Innovative Food Science and Emerging Technologies 43 (2017) 136–153

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Fruit juice processing using membrane technology: A review

Chiranjit Bhattacharjee*, V.K. Saxena, Suman Dutta

Department of Chemical Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand 826004, India

ARTICLE INFO

Keywords:
Membrane separation
Fruit juice
Membrane fouling
Ultrafiltration
Membrane distillation

ABSTRACT

Membrane technology has emerged as a substitute to traditional juice clarification and concentration processes as they require less manpower, reduce operating cost and low temperature. It is a low temperature process in which the organoleptic quality of the juice is almost retained. The advantages of these membrane processes over traditional methods are lower thermal damage to product, increase in aroma retention, less energy consumption, and lower equipment costs. Membrane concentration of fruit juice not only provides microbiological stability but also permits economy in packaging and distribution of the finished product due to a reduction in bulk by weight and volume. The biggest problem in the use of membrane based processes for the clarification/concentration of fruit juices is membrane fouling. Membrane fouling manifests itself as a decline in flux with the time of operation, reducing the membrane permeability. The degree of membrane fouling determines the frequency of cleaning, the lifetime of the membrane, the membrane area needed and consequently costs, design and operation of membrane plants. In this review, different membrane separation methods including microfiltration, ultrafiltration, nanofiltration and reverse osmosis for fruit juice clarification/concentration reported in the literature in the last fifteen years are discussed. Membrane Distillation methods for juice concentration is also covered in this review.

1. Introduction

Thermal processing remains the most widely employed method for shelf-life extension and food preservation and concentration. However, industrial thermal treatments may have negative impacts on nutritious components (such as anthocyanins, carotenoids, vitamins and bioactive proteins (Barros, Nunes, Gonçalves, Bennett, & Silva, 2011; Kechinski, Guimarães, Noreña, Tessaro, & Marczak, 2010; Provesi, Dias, & Amante, 2011; Van den Hout, Meerdink, & Vant Riet, 1999)) and sensory parameters (such as color, aroma, flavor (Nisha, Singhal, & Pandit, 2009; Timoumi, Mihoubi, & Zagrouba, 2007)). Membrane technology has emerged as the alternative to traditional thermal techniques for fruit juice clarification and concentration that were widely applied in the dairy and beverage industries. Membrane Separation methods are utilized in the food industry due to their less manpower requirement, greater efficiency and shorter processing time than conventional filtration. Consequently, the operational costs of using membrane processes are significantly lower than those of conventional processes (Nunes & Peinemann, 2001). Fruit juices are usually concentrated by multi-stage vacuum evaporation in order to reduce the storage and shipping costs, and to achieve stability and longer storage. However, loss of fresh juice flavors, color degradation and a "cooked" taste are some unwanted effects are associated with this method mainly due to the thermal impact. Researchers, over the years have tried to develop novel methods for retaining the flavor, aroma, appearance and mouth feel of freshly squeezed juices in the concentrate and ultimately in the reconstituted juice. Researchers have greatly succeeded in developing aroma retention, innovative process control and product blending methods to produce a good quality concentrate that can lead to consumer satisfaction, but not up to that level to make it readily unrecognizable from fresh juice. Significant efforts have been devoted in studying Ultrafiltration and Reverse Osmosis for juice clarification/concentration. Improved methods such as freeze concentration, sublimation concentration are also analyzed for juice processing (Koseoglu, Lawhon, & Lusas, 1990). But, based on recent research, the most encouraging alternative has to be membrane concentration. The types of pressure driven membrane separation processes which are most commonly used in juice processing are ultrafiltration (UF) and microfiltration (MF). They are able to separate particles in the approximate size ranges of 1–100 μm and 0.1–10 μm, respectively (Katasonova & Fedotov, 2009).

In recent times, advancements made in basic science and technology has enabled researchers to develop new membrane materials and improvements made in process engineering and intensification have helped overcoming major limitations of membrane based techniques. New membrane processes including membrane and osmotic distillation

* Corresponding author.
E-mail address: chiranjit@ce.ism.ac.in (C. Bhattacharjee).

http://dx.doi.org/10.1016/j.ifset.2017.08.002
Received 11 April 2017; Received in revised form 25 July 2017; Accepted 4 August 2017
Available online 05 August 2017
1466-8564/

and integration of these techniques might contribute to the improvement of quality and make it economically feasible at an industrial level for fruit juice processing (Calabro, Jiao, & Drioli, 1994; Girard & Fukumoto, 2000). Wide variety of membrane modules including tubular, hollow fiber and spiral wound have been used in the food industry according to their advantages. They can be applied within the production process, i.e. for clarification and concentration, as well as for treating the resulting wastewater that is generated prior to disposal (sewer or surface discharge) or re-use.

Raw fruit juice contains lower molecular weight components like sugar, acid, salt, flavor, and aroma compounds. It additionally contains noteworthy measure of macromolecules (100–1000 ppm) for example, polysaccharides (pectins, cellulose, hemicellulose, and starch), dimness shaping segments (suspended solids (SSs), colloidal particles, proteins, and polyphenols) and so forth. Therefore in order to store for longer periods for commercial use, the juice needs to be clarified. Clarification is necessary for the removal of such macromolecules. In traditional processes, enzyme treatment of raw juice is being performed with the help of enzymes (pectinase and amylase) for reducing the pectic substances and starch content followed by addition of fining agents. This enzymatic treatment helps in reducing the cloudiness and viscosity and thereby makes the clarification process easier. The main function of the fining agents such as gelatin, bentonite etc. is to enhance the settling of formed flocs. Then suspended solids, colloidal particles, proteins etc. are removed by conventional filtration. To facilitate the filtration process, filter aids such as diatomaceous earth or kieselguhr are used. The above mentioned traditional methods to clarify fruit juice are batch processes and are highly labor-intensive and time-consuming. Also one major concern is the incomplete removal of additives (fining agents and filter aids) from product juice which can affect the taste of juice. (DasGupta & Sarkar, 2012)

Thermal evaporation is one of the most conventional techniques for fruit juice concentration. Despite its economic feasibility and technology, it does exhibit some disadvantages when applied to fruit juices. Even under vacuum, operating temperatures are still high enough to bring about significant deterioration in the product juice such as degradation of color, loss of nutritional characteristics, and the development of a “cooked” taste. For example, lipids and ascorbic acid can be oxidized, amino acids and sugars can undergo the Maillard browning reaction, and pigments, especially anthocyanin, carotenoids, and chlorophyll, can be degraded (Toribo & Lozano, 1986; Lozano & Ibarz, 1997; Mikkelsen & Poll, 2002; Kato et al., 2003; Maskan, 2006). Due to high temperatures of evaporation, loss of aroma compounds occur in fruit juices (Lin, Rouseff, Barros, & Naim, 2002; Ramteke, Eipeson, & Patwardhan, 1990; Nisperos-Carriedo & Shaw, 1990).

Hence, compared to these traditional methods, energy saving membrane operations such as microfiltration (MF) and ultrafiltration (UF), represent a valid alternative for the clarification of additive-free high-quality fruit juices with natural fresh taste (DasGupta & Sarkar, 2012). One of the important plus points of using membranes in the clarification/concentration of fruit juice is that traditionally used dead-end mode operated cartridge or bag filters, generates a lot of media waste that needs to be disposed of. But there is very little build up on the surface in crossflow membrane separation processes therefore media disposal problems are minimized. (Ionics Inc, 2004). This paper will review the recent significant progress on membrane processes for clarifying and concentrating fruit juices, including the use of microfiltration, ultrafiltration, reverse osmosis, direct osmosis concentration, membrane and osmotic distillation, and integrated membrane processes.

2. Membrane processes

Below we present different membrane processes commonly used in the food processing industry and their applications in fruit juice processing.

2.1. Microfiltration (MF)

In the fruit juice processing industry, the main purpose of MF is mainly clarification to remove suspended solids (SS), fat and high molecular weight (HMW) proteins. In dairy industry, MF is used to clarify cheese whey, as well as de-fat and reduce the microbial load of milk (Merin, 1986). Microfiltration can also be used to separate fruit juices into a fibrous concentrated pulp, and a clarified fraction free of spoilage micro-organisms. Fruit juice processing industry widely uses MF for juice clarification purpose (De Oliveira, Doce, & de Barros, 2012; Vaillant, Millan, Dornier, Decloux, & Reynes, 2001).

2.2. Ultrafiltration (UF)

UF is essentially utilized for fractionation, fixation and filtration. For instance, UF can be utilized to fractionate milk for cheese generation, i.e. the retentate part contains proteins, fat and certain insoluble and bound salts, while the permeate contains lactose and solvent salts (Brans, Schroën, van der Sman, & Boom, 2004). Concentration of skimmed milk using UF produces a high calcium and protein content product (Vyas & Tong, 2003) which is one of its major applications in the dairy industry.

The fruit juice industry also uses UF for both clarification and concentration depending upon the MWCO. For elucidation, the permeate instead of the retentate is the result of intrigue. UF is utilized to clear up a wide assortment of natural juices by evacuating polluting influences, for example, yeast, molds, microscopic organisms and colloids, together with proteins, tannins and polysaccharides, which all confers stability to the last item (Mohammad, Ng, Lim, & Ng, 2012).

2.3. Nanofiltration (NF)

NF is most normally used to isolate a mixture that has a blend of some attractive parts and some that are not alluring. A case of this is the concentration of lactose syrup (Zhang, Yang, Zhang, Zhao, & Hua, 2011). It facilitates the passing of water through the membrane and at the same time holding back the sugar, and thereby concentrating the solution. NF is also effective in concentrating divalent salts, bacteria, proteins and other constituents that have a molecular weight $>$ 1 kDa.

NF can be utilized to in part demineralization, and in addition to concentration. NF is a moderately new process for the demineralization of whey (Pan, Song, Wang, & Cao, 2011) in the dairy industry. In the juice processing industry, NF can be used to concentrate useful bioactive compounds from fruit juices e.g. lycopene in case of watermelon juice (Arriola et al., 2014).

2.4. Reverse osmosis (RO)

The main application of RO in food processing industries is to concentrate, purify and recover valuable components. RO can also be used in combination with other membrane separation processes, such as MF and UF. RO requires less operational cost due to evaporation, or even the elimination of this step (Hedrick, 1983; Merson, Paredes, & Hosaka, 1980). The energy requirements of RO have been shown to be significantly less than for mechanical vapor compression. RO is also applied for preconcentration of fruit juices. The method can be used instead of high temperatures. In this way, the qualitative degradation of the product due to exposure to heat is significantly reduced and the process becomes of lower cost (Kotsanopoulos & Arvanitoyannis, 2015). RO's other advantages include:

- Quality of separation
- Minimal heat damage
- Low amount of waste generation and treatment
- Smaller footprint
- Lower capital requirements