Effect of operating parameters on performance of nanofiltration of sugar beet press water


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Abstract

Sugar beet press water is one of the main wastewater in the sugar industry, which presently returned to the diffuser with no further treatment. Some form of treatment, such as pretreatment with membrane may however, improved the output efficiency of sugar plants. In this study, nanofiltration membrane (AFC80) were used to investigate the permeate flux, fouling percent and rejection percent of most important molassogenic ions (sodium and potassium) and sucrose. Sugar beet press water was provided by Abkoh sugar beet factory. The effect of operating parameters such as temperature (at levels of 25, 40 and 55 °C), trans membrane pressure (at levels of 10, 15 and 20 bar) on nanofiltration performance (permeate flux, fouling and rejection) were investigated. The results show that maximum permeate flux is obtained at 55 °C and 20 bar, while the average value is 49.27 kgm⁻²h⁻¹. The minimum permeate flux is obtained at 25 °C and 10 bar, and the average value in this conditions is 14.63 kgm⁻²h⁻¹. Maximum and minimum fouling are reached at 55 °C and 20 bar and 25 °C and 15 bar, respectively. Furthermore maximum rejection of sodium and potassium (84.3% and 72.5% respectively) is obtained at 25 °C and 20 bar, and minimum of rejection of sodium and potassium (74.3% and 69.05% respectively) is obtained on 55 °C and 10 bar. For all operating conditions, sucrose rejection was exceeded 95%. Variation in operating conditions had no significant effect on sucrose rejection.

Keywords: Flux; Fouling; Nanofiltration; Rejection coefficient; Sugar beet press water.
1. Introduction

Sugar beet press water is a thin juice containing 1-3 percent solid matters including sucrose (60-80%), salts, colloid compounds and suspension solid matters [1]. These impurities affect on diffuser draft and yield adversely due to decrease purity of raw juice. In sugar factories, press water is generally returned to diffuser and is utilized as like as fresh water to extract sucrose from sugar beet slices. It might be increased the temperature of press water before returning to diffuser to control microbial flora as well as filtration [2]. However most of impurities present in sugar beet press water can not be separated by filtration. Further, returning press water owning these characteristics leads to increase impurities content of raw juice. Some of these impurities may not remove in purification step cause to increase sucrose solubility in crystallization step which it results to prevent sucrose crystallization and increase molasses producing as well as decrease yield. It was reported that sodium and potassium ions are the most important mollasogenic compounds so that every ion of them can prevent crystallization of five sucrose molecules [3]. Attention to its advantages, it seems that membrane technology can be an alternative for purification of sugar beet press water in order to reuse in diffuser. There are a few literatures related to membrane processing of sugar beet press water. Bogliolo et.al (1996) studied on purification of sugar beet press water using reverse osmosis process. Press water was pretreated as conventional method of raw juice refining which followed by reverse osmosis processing [4].

In this study purification of sugar beet press water by nanofiltration as well as effect of operation conditions (temperature and trans membrane pressure (TMP)) on process efficiency were investigated.

2. Materials & Methods

The study was conducted by polyamide membrane (AFC80) with tubular module (MIC-RO 240) and 240 cm² effective surface in various temperatures (25, 40 and 55°C) and pressures (10, 15 and 20 bar). Sugar beet press water was provided by Abkoh factory (Iran). Permeate flux, fouling and rejection of sucrose and mollasogenic ions (sodium and potassium) were determined. Permeate flux (J) and fouling as equation 1 and 2 respectively.

\[
J \text{ (kg/m}^2\text{s)} = \frac{(w_1-w_2)}{(\Delta t \times A)}
\]  

\[
\text{Fouling (%) } = (1-J_{wf}/J_w) \times 100
\]  

Which \(w_1\) and \(w_2\) are measured weights (kg) in time (second) in \(t_1\) and \(t_2\), respectively. \(A\) (m²) is effective surface of membrane. \(J_w\) and \(J_{wf}\) are water flux before and after nanofiltration process, respectively. Rejection (R%) of impurities was calculated as follow:

\[
R(\%) = (1- \frac{C_p}{C_f}) \times 100
\]  

Where \(C_p\) and \(C_f\) are components concentrations in permeate and feed, respectively.

3. Results & Discussion

As it was observed in Fig 1 the permeate flux reached to steady state at Initial minutes of starting the process at low pressures (10 and 15 bar). However it gradually decreased at pressure 20 bar and reached to steady state after about 20-25 minutes of beginning of process due to formation of concentration polarization layer [5]. The results showed that increasing TMP resulted to longer time to achieve constant
flux. By increasing TMP from 10 to 20 bar, the permeate flux improved approximately 78%. The results revealed that increasing operation temperature from 25 to 45°C led to increasing permeate flux to extent of 72.5%.

![Fig 1. Effect of trans membrane pressures on permeate flux at 25 C during the nanofiltration of sugar beet press water](image1)

![Fig 2. Effect of temperature on permeate flux at pressure 15 bar during the nanofiltration of sugar beet press water](image2)

The highest rejection of components was obtained at ambient temperature. Increasing temperature decreased rejection of sodium and potassium salts as well as sucrose (Table 1) while increasing TMP enhanced rejection of them due to thicker concentration polarization layer which was formed on membrane at higher pressures (Table 2). Our results are in agreement with the findings of Al-Zoubi et al. (2007) who studied on rejection of sulphate and potassium by nanofiltration process [7]. They observed that increasing pressure from 2 bar to 9 bar resulted increase the rejection of potassium.
Table 1. Effect of temperature on fouling and rejection of sucrose, sodium and potassium during nanofiltration of sugar beet press water

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Rejection (%) Sucrose</th>
<th>Rejection (%) Sodium</th>
<th>Rejection (%) Potassium</th>
<th>Fouling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>99.71</td>
<td>78.61</td>
<td>72.98</td>
<td>7.03</td>
</tr>
<tr>
<td>40</td>
<td>97.96</td>
<td>76.07</td>
<td>68.84</td>
<td>7.56</td>
</tr>
<tr>
<td>55</td>
<td>96.88</td>
<td>73.79</td>
<td>65.83</td>
<td>8.21</td>
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</tbody>
</table>

According to our results it can be concluded that by increasing operation temperature and pressure the permeate flux improved while the fouling on membrane increased. Then both of them should be considered for optimization the operation conditions at the industrial scale.

The results also showed the rejection of sucrose was more than 95 % thorough polyamide membrane at all operation conditions which confirmed by the results of Vellenga and Trägardh [8]. They reported that the rejection of sucrose was more than 99 % through thin film DS5 membrane.

High rejection of mollasogenic ions including sodium and potassium during the nanofiltration of sugar beet water press is a pleasuring result due to increase the purity of sugar beet raw juice and crystallization yield.

Table 2. Effect of trans membrane pressure on fouling and rejection of sucrose, sodium and potassium during nanofiltration of sugar beet press water

<table>
<thead>
<tr>
<th>Trans membrane pressure (bar)</th>
<th>Rejection (%) Sucrose</th>
<th>Rejection (%) Sodium</th>
<th>Rejection (%) Potassium</th>
<th>Fouling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>97.92</td>
<td>74.44</td>
<td>66.86</td>
<td>7.00</td>
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<tr>
<td>15</td>
<td>98.11</td>
<td>76.37</td>
<td>68.40</td>
<td>7.40</td>
</tr>
<tr>
<td>20</td>
<td>98.51</td>
<td>77.65</td>
<td>72.37</td>
<td>8.36</td>
</tr>
</tbody>
</table>

4. Conclusion

It seems that nanofiltration has good efficiency for sugar beet water press purification. According to our results, it was concluded that the best operation temperature is 55 °C due to achieve optimum permeate flux and appropriate rejection of impurities. Also the process can conducted at pressure 20 bar.

References


Presented at ICEF11 (May 22-26, 2011 – Athens, Greece) as paper FMS282.