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Change of microbial and quality attributes of mango juice treated by high pressure homogenization combined with moderate inlet temperatures during storage

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The effects of high pressure homogenization (HPH) on microbial inactivation and quality attributes (physio-chemical properties, bioactive components and antioxidant capacity) of mango juice, as well as their changes during storage at 4 °C and room temperature were investigated. Pressure levels ranged from 40 to 190 MPa, the inlet temperature from 20 °C to 60 °C and the number of passes from 1 to 5. Complete inactivation of molds and yeasts was achieved by 1 and 3 passes at 190 MPa and 60 °C, while total plate count was below 2.0 $\log_{10}$ CFU/mL. No multiplication of microorganisms was observed in mango juice over 60 days of storage at 4 °C. HPH treatment could retain or even increase the carotenoids and total phenols by 11.8% and 21.4%, respectively, while significant reductions were found for heat treatment (HT) samples. During the storage of 60 days, HPH treatment also provided better preservation of color, bioactive components and antioxidant capacity of mango juice than HT.

Industrial relevance: High pressure homogenization (HPH) is a novel non-thermal technique, particularly suitable for continuous production of liquid foods limiting thermal damage and promoting "freshness". Results showed that high pressure homogenization had the advantage of notably reducing the microbial load to levels equivalent to thermal pasteurization. Moreover, HPH treatment was superior to heat treatment with regard to post-treatment levels of bioactive.

1. Introduction

In recent years, the consumers' demands for fruit juice, such as higher nutritive values, minimal processing and high quality have been growing quickly (Calligaris, Foschia, Bartolomeoli, Maifreni, & Manzocco, 2012; Suárez-Jacobo, Gervilla, Guamis, Roig-Sagués, & Saldo, 2010). Mango juice is a popular juice for its strong aroma, attractive color, delicious taste and high nutritive value with high contents of ascorbic acid, phenols and carotenoids (Liu, Li, Wang, Bi, & Liao, 2014; Tharanathan, Yashoda, & Prabha, 2006). Heat treatment (HT) is the most common technology used to extend shelf-life of juice, as it effectively destroys pathogenic microorganisms and reduces microbial spoilage (Suárez-Jacobo et al., 2010; Wibowo et al., 2015; Yu et al., 2014). Nevertheless, HT inevitably causes deterioration on nutrition and undesirable physicochemical changes, such as color change, flavor and aroma decreases. Thus, non-thermal technologies have been proposed for cold pasteurization, which could reduce the damage of heat on the nutritive and physio-chemical quality of fruit juice (Amador-Espejo, Suàrez-Berencia, Juan, Bárcenas, & Trujillo, 2014; Velázquez-Estrada, Hernández-Herrero, Rüfer, Guamis-López, & Roig-Sagués, 2013). High pressure homogenization (HPH) is a promising non-thermal technology, particularly suitable for continuous production of liquid foods limiting thermal damage and promoting "freshness" (Calligaris et al., 2012). Pressures of homogenization normally used in the industry are between 20 and 50 MPa, but today the available homogenizers reach much higher pressures up to 400 MPa (Calligaris et al., 2012). Depending on the nominal pressure level, the technology will be called HPH (up to 150–200 MPa) or ultra-high-pressure homogenization (UHPH, up to 350–400 MPa) (Dumay et al., 2013; Grácia-Juliá et al., 2008).

HPH treatment has showed the good potential on inactivation of microorganism in orange, apple, and carrot juices in recent researches. For instance, the application of HPH treatment (200 MPa/20 °C/1 pass) to apple juice could decrease counts of aerobic mesophilic, bacteria, psychrotrophic bacteria, lactobacilli, Enterobacteriaceae and faecal coliforms to the detectable limit, increasing the shelf-life of the

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products to several weeks (Suárez-Jacobo et al., 2010). In addition, *Lactobacillus plantarum*, *Saccharomyces cerevisiae* (Campos & Cristianini, 2007), *Salmonella enterica* serovar Senftenberg 775 W & *Listeria monocytogenes* (Velázquez-Estrada et al., 2011) in orange juice can be reduced by ≥5.0 $\log_{10}$ CFU/mL by HPH treatment. Moreover, several studies showed that in comparison with HT, greater preservation of color, bioactive compounds and antioxidant activity of fruit juice could be achieved by using HPH treatment. Suárez-Jacobo et al. (2010) and Maresca, Donsì, and Ferrari (2011) found HPH treatment did not change pH, total soluble solids (TSS) and titratable acid (TA) in apple juice, and those values kept stable over the storage of 28 days at 4 °C. Color of juice could be preserved even improved by HPH treatment. The color parameters (L^*, a^*, b^* and ΔE) of apple juice were not significantly affected after 3 passes of HPH at 150 MPa and 20 °C and during the storage of 28 days at 4 °C (Maresca et al., 2011). Color of banana juice (150–400 MPa/4 °C/1 pass) and apple juice (300 MPa/4 °C or 20 °C/1 pass) were significantly improved by HPH treatment with increasing the L^* values and decreasing a^* value (Calligaris et al., 2012; Saldo, Suárez-Jacobo, Gervilla, Guamis, & Roig-Sagués, 2009). Velázquez-Estrada et al. (2013) reported that HPH treatment (200 MPa and 300 MPa/6 °C/1 pass) caused a 5% and 11% reduction of vitamin C in orange juice, but the reductions were still lower than that of thermal pasteurization (90 °C/1 min, 17.4%), and other researchers found that HPH treatment with different pressure and passes number did not change vitamin C in orange juice (50–250 MPa/22 °C/1 pass) and apple juice (100–300 MPa/4 °C or 20 °C/1 pass) (Suárez-Jacobo et al., 2011; Welti-Chanes, Ochoa-Velasco, & Guerrero-Beltrán, 2009). Total phenols in apple juice (100–300 MPa/4 °C/1 pass, 100–200 MPa/20 °C/1 pass) and mulberry juice (200 MPa/4 °C/1 and 3 passes) were also not significantly changed by HPH treatment (Suárez-Jacobo et al., 2011; Yu et al., 2014).

The most important processing parameters for HPH treatment are the operating pressure, inlet temperature, and the number of passes (Amador-Espejo et al., 2014; Diels & Michiels, 2006; Dumay et al., 2013; Maresca et al., 2011). Most of previous studies regarding to HPH applied for juice processing were conducted under room or lower temperature during HPH processing. Tribst, Franchi, Cristianini, Massaguer, and Inactivation of Aspergillus niger in mango nectar by high-pressure homogenization combined with heat shock (2009) found that *Aspergillus niger* in mango nectar treated by one HPH pass at 200 MPa combined with post heat stock (80 °C/15 min) was reduced by 6.24 $\log_{10}$ CFU/mL, significant higher than that of HPH treatment alone (2.0 $\log_{10}$ CFU/mL). The total bacteria count inactivation of milk by 1 HPH pass at 300 MPa and 24 °C was achieved 2.9 $\log_{10}$ CFU/mL (Picart et al., 2006), and the inactivation was enhanced to 5.8 $\log_{10}$ CFU/mL when the inlet temperature increasing to 85 °C (Amador-Espejo et al., 2014). However, changes of microorganism and quality of mango juice treated by HPH treatment combined with moderate inlet heat during storage were not reported. Thus, the aim of the study was to evaluate the microbial inactivation and quality attributes of mango juice treated by HPH treatment with different inlet temperature (20–60 °C), pressure (40–190 MPa) and number of passes (1–5 passes) compared with heat treatment (90 °C/5 min), as well as their changes during storage at 4 °C and room temperature.

2. Materials and methods

2.1. Materials

Fresh "Tainong No. 1" Mangos (*Mangifera indica* L.), harvested in Hainan province in June, were purchased from Xiaoying market, Beijing, China. Before further processing, mangos were washed, peeled, deseeded and sliced. Then pulps were immediately frozen by using liquid nitrogen and stored at −40 °C.

2.2. Chemicals

Chlorine dioxide disinfectant was purchased from Startech Science & Technology Co., Ltd. (Beijing, China); nutrient agar medium, Rose Bengal medium were purchased from Beijing Land Bridge Technology Co., Ltd. (Beijing, China); L-ascorbic acid, Folin-Ciocalteu reagent, standard gallic acid, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 1,1-diphenyl-2-picryl-hydrazyl (DPPH), tripyridyltriazine (TPTZ), 2,2′-azinobis-(3-ethylbenzthiazoline-6-sulphonate) (ABTS), methanol (HPLC) were purchased from Sigma-Aldrich (St. Louis, USA). Other chemicals were purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China).

2.3. Mango juice preparation

The mango pulps were thawed at 4 °C for 2.5 h, and steam blanched for 1 min in a steamer in order to inactivate enzyme according to Liu, Wang, Li, Bi, and Liao (2014). One-hundred g of blanched pulps were pureed with 300-mL distilled water for 3 min in a blender (Joyong Electric Appliance Co., Shandong, China), and then filtrated twice through four layers of gauze. The juice was then immediately used for high pressure homogenization and heat treatments.

2.4. High pressure homogenization (HPH) treatment of mango juice

High pressure homogenization (HPH) was carried out in a bench-scale high pressure homogenization (JN-02HC series, Guangzhou Juneng biology & technology Co., Ltd., Guangdong, China) with a continuous operating pressure up to 207 MPa. The homogenizer is connected with a water circulating system (4–80 °C) (HL-01AS, Guangzhou Juneng biology & technology Co., Ltd., Guangdong, China) to control the temperature of the circulating water around the homogenization valve. This design was applied to decrease the temperature increase of valve induced by pressure increasing.

The homogenizer was sterilized using 50 mM chlorine dioxide disinfectant before each treatment. Fresh mango juice (250 mL) was subjected to HPH treatment (pressure, 40–190 MPa; inlet temperature, 20–60 °C; number of passes, 1–5 passes). Before HPH processing, mango juice was heated in a water bath to make its center temperature reached to the required temperature. Meanwhile the circulating water temperature was set to the same value as inlet temperature. Mango juice was fed into HPH with a flow rate at 2.1 L/h, and its retention time in the equipment was around 15 s. Despite the design of cooling circulating system, the outlet temperature of mango juice after HPH treatment still increased with the increasing pressure, and maximum increase was 12 °C. Sample after HPH treatment were collected in 150 mL sterile glass bottles, and quickly cooled to room temperature in an ice bath for around 10 min.

2.5. Heat treatment (HT) of mango juice

Mango juice (250 mL) in a glass beaker (1000 mL) was heated in a boiling water bath until the center temperature reached to 90 °C, then the mango juice was kept at 90 °C for 5 min in a temperature-controlled water bath (HZS-HA, Beijing donglianhar instrument manufacture Co., Ltd., China) according to Lin and Chen (2005). The time needed for the samples to reach the process temperature was around 7 min. After treatment, the samples were collected in 150 mL sterile glass bottles, and immediately cooled in an ice water bath for 10 min. The whole process of HT was performed in a sterile environment (SW-CJ-1F Benchtop, Suzhou AntaiAirtech Co., Ltd).