LWT - Food Science and Technology 45 (2012) 117–121

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Research Note

Study on the applicability of high-pressure homogenization for the production of banana juices

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ARTICLE INFO

Article history:
Received 30 April 2010
Received in revised form
18 July 2011
Accepted 19 July 2011

Keywords:
Fruit
High-pressure homogenization
Enzyme inactivation
Bacterial inactivation

ABSTRACT

The aim of this preliminary study was to evaluate the potential applicability of high-pressure homogenization (HPH) for the production of banana juices. To this purpose, a prototype equipment working up to 400 MPa and a lab-scale homogenizer working up to 150 MPa were used. Temperature, microbial load, pectate lyase activity, colour and viscosity of the samples homogenized at increasing pressure were evaluated. Pressures higher than 200 MPa were needed to obtain 4 log unit reduction of total mesophilic bacteria and pectate lyase inactivation. Following HPH, banana juice resulted brighter and less viscous than the untreated one. Data suggest that HPH treatments could be a reliable technological alternative to conventional heat treatments for the production of added-value fruit juices. However, the homogenization design could play a critical role in affecting the product quality attributes. In fact, homogenization performed at the same operative pressure by using different equipment leads to different effects on product quality.

1. Introduction

In recent time, the demand for fresh fruit juices and smoothies with high quality level has been growing quickly. As known, pasteurisation is essential to obtain safe products by destroying spoilage microorganisms and inactivating enzymes. However, thermal processing causes some undesirable detrimental effects, such as non enzymatic browning, off-flavour formation and vitamin damage. High-pressure homogenization (HPH) is a promising technique, particularly suitable for continuous production of fluid foods, allowing to limit thermal damage and promote "freshness". Different equipments based on high-pressure homogenization are actually in development, at both prototype and industrial scales. Pressures normally used in the industry are between 20 and 50 MPa, but today the available homogenizers reach much higher pressures up to 400 MPa. In general terms, if the fluid is subjected to pressure about 300–400 MPa it is referred to an ultra high-pressure treatment (Cruz et al., 2007; Cortès-Muñoz, Chevalier, & Dumay, 2009; Pereda, Ferragut, Quevedo, Guamis, & Trujillo, 2007).

Piston-gap type high-pressure homogenizers consist of one or two piston intensifier(s) able to generate high-pressure and high-pressure valve (s) with specially studied design. During HPH, the fluid is forced to pass through a narrow gap in the homogenizer valve, where it is submitted to a rapid acceleration (Floury, Belletre, Legrand, & Desrumaux, 2004a; Floury, Legrand, & Desrumaux, 2004b). As a consequence, phenomena such as cavitation, shear and turbulence are simultaneously inducted (Freudig, Tesch, & Schubert, 2003; Pasquin, 1999) leading to an instant temperature increase whose magnitude depends on the intensity of the applied pressure.

The main industrial application of HPH is linked to the production of stable emulsions. For this reason, it is widely used in pharmaceutical, cosmetic and food industries. In particular, HPH has shown good potential for applicability mainly in the dairy sector (Vannini, Lanciotti, Baldi, & Guerzoni, 2004; Lanciotti, Patrignani, Lucci, Saracino, & Guerzoni, 2007; Burns et al., 2008; Serra, Trujillo, Guamis, & Ferragut, 2009). Several studies have shown that HPH could inactivate bacteria and yeast (Lanciotti, Sinigaglia, Angelini, & Guerzoni, 1994; Lanciotti, Gardini, Sinigaglia, & Guerzoni, 1996; Briñez, Roig-Saguès, Herrero, & Lopez, 2006; Diels & Michiels, 2006; Corbo et al., 2009). Microorganisms are inactivated through mechanical disruption of cells caused by spatial pressure and velocity gradients, turbulence and cavitation. The level of inactivation depends on the nature of the microorganism and the applied pressure. In general, gram positive bacteria are most resistant to HPH, while gram negative bacteria are more sensitive to HPH, followed by yeast and moulds (Donsì, Ferrari, & Maresca, 2006; Lanciotti et al., 2006; Tahiri, Makhlouf, Pasquin, & Fliss, 2006; Vachon, Kheadar, Giasson, Pasquin, & Fliss,

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doi:10.1016/j.lwt.2011.07.026

2002; Wuytack, Diels, & Michiels, 2002). On the basis of literature data, treatments at 100 MPa reduced *Escherichia coli*, *Streptococcus lactis* and *Bacillus subtilis* population of ca 3-log units and *Listeria monocytogenes*, *Yersinia enterocolitica* and *Yarrowia lipolytica* cell population of 2/6-log (Lanciotti et al., 1994; Popper & Knorr, 1990). Ultra high-pressure homogenization (UHPH) must be used to obtain higher microbial inactivation level. Results of Campos and Cristianini (2007) indicate that pressure higher than 250 MPa is needed to completely destroy an initial population of 10^7 CFU of *Lactobacillus plantarum* and 10^5 CFU of *Saccharomyces cerevisiae* in orange juice. Similar results were obtained by Pathanibul, Taylor, Davidson, and Harte (2009) on *E. coli* and *Listeria innocua* in apple and carrot juice. These authors suggested that UHPH could be considered as an alternative processing technology to produce safe juices.

To obtain a high quality fresh fruit product, microbial inactivation is not the sole goal. In fact, the novel technology should also have the power to inactivate the enzymes responsible for food quality depletion during storage. The effect of HPH on enzyme activity has received little attention in literature. Lacroix, Fliss, and Makhlouf (2005) showed that the application of 170 MPa treatments on orange juice decreases the pectin methylesterase activity by 20%, but this is insufficient to obtain any appreciable increase in the juice quality during storage. Only by applying 250 MPa pressures, pectin methylesterase activity of orange juice could be reduced by 80% (Welti-Chanes, Ochoa-Velasco, & Guerrero-Beltran, 2009). Some additional indications come from Pedera, Ferragut, Buffa, Guamis, and Trujillo (2008), whose results showed that milk plasmim activity could be reduced up to 70% by UHPH at 300 MPa. Finally, Liu et al. (2009) evidenced that polyphenoloxidase activity increases as a consequence of a 150 MPa treatment. However, in this case high pressure was achieved by using microfluidization instead of valve homogenization.

This study is a preliminary work addressed to evaluate the potential applicability of HPH for the production of fruit smoothies and juices. To this purpose, a prototype equipment working up to 400 MPa and a lab-scale homogenizer working up to 150 MP was used to process banana juice. The latter was chosen as target product since it is an increasingly used ingredient in several tropical flavoured juices. Temperature, viscosity, colour, microbial count and pectate lyase activity of the samples homogenized at increasing pressure were evaluated.

2. Materials and methods

2.1. Sample preparation

Banana juice was prepared from fresh bananas of similar size and stage of ripening (5 on a 1–7 color scale) purchased at the local market. Intact unpeeled banana were washed, peeled and deseeded by hand. Aliquots of 500 g of fruits were reduced to a puree by mixing for 2 min at a maximum rate in a domestic mixer (Masterchef 5000, Moulinex International, Paris, France). The samples were then poured into 1 L capacity beaker and further homogenized for 1 min by using a high speed mixer (Ika-Werke, DI 25 basic, Staufen, Germany). Aliquots of 1 kg of banana puree were packed under vacuum in plastic bags and immediately frozen at −30 °C. This procedure was repeated until reaching 50 kg of banana puree.

Before high-pressure homogenization, the banana puree was thawed by storing it at 10 °C overnight. Banana puree was then mixed with drinkable water (1:1 w/w) at 4 °C to obtain a banana juice like product. The pH of the juice was 4.8. Banana juice was maintained at 4 °C until high-pressure homogenization.

2.2. High-pressure homogenization

The banana juice was treated by using the Model UHP 4000 bar prototype homogenizer (GEA Niro Soavi S.p.a., Parma, Italy) and the lab-scale high-pressure homogenizer NS1001L-PANDA 2K (GEA Niro Soavi S.p.a., Parma, Italy).

The Model UHP 4000 bar is a prototype unit homogenizer equipped with a single homogenization valve R design, made of a tungsten carbide, with a “sharp edge” (GEA Niro Soavi S.p.A., Parma, Italy). The sharp edge profile of the passage head is characterized by an inside diameter of 10.9–14 mm and an outside diameter of 11.9–15 mm (Grasselli, Gandini, & Grandi, 2005). The prototype is equipped with a heat exchanger after the homogenization stage allowing fluid cooling. The coolant temperature was 4 °C. An aliquot of 100 L of banana juice at 4 °C was homogenized at flow rate of 200 L/h using the following test pressures: 0, 150, 200, 300 and 400 MPa. Temperature after homogenization valve (T_h) and outlet temperature after cooling (T_{out}) were monitored instantaneously after the passage of the fluid by using a thermocouple probe mounted in the homogenizer.

The lab-scale high-pressure homogenizer NS1001L-PANDA 2K is a two stage homogenizer whose valves are composed of a ceramic ball (GEA Niro Soavi S.p.A., Parma, Italy). The first valve is the actual homogenization stage and was set at increasing pressure from 0 (control) to 150 MPa. The second valve was set at the constant value of 5 MPa. An aliquot of 250 mL of suspension was homogenized at flow rate of 10.0 L/h. The banana extract temperature was monitored just before and immediately after homogenization by using a thermocouple probe (Hanna Intruments, Tersid s.r.l., Milan, Italy).

After the homogenization processes, samples were immediately collected in sterile containers and stored at 4 °C for up to 30 days.

2.3. Dry matter

Total solid content was determined by gravimetric method according to AOAC (AOAC, 2000).

2.4. Colour analysis

Colour analysis was carried out using a tristimulus colorimeter (Chromameter-2 Reflectance, Minolta, Osaka, Japan) equipped with a CR-400 measuring head. The instrument was standardised against a white tile before measurements. Colour was expressed as Hunter scale parameters L*, a* and b*. Each sample was measured in triplicate.

2.5. Viscosity

Rheological determinations were performed at 4.0 ± 0.2 °C with a Stresstech Rheometer (Reologica Instruments AB, Lund, Sweden) using concentric cylinders geometry. The temperature control was obtained by using a circulating coolant connected to a thermostat. Experimental flow curves were obtained at shear rate ranging from 0.1 to 87.7 s^{-1}. Samples showed a pseudoplastic behaviour. Each sample was measured in triplicate.

2.6. Microbiological analysis

Samples were diluted in Maximum Recovery diluent (OXOID, Milan, Italy). Decimal dilutions in peptone water solution were plated in duplicate on to Plate Count Agar (PCA) (OXOID, Milan, Italy). Samples were analysed for total mesophilic bacteria (TMB) on PCA medium incubated at 30 °C for 24–48 h.