Study on Asymmetry Stainless Steel Filtration Membrane Used in Juice Industry

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Abstract: The changes of the brix, the color values, the turbidity, and the transparency of the juice during the process of filtering juice under operating pressure were discussed. Results show that compared with the relevant physical and chemical indexes of the juice before filtering, the brix of the apple juice after filtering decreases from 15% to 14.3%, transparency (T625) is more than 80%, turbidity (NTU) is smaller than 1, and the juice color values (T440) can amount to more than 40%. The above mentioned results predict that the application of the asymmetric stainless steel filtration membrane in juice industry presents a very good potential prospect.

Key words: porous metals; metal membrane; asymmetry stainless steel filtration membrane; juice industry

The metal porous materials are widely applied in the fields of metallurgy, chemical industry, medicine manufacture, aeronautics, aviation and so on[1-6]. Along with the development of the industry, the future development trend of porous metals focus on the high accuracy, highly effective rate, low cost, and multi-functions[7-12]. At present, the filtration media used in the juice industry is ceramic membrane and organic membrane. They have exposed some disadvantages when used in the filtration. Compared with the ceramic membrane and organic membrane, the metal membrane possesses good hot shock resistance, and is easy to join and fit, so it can be successfully used for juice industry[13-17].

1 Experiment

Apple juice was filtered by an asymmetry stainless steel filtration membrane manufactured by centrifugal casting of suspension. The membrane was composed of a stainless steel porous membrane layer and stainless steel support. The membrane pore size was about 5 µm. Fig.1 shows the cross section of the asymmetry stainless steel membrane. The membrane layer is located on the inside surface of a tube.

The experimental apparatus consisted of one tube with an inner diameter of 44 mm and a length of 1600 mm and a thickness of 3 mm, and offered an effective membrane area of 0.22 m². Fig.2 shows a schematic diagram of the system.

The relevant physical and chemical indexes of apple juice before and after filtration were compared, and the filtration effect of asymmetry stainless steel filtration membrane was analyzed; the physical and chemical indexes of apple juice after enzymatic hydrolysis and filtration were compared, and the application feasibility of asymmetry stainless steel filtration membrane in the juice industry was discussed. The turbidity and the color value of the apple juice were evaluated based on GB/T 18963-2003[18]. The contents of pectin and starch of juice were tested by trial of the pectin and starch.

Fig.1 Fracture appearance of membrane
2 Results and Discussion

2.1 Effect of different operating pressures on fluxes of apple juice

The filtration flux of asymmetric metal membrane has been studied at different pressures. With prolongation of the time, the flux is reduced quickly in the early stage and subsequently the falling rate is decreased slowly; with the increase of pressure, the flux of juice increases fast; but at the level of 1 MPa, the flux increases slowly in the end of filtration. This is because that the pollution layers is less at beginning, the channel is run-through, the flow speed of the juice is fast and the main filtration resistance comes from the membrane filtration. The flux is proportional to the pressure and increases with increasing of pressure. With the further increasing of pressure, the concentration polarization is increased, thick membrane gel layers are formed and those layers make the channels blocked, which strengthens the concentration polarization and causes a vicious circle. There exists gel layer resistance besides the membrane resistance and polarized layer resistance. With increasing of the thickness and the concentration polarization, the total resistance is increased and the flux decreased.

2.2 Changes of the contents of brix in juice before and after filtration

The result of the metal membrane effect on the content of the soluble solids in concentrate apple juice is shown in Fig.3. It’s easy to see that under different operating pressures, the brix contents of the apple juice after filtering decrease from 15% to 14.3%. With the pressure increase, the content of brix in fruit juice is towards stability. The fruit juice filtrated by asymmetric metal membrane has less effect on effective components which can dissolve within water in the fruit juice, such as sucrose, glucose, fructose, organic acids, amino acids, vitamin and mineral.

2.3 Changes of color value of apple juice before and after filtration

The result of the metal membrane effect on the color value of apple juice is shown in Fig.4. It is clear to see from the figure that the change of color value of the fruit juice has a big difference after filtration by asymmetry stainless steel filtration membrane. With the pressure increase, the color value of the fruit juice is diminished gradually and the increased amplitude is also reduced gradually, but the color values of the fruit juice are all more than 45%. When the fruit juice is filtrated under non-pressure, the color value of the fruit juice is the highest. Experiments show that the color value of the fruit juice after filtration by metal membrane is higher than that before filtration. The micro-filtration of metal membrane has a stated de-coloration to the fruit juice. It can filter the pigment in fruit juice and improve the color value.

2.4 Changes of turbidities of fruit juice before and after filtration

The result of the asymmetric metal membrane effect on the turbidity of apple juice is shown in Fig.5. The great changes of the turbidity of fruit juice take place after filtration by metal membrane. The turbidity is less than 1.5 after filtration and it can achieve the physical and chemical standard indexes of GB/T18963-2003. The micropores of the metal membrane and the higher retention rate in opacity body make the turbidity obviously decrease. So the filtration of asymmetric metal membrane has a clarification effect on fruit juice and decreases the turbidity of the fruit juice greatly.

2.5 Influence of filtration on transparency of apple juice

The result of metal membrane effect on the transparency of apple juice is shown in Fig.6. It shows that with the increase...
2.6 Effects of filtration on pectin and starch

Pectin existing in the apple juice is a hydrocolloid material dissolved in water. Since the pectin in the fruit juice hinders the operation of clarification and filtration, some pectinase is usually added in to decompose the colloids formed by the pectin on concentrated apple juice products, and promotes the sediments separation, so the fruit juice gets clarified. Because the pectin molecular and starch molecular are bigger, if pectinase is not decomposed into smaller molecular, it will plug the ultra-filtration membrane in the ultra-filtration. So the enzyme hydrolysis of the original fruit juice must be done first, followed by ultra-filtration.

Table 1 shows that the fruit juice after filtration does not contain pectin and starch. It indicates that the pectin and starch in original fruit juice can be filtered by the asymmetric metal membrane. On the basis of above analysis, when the asymmetric metal membrane filtrates the original fruit juice, it removes not only the pectin and starch, but also the pigment and opacity body in the fruit juice, furthermore, the color value and the transparency of the fruit juice are improved, and the turbidity decreases (Table 2).

Table 2 shows that the five physical and chemical quality indexes of the apple juice after filtration are all higher than those decomposed by the pectinase. Some indexes exceed the GB/T18963-2003. Achieving of the technology requirement of the downstream ultra-filtration, can be helpful to the improvement of the ultra-filtration membrane life and the product quality of the concentrated apple juice. So removing of the pectin and starch in the original fruit juice and adopting filtration by the asymmetric metal membrane are feasible. Also according to the characteristics of porous metal materials, the equipment can be disinfected by vapor, using high pressure inverse washer. The porous metal filtration membrane is better to be used in juice clarification than polymer membrane. So the juice quality is better and has stronger aroma by adding pasteurization when filtrated. The significance to use metal porous membrane instead of traditional technology in the production of the juice is obvious.

<table>
<thead>
<tr>
<th>Item</th>
<th>Amylum</th>
<th>Pectin</th>
</tr>
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<tbody>
<tr>
<td>Before filtration</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>After filtration</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 2 Comparison of indexes of apple juice after enzymatic hydrolysis and filtration (%)

<table>
<thead>
<tr>
<th>Item</th>
<th>Enzymatic hydrolysis</th>
<th>Filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectic</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Starch</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brix</td>
<td>11.9</td>
<td>14.3</td>
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<tr>
<td>Transparency</td>
<td>50</td>
<td>56</td>
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<tr>
<td>Color values</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Turbidity</td>
<td>1</td>
<td>0.9</td>
</tr>
</tbody>
</table>
3 Conclusions

1) The juice does not contain pectin and starch after filtration by asymmetry stainless steel filtration membrane. The juice production by the filtration technology of asymmetry stainless steel filtration membrane instead of the traditional production techniques is feasible.

2) The color value and the transparency of the apple juice can be increased and the turbidity of the apple juice can be decreased by filtration technology of asymmetry stainless steel filtration membrane.

References

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