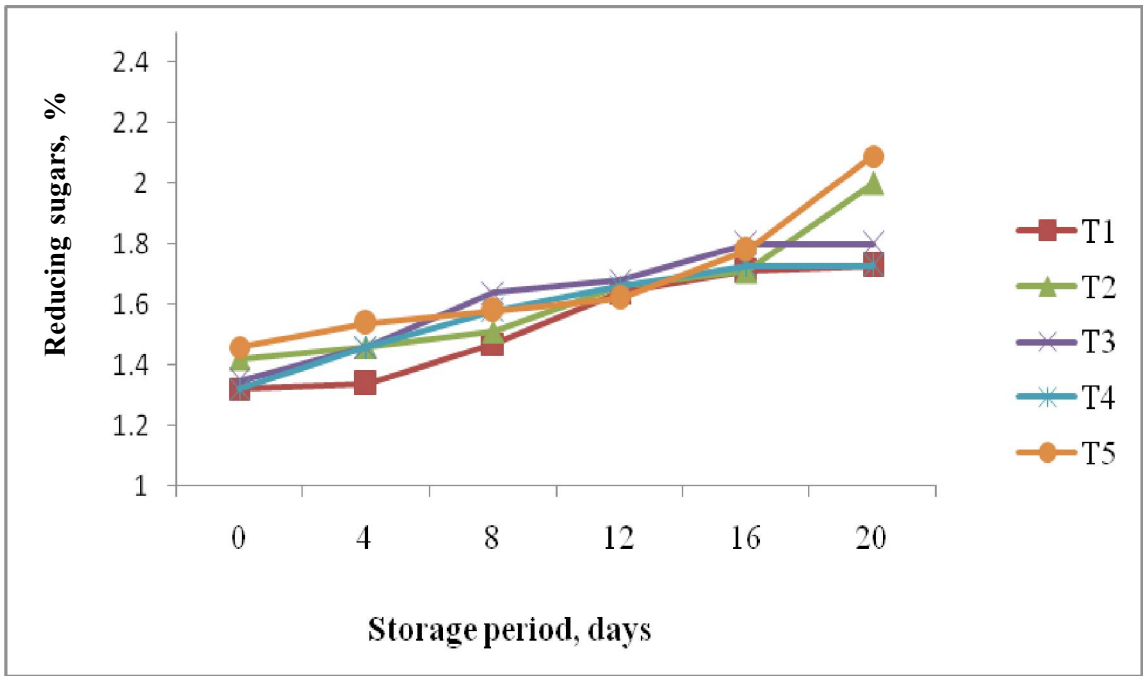

Fig. 7. Variation of reducing sugars of different treatments of sugarcane juice during storage.

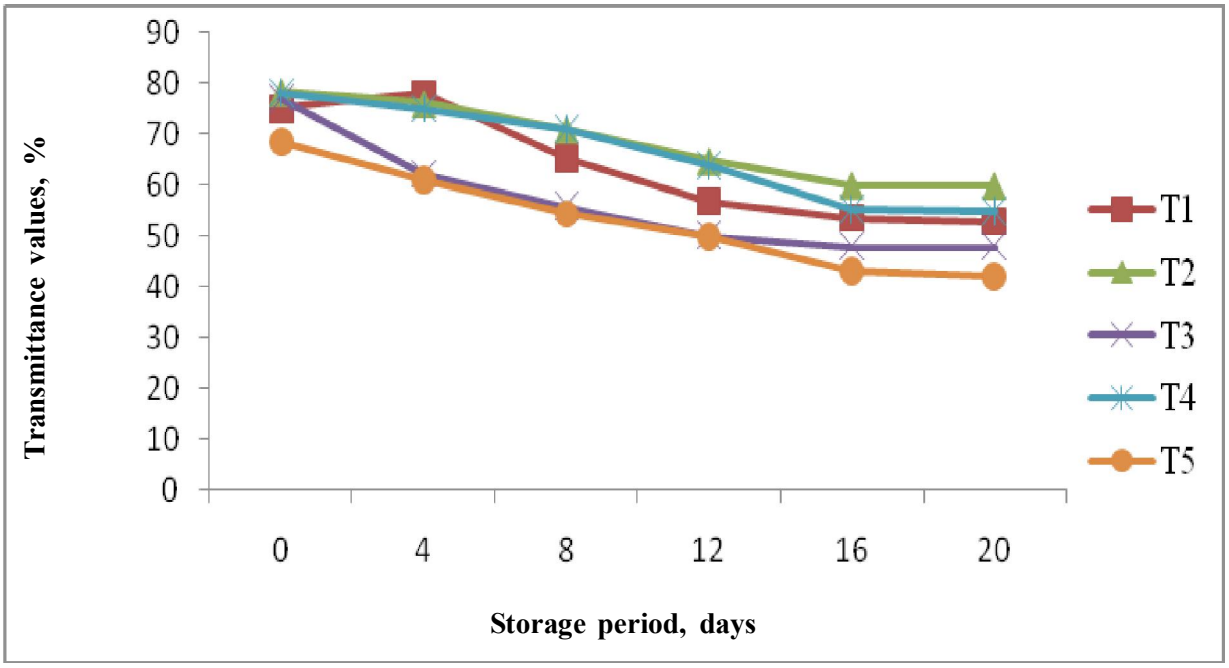

Fig.8. Variation of transmittance (%) of different treatments of sugarcane juice during storage

There is an increase in the % of reducing sugars in all the treatments upon storage (Table 2 & Fig.7). The reducing sugars increased because of the breakdown of total sugars into reducing sugars. The reducing sugars might have also increased because of the hydrolysis of non-reducing sugars to reducing sugars. Similar observations were made by Chauhan *et al*. (2002).

The Turbidity of the sugarcane juice was measured in terms of transmission of light at a wavelength of 900 nm using a spectrophotometer. Turbidity is inversely related to light transmission values. It was evident that treatment T_5 had shown a greater decrease in transmittance values from 68.7 to 42.0 % during the period of storage. The turbidity of juice samples was found to increase during storage (Table 2 and Fig.8). Control sample exhibited more turbidity because of the faster fermentation process would have taken place and breakdown of sugars was more leading to high turbidity of juice. The treatment T_2 had very high transmittance values because of removal of colloidal particles by PAC and microfiltration process. Treatments T_3 and T_4 also recorded as high transmittance value when compared to treatment T_5 because it was a combination filtration process by which most of solids were removed and the juice was less turbid.

The color of fresh sugarcane juice was light lemonish yellow. Upon storage the color faded with time and turned into a light whitish homogenous turbid solution at the end of 20 days. However, the color fade was comparatively slower in treatments T_1, T_2, T_3 and T_4 than for sample in treatment T_5. The Chroma or Colour values decreased for all the samples (Table 2 and Fig. 9). Similar results were obtained by Rosa *et al*. (2012). Colour is attributed to the presence of different pigments in the juice. The pigments underwent oxidative cleavage releasing the compounds that caused colour changes in juice (Fennema, 1976).

In microbial quality analysis, there was no yeast count found initially in pasteurized, microfiltered pasteurized and PAC added microfiltered pasteurized juices. Upon storage, the count it increased to 1 x 10^6 CFU / 10 ml. This may be due to thermal treatment and addition of preservative Sodium Benzoate (Table 2). Chauhan *et al*. (2002) also reported similar microbial changes in pasteurized stored sugarcane juice. The mould count indicated no growth in all treated samples and in Sample T_5, it was 1 x 10^6 CFU / 10 ml and increased to 3 x 10^6 CFU / 10 ml on 12^{th}, 16^{th} and 20^{th} days. The Total Plate Count (TPC) was also observed to be more in treatment T_5 upon storage (Table 2).

Conclusions

The results revealed that good quality sugarcane juice of variety CO380 with satisfactory storage stability at refrigeration could be prepared by microfiltration and pasteurization of sugarcane juice with addition of flocculant. The permeate flux of microfiltered and pasteurized sugarcane juice with addition of flocculant decreased from 9.14 to 6.53 L/h m^2 with time. The TSS and pH value of sugarcane juice decreased during storage. The highest pH of 4.65 was recorded for microfiltered and pasteurized juice with addition of flocculant (PAC) on 20^{th} day of storage. The total sugars generally decreased during storage of sugarcane juice in the study. The reducing sugars increased during storage. The turbidity of the sugarcane juice increased during storage as indicated by decrease in the transmittance values. Turbidity was observed to be low from 78.4 to 60 % for microfiltered and pasteurized juice with addition of PAC. The colour values generally decreased in all the treatments. In microbial analysis, Yeast, Mould and Total Plate Count were observed to be less in microfiltered and pasteurised with and without addition of PAC treatments. It can be concluded that membrane processing of sugarcane juice is one of the alternate methods in combination with thermal processing for producing quality juice.

LITERATURE CITED

Ashish K, Apoorva B L, Anurag S and Amit P S 2012 Shelflife Enhancement of Sugarcane Juice. *Croatian Journal of Food Technology, Biotechnology and Nutrition*. 7 (3):179-183.

Blatt W F, Dravid A, Michaels A S and Nelsen L 1970 Solute Polarization and cake formation in membrane ultrafiltration: causes, consequences, and control techniques. Membrane Science and Technology.47-97.

Bottino A, Capannelli G, Turchini A, Della Valle, P and Trevisan M 2002 Integrated membrane processes for the concentration of tomato juice. *Desalination.* 148:73-77.

Cappannelli G, Bottino A, Munari S, Ballarino G, Mirzaian H, Rispoli G, Lister D G and Maschino G 1992 Ultrafiltration of Fresh Orange and Lemon Juices.25:518-522.

Chilukuri V V S, Marshall A D, Munro P A and Singh H 2001 Influence of permeate flux and calcium on membrane fouling during crossflow microfiltration of bovine serum albumin solutions. Proceedings of the third New Zealand post graduate conference for Engg. and Technology students. 130- 134.

Chauhan O P, Dheer S, Tyagi S M and Balyan D K 2002 Studies on preservation of sugarcane juice. *International journal of food properties*, 5(1): 217–229.

Fennema O R 1976 Priciples of Food Science.Publisher-CRC press,Marcel Dekker Inc. New York-Basel.

Katia R, Leo S, Frederico M P, Rodrigo R P and José C C P 2014 Cross flow microfiltration of sugarcane juice – effects of processing conditions and juice quality. *Journal of Food Science and Technology*, 34(1): 210-217.

Krishnakumar T, Thamilselvi C and Devadas C T 2013 Effect of delayed extraction and storage on quality of sugarcane juice. *African Journal of Agricultural Research,* 8 (10): 930-935.

Lo W M, Chua L S T, Al-Kharki A F and Azhar M E 2007 Evaluantion of freeze-concentrated Sugar-cane juice. *Journal of Tropical Agriculture and Food Science, School of Industrial Technology University Sains Malaysia Minden, Pinang, Malaysia*, 35 (1):121-129.

Ranganna S 1986 Hand book analysis and quality control for fruit and vegetable products. Publisher – Tata McGraew-Hill, New Delhi. 182-189, 872-879.

Rosa M,Ricardo O and Sueli B 2012 Comparison between microfiltration and addition of coagulating agents in the clarification of sugar cane juice. *Acta Scientiarum. Technology*, 34(4):413-419.

(Received on 24.06.2016 and revised on 30.11.2016)