FOOD AND BIOPRODUCTS PROCESSING 91 (2013) 473–480

Contents lists available at ScienceDirect

Food and Bioproducts Processing

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

Clarification of red raspberry juice using microfiltration with gas backwashing: A viable strategy to maximize permeate flux and minimize a loss of anthocyanins

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ABSTRACT

Red raspberry (*Rubus idaeus*) juice was produced by maceration of raspberry pulp at 50 °C for 2 h using 400 mg kg^{-1} Klerzyme® 150 enzymatic pectolitic preparation followed by raw juice clarification with gelatin and bentonite or cross-flow membrane filtration. A minimal loss of anthocyanins from 630 to 540 mg l^{-1} was obtained when the juice was clarified using a ceramic multichannel microfilter (MF) with a pore size of 0.2 μm. A light transmission at 625 nm in MF permeate was above 85% and the residual pectin (900 mg l^{-1}) was completely removed. During ultrafiltration through ceramic or polysulfone membranes with a molecular weight cut-off of 30–300 kDa, the content of anthocyanins was reduced to 220–370 mg l^{-1}, but a light transmission at 625 nm was as high as 96%. The permeate flux in MF was maintained at high values above 170 l m^{-2} h^{-1} at 3 bar for more than 2 h by backwashing the membrane with a compressed air every 6 min for 1 min. The cake compression at high pressures was avoided by short filtration times between backwashing.

Keywords: Microfiltration; Ultrafiltration; Red raspberry juice; Clarification; Anthocyanin

1. Introduction

Red raspberries (*Rubus idaeus* L.) are produced in 37 countries worldwide on about 184,000 acres with a global production estimated at over 400,000 tons per year. Only about 3% of red raspberries are sold fresh and the rest are processed into juices and other products such as jams, jellies, confectionery products, and yogurts. Red raspberry juice is a rich source of phenolic compounds with antioxidant capacity, such as anthocyanins and elagitannins (Weber et al., 2001; Suh et al., 2011; Mejia-Meza et al., 2010). Phenolic compounds from red raspberries show strong antimicrobial properties and can selectively inhibit the growth of intestinal pathogens, especially *Staphylococcus* strains (Puupponen-Pimiä et al., 2005). Consumption of red raspberry juice has been shown to lead to a marked reduction in aortic lipid deposition, which can help to prevent the development of early atherosclerosis (Suh et al., 2011; Rouanet et al., 2010). Red raspberry juice may also have beneficial effects against several types of human cancers, which is attributed to its ability to reduce damage resulting from oxidative stress and inflammation (Seeram, 2008; Zafra-Stone et al., 2007).

Red raspberry juice is usually stored and traded in the form of a clear juice concentrate to reduce the storage and transportation costs. A cloudy juice can be clarified by flocculation of suspended solids with fining agents, such as gelatin and bentonite (Benitez and Lozano, 2007) or using membrane filtration. Compared to traditional processing with fining agents that require subsequent diatomaceous earth filtration, ultrafiltration (UF) or microfiltration (MF) entirely eliminates the

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Received 6 January 2013; Received in revised form 24 April 2013; Accepted 2 May 2013
0960-3085/$ – see front matter
http://dx.doi.org/10.1016/j.fbp.2013.05.004

use of diatomaceous earth and fining agents, the consumption of pectolitic enzymes is reduced because enzymes can be recycled, and the total processing time can be significantly shortened (Girard and Fukumoto, 2000).

The major problem in the operation of UF and MF in the fruit juice industry is membrane fouling, which leads to a significant reduction in permeate flux with time (Mondor et al., 2000). In order to control membrane fouling and maximize permeate flux during juice clarification, several flux enhancement methods have been studied including periodic backwash with air or N_2 (Su et al., 1993; Padilla-Zakour and McLellan, 1993), pressure and flow pulsations superimposed on a steady operating pressure (Gupta et al., 1992), gas sparging, i.e. injection of gas bubbles into the feed stream (Laorko et al., 2011), insertion of turbulence promoters in the feed channel (Pal et al., 2008), application of electric field in constant or pulsed mode (Sarkar et al., 2008a,b), and implementation of various juice pretreatment methods, such as fining treatment with gelatin and bentonite (Rai et al., 2007) and treatment with various filter aids (Youn et al., 2004).

In the past several decades, UF and MF have been increasingly investigated for clarification of juices of different fruits including apple (Vladisavljević et al., 2003), blackcurrant (Pap et al., 2012), sour cherry (Wang et al., 2005), pear (Kirk et al., 1983), melon and watermelon (Vaillant et al., 2005; Rai et al., 2010), kiwifruit (Cassano et al., 2008), passion fruit (Vaillant et al., 1999), starfruit (Sulaiman et al., 1998), orange and lemon (Rai et al., 2007; Espamer et al., 2006), grapefruit (Snir et al., 1995), mango (Vaillant et al., 2001), banana, pineapple and blackberry (Vaillant et al., 2008), chokeberry and redcurrant (Koroknai et al., 2008), grape (Rektor et al., 2004), peach (Brenna et al., 2000) and plum (Ushikubo et al., 2007).

However, to the best of our knowledge, there has been no previous research on using MF and UF to the clarification of red raspberry juice. The objectives of this study were: (i) to compare the quality of red raspberry juice clarified using conventional methods and UF or MF; (ii) to estimate the changes of color during production of fresh and reconstituted red raspberry juice; (iii) to investigate the effects of operating parameters and periodic gas backwash on the permeate flux during MF of red raspberry juice using a ceramic membrane.

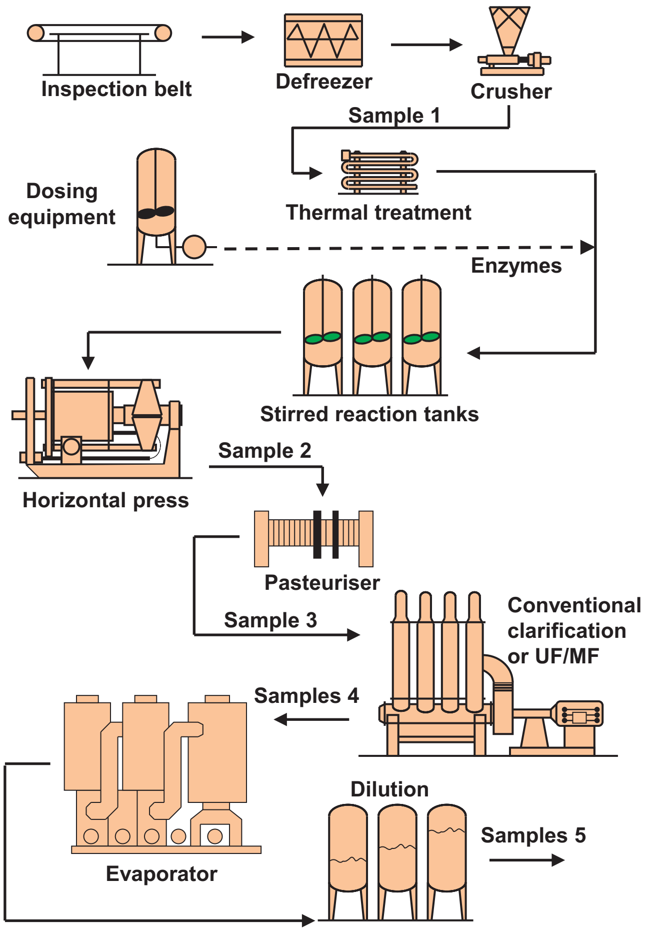

Fig. 1 – A scheme of the manufacturing process used in this work for red raspberry processing in clear juice concentrate using conventional clarification or membrane filtration (MF or UF). A light transmittance at 625 nm in samples 4 and the amount of total anthocyanins in samples 1–5 are given in Figs. 3 and 4, respectively.

2. Materials and methods

2.1. *Juice manufacturing process*

Red raspberry juice was produced from a Villamete variety using the manufacturing process shown in Fig. 1. Fruit was first defrosted and crushed to a pulp (sample 1). The pulp was heated at 90 °C for 2 min to destroy the endogenous polyphenol oxidase. If not inactivated, this enzyme can cause the oxidation of monophenols and o-diphenols in the fruit to o-quinones, which then undergo non-enzymatic polymerization or condensation reactions, leading to decolorizing and browning (Yoruk and Marshall, 2003). The pulp was then cooled down to 50 °C for a single-stage enzymatic maceration (Aehle, 2007). The maceration was performed at 50 °C for 2 h using 400 mg kg^{-1} pectinase preparation produced from *Aspergillus niger* (Klerzyme®150, DSM, Lill, France). Pectinases were used to increase juice yield and accelerate juice clarification. After that, the pulp was pressed in a hydraulic press with a volume of 5 l under a pressure of 150 bar to extract juice (sample 2). A cotton bag filter with a pore size of about 20 μm was used to retain the pulp in the press. A juice yield during pressing was 89.2%, which means that 89.2 kg of a raw juice was extracted per 100 kg of pulp. The juice was tested for pectin using the alcohol test and a result was negative. The juice was then pasteurized at 90 °C to denature the proteins, followed by fast cooling to allow denatured proteins to precipitate.

A pasteurized raw juice (sample 3) was clarified using seven different methods, namely fining with 36 mg l^{-1} gelatin and 1000 mg l^{-1} bentonite (sample 4a), fining with 65 mg l^{-1} gelatin and 1000 mg l^{-1} bentonite (sample 4b), UF using a 300-kDa Carbosep M9 membrane (sample 4c), UF using a 50-kDa Carbosep M8 membrane (sample 4d), UF using a 30-kDa Carbosep M7 membrane (sample 4e); UF using a 30-kDa polysulfone hollow fiber membrane (sample 4f), and MF using a 0.2-μm pore size Kerasep W5 membrane (sample 4 g). The clarified juice was evaporated from 9 to 60 °Bx at a pressure of 0.1 bar, corresponding to the boiling point of 46 °C. The concentration of solids in the juice after evaporation was similar to typical Brix levels in a commercial red raspberry concentrate of 60–65 °Bx". Finally, the juice concentrate produced using different clarification methods was diluted with distilled water back to its original strength of 9.4 °Bx (samples 5) in order to compare the loss of anthocyanins in the fresh and reconstituted juice samples.