

## **Determining Optimum Conditions for Sugarcane Juice Refinement by Pilot Plant Dead-end Ceramic Micro-filtration**

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### **ABSTRACT**

The conditions for the refinement of clarified sugarcane juice, including temperature (50°, 60° and 70°C) and pressure (0, 0.5, 1 and 1.5 bars) by micro-filtration membrane technology were investigated. The raw sugarcane juice was initially pre-filtrated with lime and then the juice obtained (clarified juice) processed using a ceramic micro-filter membrane (0.2 micrometer). The characteristics investigated included brix, polarity (sucrose percent), turbidity, color and purity. The results showed that the effects of different process conditions with micro-filtration on reduction of turbidity and color were significant at probably <0.01 and probably <0.05, respectively. For other characteristics, no significant difference was observed. Finally, a temperature of 70°C and transmembrane pressure of 1.5 bar were determined as the optimum conditions for ceramic micro-filtration. Membrane processing at 70°C and 1.5 bars reduced the turbidity, viscosity and color of clarified juice 56.25%, 16.67% and 6.49%, respectively, and increased 0.87 units of purity.

**Keywords:** Ceramic membrane, Clarification, Colorants, Sugarcane juice, Turbidity.

### **INTRODUCTION**

Ripe sugarcane consists of 69-75% water, 8-16% sucrose, 0.5-2.0% reducing sugars, 0.5-1.0% organic matter, 0.2-0.6% inorganic compounds, 0.5-1.0% nitrogenous compounds, 0.3-0.8% ash and 10.0-16.0% fiber (Mathur, 1990). Pectin, one of main factors in fouling membrane pores, exists in a very low concentration in raw sugarcane juice due to cold press extraction (Reyahi, 1971; Hatziantoniou and Howell, 2002). The main impurities of sugarcane juice include polysaccharides, starches, waxes, proteins, fibers and colorful polymers (Ghosh *et al.*, 2000). Recently, the sugar industry has been at-

tracted by the possibility of the elimination of calco-carbonic purification, reduction in the consumption of energy and water, simplification of instruments and efficiency raising (Mathlouthi, 2001).

Systematic studies of membrane phenomena can be traced to the eighteenth century philosopher scientists but, in 1960, the elements of modern membrane science were developed (Baker, 2004). During the harvest season, the membrane system can purify the juice and, out of season, the same membrane system can be used for purifying a melt of raw sugar purchased from other sugar mills (Lancrenon, 2003). Sugar processing is one of the most energy-intensive processes

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among the food and chemical industry (Hinkova *et al.*, 2005), and so, membrane separation processes such as micro-filtration (MF), ultra-filtration (UF), nano-filtration and reverse osmosis appear to be funded in several applications by the sugar industry (Hinkova *et al.*, 2005). MF membranes are applied for the separation of particles at the 0.1-10.0 micrometer ( $\mu\text{m}$ ) ranges (Scholz and Lucas, 2003). These ranges include microorganisms, suspense materials, colloids and emulsions (Carwright, 1994). Lancrenon *et al.* (1993) analyzed the application of MF (0.1-10  $\mu\text{m}$ ) and UF (2-200 nm) in sugar beet and sugarcane refinements (Hinkova *et al.*, 2005).

Membrane separations are characterized by several advantages as follows: a selective barrier that causes physical separation of the chosen components without addition of any extraneous chemicals, clean and environmental friendly technology, a lower space requirement (Balakrishnan and Ghosh, 2000), reutilization of by-products or waste products as secondary raw materials, decrease or elimination of processes which are not eco-compatible and optimizing the utilization of energy and water (Vaccari *et al.*, 2005).

It has been shown that pre-filtration of raw sugarcane juice prior to membrane separation increased yield and decreased substantial cost of subsequent UF/MF (Hinkova *et al.*, 2002). The useful results obtained from membrane technology have led to the increasing utilization of modern technology (Kearney and Rearick, 1996). The overall yields of crystallization were comparable with those obtained from the traditional calco-carbonic and membrane technology processes (Mantovani and Vaccari, 1999). Vern *et al.* (1993) and Hinkova *et al.* (2005) referred to membrane technologies for refining raw juice by MF (raw juice through the Filmtec Selectflo cross-flow MF synthetic membranes) with a porosity of 0.2  $\mu\text{m}$  and obtained such a high purity of raw juice that direct crystallization was possible without calco-carbonic process.

The preliminary results of the raw juice treatment by MF on ceramic membranes are specified in the papers published by Bubnik *et al.* (Hinkova *et al.*, 2005). Permeate obtained by membrane filtration processes had a higher clarity, lower viscosity and reduced color. Consequent benefits included higher crystallization yield, energy savings due to reduction of steam consumption by the evaporator and increased capacity of evaporators, vacuum pans, crystallizers and centrifuges (Ghosh and Balakrishnan, 2003). Saska (Lancrenon, 2003) in Louisiana State University demonstrated that the membrane filtration of sugarcane juice reduces the crystallization time in boiling of a sugar by 20-30%.

In this study, the influences of different conditions of the MF process (0.2  $\mu\text{m}$ ) as a modern technology on pre-filtrated raw sugarcane juice (clarified juice) were investigated and the optimal temperature and pressure were determined.

## MATERIALS AND METHODS

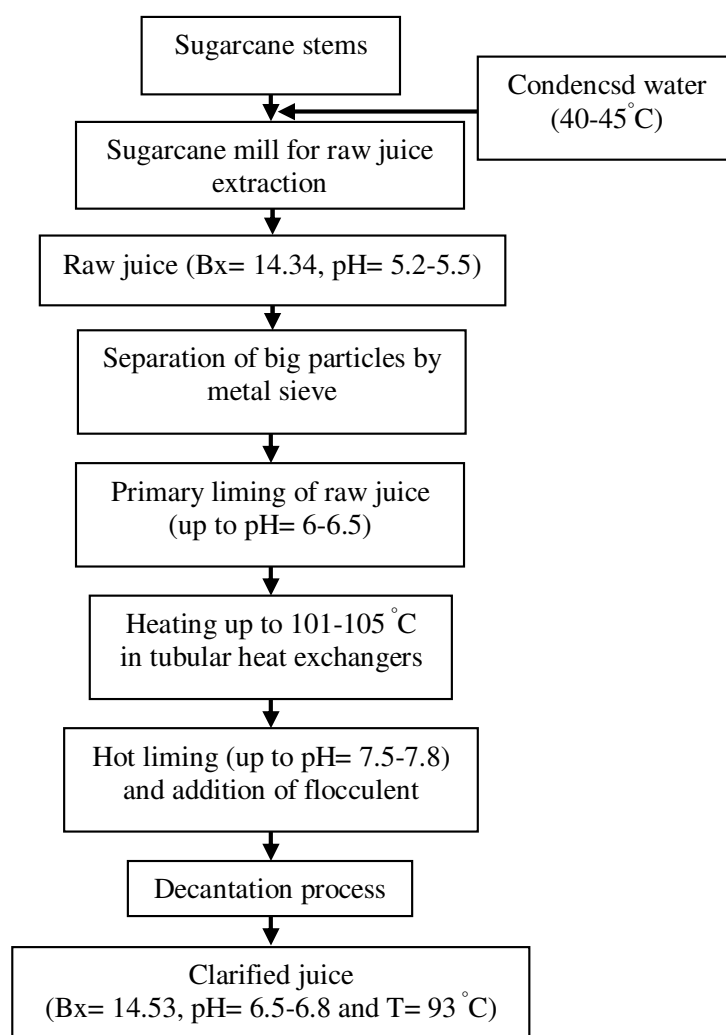
The research was carried out in 2004-2005 at the Deabal-Khazae cultivation and industry unit in Khuzestan Province, Iran. The main varieties of sugarcane used in this project were CP<sub>48</sub>, CP<sub>57</sub> and CP<sub>69</sub>.

### Materials

Clarified sugarcane juice, Whatman filter paper (Cat. No. 900208 Grade 1), ordinary filter paper (Sort/Type: 751/75/20), Merck lead acetate alkaline powder, condensed water and distilled water. Clarified sugarcane juice was obtained from a clarifier set which was produced by the industry according to Figure 1.

### Equipment

Equipment used included a ceramic MF set (0.2  $\mu\text{m}$ ) with 2 lit/min flux speed equipped a barometer (Made in Iran, 3 ceramic membranes, EVA-ceramic filter type (Korea),



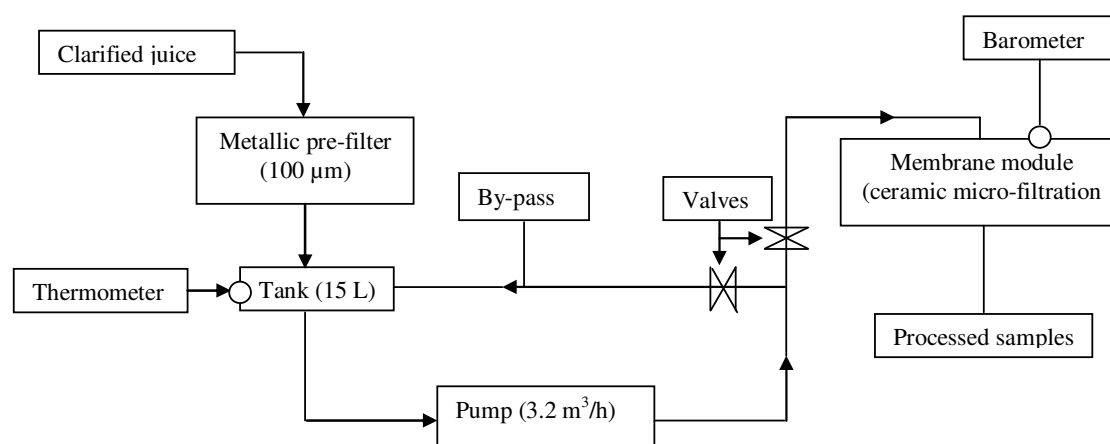
**Figure 1.** Lime pre-filtration of raw sugarcane juice for preparing of clarified juice. (Farmani *et al.*, 2006).

semi circle with effective surface each 202.66 cm<sup>2</sup>), spectrophotometer (JENWAY 3600), polarity-meter (SACCHAROMATZ), refract-meter (DUR-SW), turbidity-meter (SPEC TRONI 20 D), pH-meter (pH Level inolab), rotary viscometer (VISCO STAR-L) and other laboratory equipment.

### Methods

The research was carried out by factorial experiment based on a randomized complete block design (RCBD) in three replications (R). The factors were: 1) temperature (T) at

3 levels ( $T_1 = 50$ ,  $T_2 = 60$  and  $T_3 = 70^\circ\text{C}$ ) and 2) transmembrane pressure (P) at 4 levels ( $P_0 = \text{control}$ ,  $P_1 = 0.5$ ,  $P_2 = 1$  and  $P_3 = 1.5$  bar). Parameters investigated were brix, polarity, turbidity, color and purity and pH, which have been measured according to the ICUMSA method (Anonymous, 1994). Viscosity was measured with a rotary viscometer according to the set catalog with 200 r.p.m. rotary speed and  $L_1$  spindle. Experimental errors of all the parameters were normally distributed. Comparison of means for all the traits was carried out by Duncan's multiple range tests at a probability level (P)



**Figure 2.** Clarified juice processing by dead-end ceramic micro-filtration pilot plant.

of 0.05. The control sample was clarified sugarcane juice under atmospheric pressure just changed its temperature. Analyses of variance and comparison of means were carried out by software of MSTAT-C (version 1.42).

## RESULTS AND DISCUSSION

The effect of different process conditions of MF is shown in Table 1. Significant difference for brix was observed between the R's ( $P<0.01$ ). The Effects of T, P and T×P on clarified juice brix were not significant.

According to Table 1, significant difference for polarity was observed between the R's ( $P<0.01$ ). The effects of T, P and T×P

were not significant on clarified juice polarity.

Similarly, there was significant difference between R's ( $P<0.01$ ) for turbidity. The effects of P and T×P on turbidity reduction were significant ( $P<0.01$ ) but the effect of T was not significant.

For determination of the suitable treatment in comparison with the control sample, means of the results were compared. Figure 3 shows comparison of the turbidity means between processed samples with MF and the control sample. There was a difference between the processed samples and both MF and the control ( $P=0.05$ ) but no difference was observed between processed and the MF samples.

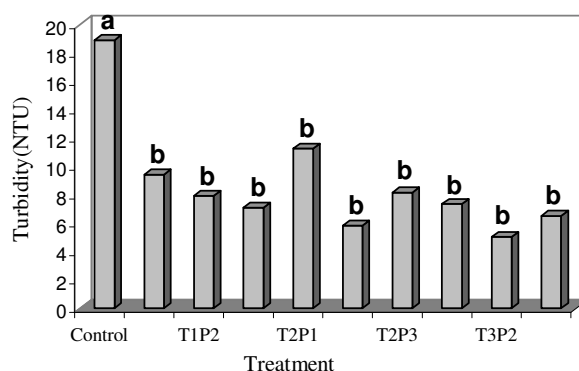
According to Table 1, significant differ-

**Table 1.** Mean squares of some parameters in experimental samples with MF and the control sample.

| S.V. <sup>a</sup> | df <sup>b</sup> | Mean squares |          |           |               |          |
|-------------------|-----------------|--------------|----------|-----------|---------------|----------|
|                   |                 | Brix         | Polarity | Turbidity | Color         | Purity   |
| R                 | 2               | 1.614**      | 1.633    | 128.769** | 6817966.956*  | 23.042** |
| T                 | 2               | 0.385ns      | 0.320ns  | 16.229ns  | 2546876.771ns | 1453ns   |
| P                 | 3               | 0.216ns      | 0.193ns  | 301.831** | 4525954.175ns | 0.394ns  |
| T×P               | 6               | 0.033ns      | 0.032ns  | 3.520     | 561156.770*   | 0.164ns  |
| E <sup>d</sup>    | 22              | 0.231        | 0.025    | 16.282    | 1500094.633   | 1.247    |
| C.V. <sup>c</sup> | -               | 3.47%        | 4.34%    | 38.60%    | 8.07%         | 1.247%   |

<sup>a</sup> Source of variation; <sup>b</sup> Degrees of freedom; <sup>c</sup> Coefficient of variation; <sup>d</sup> Error.

ns: Non-significant, \*\* Significant at  $P<0.01$  and \* Significant at  $P<0.05$ .



**Figure 3.** Comparison of turbidity means between treatments and control samples at  $P=0.05$ .

ence in color was observed between R's ( $P<0.05$ ). The effect of  $T \times P$  on color reduction was significant ( $P<0.05$ ) but effects of T and P were not significant.

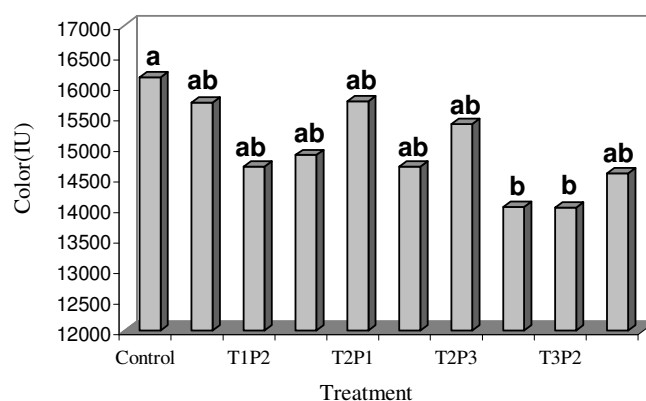
For determination of the suitable treatment in comparison with the control sample, means of the results were compared. Figure 4 shows a comparison of color means between processed samples and both MF and the control. There was difference between color reduction in  $T_3P_1$  and  $T_3P_2$  treatments processed with MF and the control ( $P=0.05$ ) but no difference was observed among samples processed with MF.

According to Table 1, there was significant difference for purity between R's ( $P<0.01$ ). The effects of T, P and  $T \times P$  on clarified

juice purity were not significant.

The results showed particularly: 1) no significant differences in brix, polarity and purity were observed between processed treatments with MF and control and 2) effects of the MF process on turbidity and color reduction (in the case of color comparison between  $T_3P_1$  and  $T_3P_2$  and control samples) were significantly different comparison to control sample.

A relatively high T ( $70^\circ\text{C}$ ) was selected in order to be close to clarified juice extracted from the clarifier set ( $93^\circ\text{C}$ ) and a high P (1.5 bars) because of high MF flux speed in comparison with lower P's, were perfected. The results showed that treatment with  $T_3P_3$  ( $T=70^\circ\text{C}$  and  $P=1.5$  bars) was better than



**Figure 4.** Comparison of color means between treatments and control at  $P=0.05$



with other treatments. Refinery of raw sugarcane juice accompanied by membrane technology decreases consumption of chemical substances. In this experiment, no chemical substances were used to remove the considerable content turbidity, viscosity and color. Experiments were continued at 70 °C and 1.5 bars. Filtration of clarified sugarcane juice with a ceramic membrane (0.2 µm) decreased turbidity, viscosity and color 56.25%, 16.67% and 6.49%, respectively and increased purity up to 0.87 units. Turbidity and viscosity are the result of colloids and suspension materials such as waxes, proteins, pantoans, gums, starch, silicate and soil particles (Mathur, 1990). Colorants are high molecular weight matters some of whose molecular weights are about one million Dalton (Godshall *et al.*, 2002). Most of these compounds cannot pass through an MF membrane (Molecular weight cut-off) (Hamachi *et al.*, 2003). According to the reporting of Vern *et al.* (Hinkova *et al.*, 2005), molecules with a high diameter (0.2 µm) are removed easily by a MF membrane (0.2 µm).

## CONCLUSIONS

In this study, 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 by 56.25%, 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. Lime pre-filtration was necessary as a pretreatment for MF because of the impurities and high silt in raw sugarcane juice (especially sugarcane produced in Iranian factories) that prevent sucrose degradation. According to the results of many researchers and this experiment, use of the ceramic MF process without lime pre-filtration causes

blocking of the membrane pores at the primary steps so that continuation of experiment was impossible.

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### تعیین شرایط بهینه تصفیه شربت نیشکر با استفاده از پالوت میکروفیلتراسیون سرامیکی

ته - بسته

ب. فرمانی، م. ح. حداد خداپرست، ج. حصارى و س. اهریزاد

### چکیده

در این مطالعه شرایط تصفیه شربت نیشکر بوسیله فن آوری غشای میکروفیلتراسیون (با منافذ  $0.2 \mu m$ ) بررسی شد. برای این کار ابتدا پیش تصفیه آهکی روی شربت خام نیشکر انجام شد، سپس شربت به دست آمده (شربت کلاریفایر) با غشای سرامیکی تحت فرایند قرار گرفت. صفات بررسی شده شامل بریکس، پلاریته، کدورت، رنگ و درجه خلوص بودند. نتایج آزمایشها نشان داد که تأثیر شرایط مختلف فرایند میکروفیلتراسیون در محدوده دما (در سه سطح ۵۰، ۶۰ و ۷۰°C) و فشار (در چهار سطح ۰، ۰/۵، ۱ و ۱/۵ بار) مورد بررسی روی کاهش کدورت و رنگ به ترتیب در سطح احتمال ۱ درصد و ۵ درصد معنی دار بود. درباره بقیه صفات اختلاف معنی دار مشاهده نشد. در نهایت دمای ۷۰°C و فشار ۱/۵ بار به عنوان شرایط مناسب برای فرآیند میکروفیلتراسیون تعیین گردید. اجرای فرایند میکروفیلتراسیون در دمای ۷۰°C و فشار ۱/۵ بار روی شربت کلاریفایر نیشکر باعث کاهش ۵۶/۲۵ درصد کدورت، ۱۶/۶۷ درصد ویسکوزیته، ۶/۴۹ درصد رنگ و افزایش ۰/۸۷ واحدی درجه خلوص شد.