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Concentration of camu–camu juice by the coupling of reverse osmosis and osmotic evaporation processes

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ABSTRACT

The objective of this work was to evaluate the technical feasibility of coupling two membrane separation processes, reverse osmosis (RO) and osmotic evaporation (OE), in order to concentrate clarified camu–camu juice, focusing on the vitamin C, phenolic compounds and antioxidant activity of the final product. The juice was firstly pre-concentrated by RO, reaching 285 g kg^{-1} of soluble solids. During this step, the juice's osmotic pressure showed to be the main factor controlling mass transfer. The juice was then concentrated by OE, reaching 530 g kg^{-1} of soluble solids. Vitamin C, total phenolics and antioxidant activity levels of 94.6 g ascorbic acid kg^{-1}, 105.2 g galic acid kg^{-1} and 762 mmol Trolox kg^{-1}, respectively, were achieved in the final product. The use of integrated membrane processes proved to be an interesting alternative to the concentration of thermosensitive juices, reaching concentration levels up to 7 times for camu–camu juice's bioactive compounds.

1. Introduction

Camu–camu (*Myrciaria dubia* (*H.B.K.*) *Mc Vaugh*) is a fruit from the Amazonian region, found on the margins of rivers and lakes. Its main characteristic is the high vitamin C content, with reported values ranging from 1000 to 6000 mg/100 g (Chirinos et al., 2010; Justi et al., 2000). Camu–camu is also considered a good source of polyphenols, with values higher than 1000 mg galic acid/100 g (Maeda et al., 2006; Rufino et al., 2010; Zanatta et al., 2005). Its high phenolic content, together with vitamin C, contributes to its high antioxidant capacity and consequent health benefits.

The high concentration of ascorbic acid and phenolic compounds results in the high acidity of camu–camu, which does not attract the consumption of its fresh pulp. However it can be mixed to other fruits in order to provide a nutritional enrichment, besides serving as raw material for obtaining products such as ice cream, nectars, jams and yoghurt (Rodrigues et al., 2004). With the development of increasingly globalized markets, the need of reduced costs associated to logistics operation (packaging, storage and transportation) has become a fundamental point for products competitiveness and conquest of new markets. In this sense, the concentration processes stand out as an important tool to facilitate commercialization, especially for imports and exports.

In general, fruit juices are preserved and concentrated by thermal processes such as pasteurization and vacuum evaporation. However, the product heating during these processes can change the natural aroma and flavor of the fresh juice and cause degradation of thermosensitive compounds such as vitamin C and other bioactive compounds responsible for its antioxidant activity (Cassano et al., 2007; Fernandes et al., 2007; Galaverna et al., 2008).

Membrane technology is an alternative to the conventional processes for juice concentration and clarification (Álvarez et al., 2000; Girard and Fukumoto, 2000). It has many advantages over traditional separation processes: in general separation occurs at room temperature, with no phase change and without using a heat source, resulting in considerable energy savings and avoiding oxidation and degradation of thermolabile compounds (Mulder, 1996). Among the different techniques of membrane separation, reverse osmosis and osmotic evaporation have stood out for their potential for concentration of fruit juices (Girard and Fukumoto, 2000; Vaillant et al., 2001).

Juices concentration by reverse osmosis has been evaluated for temperate and tropical fruits, showing satisfactory results regarding the preservation of the final product quality (Cassano et al., 2003; Kozák et al., 2008; Jesus et al., 2007). Reverse osmosis (RO)

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is a process in which a hydraulic pressure greater than the solution osmotic pressure is applied, so that water permeates from a high to low solute concentration. However, this pressure driven process is limited by the product osmotic pressure that increases with increasing concentration. For this reason, RO is in general considered a pre-concentration technique, allowing juice concentration only up to 25–35°Brix (Couto et al., 2011; Jesus et al., 2007).

Osmotic evaporation (OE) is a process able to remove water from a solution at low temperature and pressure. The driving force is the concentration difference between the solution being concentrated (in this case, the juice) and a hypertonic solution, typically a concentrated brine (Vaillant et al., 2001). Juices concentrated by osmotic evaporation can achieve high soluble solids content, higher than 60 Brix, keeping their nutritional characteristics (Cassano et al. 2003; Cissé et al., 2011; Koroknai et al., 2006).

However, the use of osmotic evaporation as a direct process to concentrate fruit juices is difficult to implement at industrial scale, since the large amount of water present in the initial juice promotes a fast brine dilution, which negatively affects the water removal from the juice. In this context, the coupling of reverse osmosis and osmotic evaporation can be considered a promising alternative, since it results in products with similar solid content than those obtained by conventional methods (such as vacuum evaporation), with less pronounced effects on the juice's quality.

The objective of this work was to evaluate the effect of coupling reverse osmosis and osmotic evaporation processes on the quality of concentrated camu–camu juice. The processes were evaluated in terms of permeate flux and volumetric reduction ratio, and the juices were evaluated for total and soluble solids, total acidity, ascorbic acid, total phenolic content and antioxidant activity.

2. Materials and methods

Fig. 1 illustrates all the steps performed for camu–camu juice concentration.

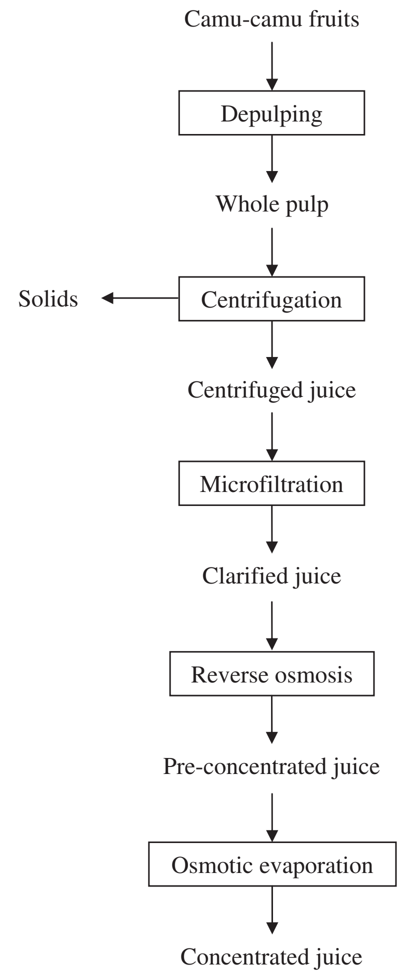

Fig. 1. Flux diagram of camu–camu juice concentration by coupling reverse osmosis and osmotic evaporation processes.

2.1. Raw material and clarified juice processing

Frozen camu–camu pulp was acquired at the Central Supply Market of Rio de Janeiro state. The pulp was thawed according to the amount necessary for each process. The camu–camu pulp was initially centrifuged, aiming to standardize and reduce the suspended solid content, with the aid of a basket centrifuge SIZE 2 (International Equipment Company, Needham, USA), at 4000 rpm (479.2 g), using a 150 μm Nylon® screen as the filter media. The centrifuged juice was then clarified in a semi-pilot system of crossflow microfiltration (TIA, Techniques Industrielles Appliquées, Bollene, France) consisting of four tubular ceramic membranes of α-alumina, T1-70 (Pall Corporation: Membralox® Ceramic Membrane Products, New York, USA), with mean pore size diameter of 0.1 μm and total permeation area of 0.022 m^2. Microfiltration was performed at 45 °C, with a transmembrane pressure of 2.5 bar and tangential velocity of 6.9 m/s.

2.2. Concentration

The concentration of camu–camu juice was carried out in two steps. Firstly, the clarified juice was concentrated by reverse osmosis up to around 300 g kg^{-1}. Then, this juice was further concentrated by osmotic evaporation up to 550–600 g kg^{-1}.

2.2.1. Reverse osmosis

The pre-concentration of the clarified juice by reverse osmosis was performed in a plate and frame reverse osmosis system Lab Unit 20 (DSS, Silkeborg, Denmark), composed of HR98PP thin film composite membranes (DSS, Silkeborg, Denmark), with 98% nominal rejection to a 0.25% NaCl solution and permeation area of 0.288 m^2. The process was carried at 20 °C and 60 bar, according to Rodrigues et al. (2004).

2.2.2. Osmotic evaporation

Osmotic evaporation was carried out in batch mode in a lab scale system consisted by two independent circuits, one for the juice and the other for the brine. The hydrophobic flat sheet membrane (Pall Gelman – TF 200) with effective surface area of 0.032 m^2 was located in the middle of a stainless steel cell (Fig. 2). This membrane is composed by a thin polytetrafluoroethylene selective layer supported by a polypropylene macro porous layer. According to the manufacturer, its average characteristics are 60% porosity, 0.2 μm average pore diameter and 165 μm thickness. Approximately one liter of 5.5 M $CaCl_2$ solution was used as brine. The brine and the pre-concentrated juice were kept at 20 °C and 35 °C using thermostatic baths, with maximum transmembrane pressure of 0.2 bar in order to avoid aqueous linkages through the membrane. During osmotic evaporation, the brine and the juice were kept under circulation at a flow rate of approximately 80 kg h^{-1} and $CaCl_2$ crystals were added to maintain the brine solution near saturation (at 5.5 mol L^{-1}).