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Concentration of Fruit Juices by Vacuum Membrane Distillation: A Review

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Abstract

In order to increase the shelf life of product, as well as reduction in their bulk weight and their transportation cost, membrane processes have been widely applied for concentration processes of the food, dairy, fruits and vegetables and beverage industry. Over the last two decades, the worldwide market for membrane technology in the food industry has increased enormously and it's now the second biggest industrial market for membranes after water and wastewater treatment including desalination. Membrane processes such as VMD have gained an important place in food technology and are being used in a broad range of applications in it. The key property that is exploited is the ability of a membrane to control the permeation rate of a chemical species through the membrane, so it can be used in concentration of fruit juices. It is observed that concentration of juice by vacuum membrane distillation have better result on allowing one component of a mixture to permeate the membrane freely, while hindering permeation of other components like antioxidant properties and the sensory properties of the fruit juices. Thus vacuum membrane distillation has been proved a better, safer, and advance technique to concentrate fruit juices.

Keywords: Membranes, Concentration, Vacuum Membrane Distillation.

1. Introduction

In order to increase shelf life of product, as well as to reduce their liquid volume and so the transportation cost, food products are concentrated by the different type of membrane processes. Fruit juices have been traditionally concentrated by multi-stage vacuum evaporation, which results into several adverse effects on the product quality as degradation of certain natural antioxidant components, loss of amino acids and discoloration in the final product.

Aroma profiles of different fruit juices usually cover a mixture of a large number of volatile organic compounds. The individual aroma of any fruit components differs according to their molecular structure, which defines the solubility, the boiling point, and the volatility of each type of compound (Ramteke, Eipeson, & Patwardhan, 1990). Aroma components are present in different concentrations and combinations, where the concentrations of individual aroma substances in common fruit juices usually range from less than 1 to 20 ppm (_Sulc, 1984).

The process of concentration of fruit juices are the one of the basic unit operations of fruit juice technology, in which the solids content of the juice is increased from 10% to 12% up to 65–75% by weight (Sulc, 1984). The fruit juices are concentrated to reduce its volume, which in turn lowers storage, packaging and transport costs. The increased concentration of solids also helps in preventing microbial spoilage of the juice concentrate (Downes, 1990).

In conventional concentration technique, the juice concentration step is usually coupled with aroma-stripping and the stripped aroma concentrate is later added back to the concentrated juice (Sulc, 1984). Nowdays, the predominantly used method for fruit juice concentration and aroma-stripping comprises one or several multistage falling film vacuum evaporators are connected to a separate aroma recovery plant. In it, the volatile aroma compounds are removed in the vapor phase obtained through falling film evaporation and subsequently trapped by condensation in an aroma recovery unit, where the efficiency of the trapping varies depending on the particular conditions and on the aroma compounds in question (Piggott, Paterson, & Clyne, 1993)

2. Membrane Processes in Food Industry

In last few years, membrane processes such as membrane distillation (MD), reverse osmosis (RO), and pervaporation have been recognized as alternative membrane based separation and concentration processes in fruit juice and other beverages (Calabr_o, Jiao, & Drioli, 1994; Girard & Fukumoto, 2000; Lagan_a, Barbieri, & Drioli, 2000).

The key membrane technologies in the food industry are the pressure-driven membrane processes microfiltration (MF), ultra filtration (UF), nanofiltration (NF) and reverse osmosis (RO). The success of membrane technology in the food and beverage market is directly linked to some of the key advantages of membrane processes over conventional separation technologies. Among these advantages, some of them are following:

- Gentle product treatment due to moderate temperature changes during processing.
- High selectivity based on unique separation mechanisms, for example sieving, solution-diffusion or ion-exchange mechanism;
- Compact and modular design for ease of installation and extension;
- Low energy consumption compared to condensers and evaporators.

The key disadvantage of membrane filtration is the fouling of the membrane causing a reduction in flux and thus a loss in process productivity over time. The effect of fouling can be minimized by regular cleaning intervals.

3. Membrane Distillation for Fruit Juice Concentration

Membrane distillation is a thermally driven separation process in which separation is enabled due to phase change. A hydrophobic membrane displays a barrier for the liquid phase, letting the vapor phase (e.g. water vapor) pass through the membrane's pores. The driving force of the process is given by a partial vapor pressure difference commonly triggered by a temperature difference.

In last few decades, membrane separation processes have become one of the emerging technologies especially in the separation processes. They are having a number of advantages over conventional methods of separation in a vast variety of applications such as distillation and evaporation. Membranes processes are method of transfer of specific components selectively; as well as they are energy efficient systems which are being operated under moderate temperature conditions which ensures gentle product treatment.

In general processing, fruit juices are traditionally concentrated by vacuum techniques (multi stage vacuum) which generally have an adverse effect on antioxidant compounds of the fruit juices. According to Balazs *etal.*, membrane technology, such as vacuum membrane distillation, have the very good results in processing of concentration of fruit juices. Vacuum membrane distillation affects the preserving quality of the fruit juices and helps in maintaining superior and natural quality of the fruit juices.

4. Vacuum Membrane Distillation

Vacuum membrane distillation is a membrane-based separation process which removes volatile organic compounds from the aqueous streams. In VMD, Micro porous hydrophobic Membranes are used to separate the aqueous stream from a gas phase which are kept under vacuum. The evaporation of the liquid phase takes place on one side of the membrane, as well as mass transfer occurs through the vapor phase inside the membrane. According to Serena Bandini *etal.*, the vacuum-side pressure is the major design factor in the process of VMD since it highly affects the separation efficiency.

5. Principle of Vacuum Membrane Distillation

The principle of vacuum membrane distillation of the solution with non-volatile solute is illustrated in Fig. 1. The feed passes through one side of the micro porous membrane (the feed side), while the other side of the membrane (the vacuum side) is vacuumed. Because the membrane is hydrophobic and micro porous, the solution in the feed side will not go into the vacuum side through the membrane because of the interface tension. When the pressure of the vacuum side is kept below the equilibrium vapor pressure of the solution on the membrane face in the feed side, the water in the feed side is evaporated continuously and goes into the vacuum side. At the same time , the vapor entering the vacuum side is vacuumed outside the membrane cell to be condensed continuously. The vacuum membrane distillation has greater flux than other forms of membrane distillation, because a differential pressure lies between the vapor-liquid interface and the vacuum side.

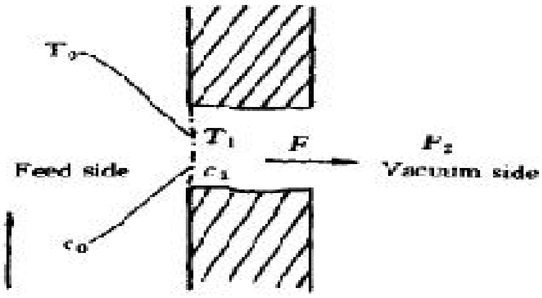

Figure 1: Theory of vacuum membrane distillation.

6. Comparison of VMD with the Conventional Method

Vacuum membrane distillation (VMD) has been proposed as an attractive membrane processes allowing very high concentrations (above 65◦Brix) to be reached at atmospheric pressure and temperatures near ambient temperature. In this process, fruit juice is separated from a receiving phase by a hydrophobic micro porous membrane to prevent penetration of aqueous solution, creating air gaps within the membrane

VMD may be a good technique for satisfactory Conservation of the original qualities of thermo sensitive Aroma compounds in highly aromatic fruit juices like Black currant juice. In VMD, the vacuum conditions can shift the Equilibria present between the vapor phase and liquid Phase at atmospheric pressure resulting into the possible recovery of azeotropic components (bielig & gr€unding, 1985; ramteke *etal.*, 1993). The complex nature of fruit aroma volatiles makes it very difficult to separate aroma volatiles from different fruit juices using one and the same aroma recovery plant. Today, there is no universal aroma recovery plant with which highly and poorly volatile aroma compounds of every fruit type can be separated, rectified and concentrated with the same efficiency (Ramteke et al., 1990).

In studies, it is found that, the amount of vapor to be extracted for aroma separation using the conventional process is 10–45% of feed volume (Bielig & Gr€unding, 1985) & aroma recovery plant transfers only 40–65% of the total volatiles into the aroma concentrate (Sulc, 1991), where as in VMD process, the amount of volatiles in the aroma permeate are substantially higher and the amount of vapor to be extracted is therefore considerably less.

According to Rico Bagger-Jørgensen *etal.,* When 5% of feed volume had been extracted, between 68% and 83% of the highly volatile compounds and between 32% and 38% of the poorly volatile compounds, had been recovered from vacuum membrane distillation process.

According to Pelin Onsekizoglua *etal.*, (2010) VMD techniques is very efficient since the concentrated juice presents nutritional and sensorial quality very similar to that of the original juice especially regarding the retention of bright natural color and pleasant aroma, which are considerably lost during thermal evaporation. Furthermore, among all the concentration treatments applied, only thermally evaporated samples resulted formation of HMF. Phenolic compounds, organic acids and sugars were very stable against all concentration processes, including thermal evaporation.

VMD is also capable of the concentration of different juice up to a high solid content. In a study of black-current juice concentration, it was found that final concentration of the blackcurrant juice reached 58.28^0 Brix at the end of the batch measurements. This high concentration prevents the juice from deterioration. In this study it was found that a few degree centigrade increases in the driving force influenced significantly the distillate flux and the operation time of the VMD process. The result of the analytical measurements shows that the density, TAC and AC of the black-currant juice increase proportionally to the increase of the TSS in the measured range (Aron *etal.*).

In concentration of citrus fruit juices and the fruits containing oily constituents (such as limonene in orange juice), membrane wetting may occur due to high affinity of hydrophobic membrane material with such compounds. Coating of membrane with hydrophilic polymers such as polyvinyl alcohol (PVA) (Mansouri & Fane, 1999) and alginate (Xu et al., 2004) has been proposed to overcome this problem. Recently, Chanachai et al. (2010) studied the coating of hydrophobic membrane PVDF with chitosan, a highly hydrophilic polymer, for protection against wetting by oils from fruit juice. The results indicated that the coated membrane well protected the membrane against wetting-out and could maintain stable flux. Coated membranes used to concentrate the oil solution (limonene 2%, v/v) for 5 h were not wetted out during flux measurement and no visual damage was observed indicating the stability on the base membrane.

7. Conclusion

Studies suggest that VMD is a very promising technique for gentle aroma stripping of thermally sensitive fruit aroma compounds. However, VMD is the only one of several known MD techniques. Other MD techniques include sweeping gas MD, osmotic MD and direct contact MD. VMD results in many advantages, with respect to conventional separation techniques, and, from an economic point of view, is comparable to alternative membrane processes, such as pervaporation. With respect to other MD configurations, VMD allows to reach higher partial pressure gradients and, hence, higher fluxes and productivity of juices. Thus, VMD can be proposed as the most promising alternative to conventional thermal evaporation technique for fruit juices.

References

[1] Aron Koz_ak*, Erika B_ek_assy-Moln_ar, Gyula Vatai, (2009) Production of black-currant juice concentrate by using membrane distillation, Desalination 241 (2009) 309_314

[2] B. Jiao (2004), Recent Advances On Membrane Processes For The Concentration Of Fruit Juices, *Journal Of Food Engineering 63 (2004) 303–324*

[3] Bielig, H. J., & Gr€unding, H. (1985). The influence of technology on flavour retention in fruit juices. In R. G. Berger, S. Nitz, & P. Schreier (Eds.), Topics in flavour research: proceedings on the 30th international conference, Freising-Weihenstephan (pp. 173–199).Freising, Germany: Bode Druck.

[4] Calabr_o, V., Jiao, B. L., & Drioli, E. (1994). Theoretical and experimental study on membrane distillation in the concentration of orange juice. *Industrial and Engineering Chemistry Research, 33(7), 1803–1808.*

[5] Chanachai, A., Meksup, K. & Jiraratananon, R. (2010) Coating of hydrophobic hollow fiber PVDF membrane with chitosan for protection against wetting and flavor loss in osmotic distillation process. *Separation and Purification Technology,* 72, 217-224.

[6] Downes, J. W. (1990). Equipment for extraction and processing of soft and pome fruit juices. In D. Hicks (Ed.), Production and packaging of non-carbonated fruit juices and fruit beverages (pp. 158–181).Glasgow: Blackie.

[7] Mansouri, J. & Fane, A. G. (1999) Osmotic distillation of oily feeds. *Journal of Membrane Science,* 153, 103-120.

[8] Pelin Onsekizoglua, (2010), K. Savas Bahcecib, M. Jale Acar, (2010)Clarification and the concentration of apple juice using membrane processes:A comparative quality assessment, *Journal of Membrane Science 352 (2010) 160–165*

[9] Pelin Onsekizoglu (2012), Membrane Distillation: Principle, Advances, Limitations and Future Prospects in Food Industry, *Advances from Modeling to Applications, p.n. 233-266*

[10] Piggott, J. R., Paterson, A., & Clyne, J. (1993). Prediction of flavor intensity of blackcurrant (Ribes nigrum L.) drinks from compositional data on fruit concentrates by partial least squares regression. *International Journal of Food Science and Technology, 28(6), 629–637*

[11] Ramteke, R. S., Eipeson, W. E., & Patwardhan, M. V. (1990). Behaviour of aroma volatiles during the evaporative concentration of some tropical fruit juices and pulps. *Journal of the Science of Food and Agriculture, 50(3), 399–405*

[12] Sulc, D. (1984). Fruit juice concentration and aroma separation. Confructa, 28(3), 258–318.

[13] Sulc, D. (1991). Fruchts€afte und fruchtsaftkonzentrate. In R. Heiss (Ed.), Lebensmittel technologie (pp. 209–227). Berlin: Springer

[14] Xu, J. B., Lange, S., Bartley, J. P. & Johnson, R. A. (2004) Alginate-coated microporous PTFE membranes for use in the osmotic distillation of oily feeds. *Journal of Membrane Science,* 240, 81-89.