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Journal of Food Engineering 79 (2007) 1397–1404

JOURNAL OF FOOD ENGINEERING

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Concentration of clarified kiwifruit juice by osmotic distillation

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Received 25 November 2005; accepted 12 April 2006
Available online 4 May 2006

Abstract

This study was undertaken in order to evaluate the potential of the osmotic distillation (OD) process for concentrating clarified kiwifruit juice on laboratory scale, taking into account the impact on the product quality especially in terms of ascorbic acid content and total antioxidant activity (TAA). The performance of the OD process in terms of flux and concentration factor was also evaluated.

The clarified juice, with an initial TSS content of 9.4°Brix, was concentrated up to final values of 66.6°Brix, by using a laboratory bench plant equipped with a Liqui-Cell® Extra-Flow 2.5 × 8 in. membrane contactor realised with polypropylene hollow fiber membranes. Calcium chloride dihydrate at 60 w/w% was used as stripping solution producing an initial evaporation flux of about 1.3 kg/m^2 h. The experimental data indicates that at low total soluble solids (TSS) concentration the evaporation flux decay is more attributable to the dilution of the stripping solution while, starting from a TSS value of 35°Brix, the evaporation flux depends mainly on juice viscosity and, consequently, on juice concentration.

The analytical measurements showed that the OD process has no influence on the acid ascorbic content independently by the concentration degree achieved, while in the retentate at 66.6°Brix obtained by thermal evaporation a reduction of 87% of Vitamin C was observed with respect the clarified juice. Also the TAA of the clarified juice was maintained constant during the osmotic distillation process while a reduction of 50% of this activity was detected in the retentate samples coming from the thermal treatment.

On the basis of the experimental results an integrated membrane process for the clarification and concentration of kiwifruit juice was proposed.

Keywords: Kiwifruit juice; Ultrafiltration; Osmotic distillation; Total antioxidant activity; Ascorbic acid

1. Introduction

The fruit of *Actinidia chinensis*, commercially known as kiwifruit, is characterised by significant amounts of biologically active compounds, including ascorbic acid, and by an impressive antioxidant capacity due to the presence of phytonutrients, including carotenoids, lutein, phenolics, flavonoids and chlorophyll (Kvesitadze, Kalandiya, Papunidze, & Vanidze, 2001). Most part of these compounds offer benefits for specific health conditions and, consequently, kiwifruit has a great potential for industrial exploitation (Cano Pilar, 1991; Ferguson, 1990; Luh & Wang, 1984).

Researches on the suitability of processing technology for kiwifruit were carried out by several authors, since 1976, as extensively reported by Dalla Rosa and Bressa (1995). However the realization of a good quality processed kiwifruit is not simple and the possibility to have an industrial valorisation of the fruit is yet away to be found.

The main goal of the kiwifruit processing is to obtain safe and stable products able to retain as more as possible the peculiarity of fresh fruit, as well as green colour, aroma, nutritional value and structural characteristics (Dalla Rosa, Mastrocola, Maltini, & Sacchetti, 1999).

At moment the kiwifruits derivatives on the market are represented mainly by semi-processed products, addressed to the food industry as ingredients or components for ice-creams, yoghurt, cakes and juice blending. In particular, the kiwifruit juice is mainly used as component of juice

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doi:10.1016/j.jfoodeng.2006.04.021

blends due to his high acidity and difficulties in maintaining the original green colour. Frozen pulp and concentrated juices are usually mixed with apple juice or other tropical juices (mango, papaya, passion fruit, etc.) for blended juice, nectar and yoghurt preparation.

In general, the concentration of fruit juices includes a series of advantages such as: weight and volume reduction with consequent reduction of packaging, transport, handling and storage costs; water activity reduction with enhancement of the product stability; a better product preparation for a final drying treatment.

Commercial processes in current use usually involve multistage vacuum evaporation of water at high temperature followed by recovery and concentration of volatile flavours and their addition back to the concentrated product (Barbe, Bartley, Jacobs, & Johnson, 1998). This technique nevertheless causes some degree of heat degradation with a consequent remarkable qualitative decline. Besides, the heat required to perform the evaporation results in some "cooked" notes recognised as off-flavours.

The production of superior quality concentrates, especially fruit juices, is a very important goal and considerable R& D efforts have been devoted to develop non thermal concentration techniques (Celere & Gostoli, 2004). These methods include: freeze concentration systems (cryoconcentration) and membrane processes.

The cryoconcentration technique, in which water is removed as ice and not as vapour, is more efficient in preserving the original qualities of thermosensitive aromatic fruit juices. However it is limited by high capital and operating costs, remarkable energy consumption and achievable degree of concentration lower than the values obtained by evaporation (Jariel et al., 1996; Köseoglu, Lawhon, & Lusas, 1990).

Membrane concentration processes, such as reverse osmosis (RO), membrane distillation (MD) and osmotic distillation (OD), present some attractive potentials to overcome limitations associated with vacuum evaporation.

Fruit juice concentration by RO has been of interest to the fruit processing industry for about 30 years. The advantages of RO over traditional evaporation are in lower thermal damage to product, increase in aroma retention, reduction of energy consumption and lower capital investments (Jiao, Cassano, & Drioli, 2004; Merson, Paredes, & Hosaka, 1980) as the process is carried out at low temperatures and it does not involve phase change for water removal. However disadvantage of RO is represented by its inability to reach the standard concentrations produced by evaporation because of high osmotic pressure limitation. In this contest RO could be used as preliminary step in a two-stage concentration process or when the degree of concentration is less than 30°Brix (Cross, 1989).

Membrane distillation permits to reach higher levels of dissolved solids than reverse osmosis. However a limitation of the process is represented by a loss of organic volatiles which can be occurred due to the necessity to heat the feed stream to maintain the water vapour pressure gradient which constitutes the driving force of the process.

Osmotic distillation is a new technology based on the use of an hydrophobic microporous membrane which separates two liquid phases that differ between them in terms of solute concentration: a dilute solution on one side and a hypertonic salt solution (concentrated brine stripper) on the opposite side. The driving force of the process is given by a water vapour pressure gradient across the membrane generated by the difference in water activity between the two sides of the membrane. The hydrophobic nature of the membrane prevents penetration of the pores by aqueous solutions, creating air gaps within the membrane. The water vapour pressure gradient across the membrane determines a transfer of vapour across the pores from the high-vapour pressure phase to the low one (Alves & Coelhoso, 2002; Barbe et al., 1998; Courel, 1999; Gostoli, 1998, 1999; Hogan, Canning, Peterson, Johnson, & Michaels, 1998; Kunz, Benabiles, & Ben-Aïm, 1996; Lebfevre, 1988).

OD can be carried out at low temperatures limiting the loss of organic volatiles to that which occurs under the influence of the partial pressure gradient across the membrane at room temperature.

This study was undertaken in order to evaluate the potential of OD for concentrating clarified kiwifruit juice on laboratory scale taking into account the impact on the product quality especially in terms of ascorbic acid content and total antioxidant activity (TAA). The performance of the OD process in terms of flux and concentration factor was also evaluated.

The possibility to design an integrated membrane process UF/OD for the production of a kiwifruit juice with high nutritional value and with organoleptic characteristics similar to those of the fresh juice was investigated. At this purpose the analytical measurements performed on the OD retentates at different values of TSS were compared with those of the juice concentrated by thermal evaporation.

2. Materials and methods

2.1. Juice extraction

Hayward kiwifruits were purchased from the local open market (Cosenza, Italy). Unpeeled fruits were manually washed in water and cut in pieces. The kiwifruits pieces were milled using a multiple shaker-liquidizer (Aristarco s.r.l., Treviso, Italy) in order to facilitate and accelerate the action of pectolytic enzymes added later. After pulping sodium sulphite (Sigma–Aldrich, Milan, Italy) was added (2–3 g kg^{-1} of pulp) in order to inhibit the enzyme polyphenol oxidase that determines a browning of the pulp. A pectinase from *Aspergillus aculeatus* (Pectinex Ultra SP-L, Novo Nordisk A/S, Novo Allè, Bagsuaerd, Denmark) (10 g kg^{-1} of pulp) was also added. The enzyme is able to hydrolyse both high and low esterified pectins and