Innovative Food Science and Emerging Technologies 21 (2014) 35–43

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Effects of high hydrostatic pressure and high temperature short time on antioxidant activity, antioxidant compounds and color of mango nectars

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ARTICLE INFO

Article history:
Received 27 May 2013
Accepted 29 September 2013

Editor Proof Receive Date 7 November 2013

Keywords:
High hydrostatic pressure
High temperature short time
Mango nectar
Antioxidant activity
Antioxidant compounds
Color
Storage

ABSTRACT

High hydrostatic pressure (HHP, 600 MPa/1 min) and high temperature short time (HTST, 110 °C/8.6 s) treatments of mango nectars were comparatively evaluated by examining their effects on antioxidant activity, antioxidant compounds, color, and browning degree (BD) immediately after treatments and during storage of 16 weeks at 4 and 25 °C. Steam blanching was used prior to HHP and HTST to inactive endogenous enzymes. Results showed that antioxidant capacity (FRAP assay), *L*-ascorbic acid, sodium erythorbate, total phenols, total carotenoids, the redness (a^*), the yellowness (b^*), and BD changed insignificant after HHP or HTST treatment. The lightness (L^*) exhibited a significant decrease in HTST-treated mango nectars, while no significant changes in HHP-treated samples. After 16 weeks storage at 4 and 25 °C, there were significant changes in antioxidant activity, antioxidant compounds, color, and BD of mango nectars, whereas differences between HHP- and HTST-treated samples were not significant except for the decrease in *L*-ascorbic acid and sodium erythorbate, which was more pronounced in HHP-treated samples. Kinetic data of changes in *L*-ascorbic acid, sodium erythorbate, total phenols, and total carotenoids during storage fitted well into a combined model for both HHP- and HTST-treated samples. *Industrial relevance:* Mango (*Mangifera indica* L.) is one of the important tropical fruits, and its processed products are of high commercial and economic importance. This research paper presents a comparison on HHP- and HTST-treated mango nectars, and also provides information about storage stability of antioxidant activity, antioxidant compounds, and color of mango nectars. The available data would provide technical support for the evaluation and application of HHP or HTST in the mango nectar industry, and also for the establishment of criteria for commercial production of high quality mango nectars with safety requirements.

1. Introduction

Mango (*Mangifera indica* L.) is one of the important tropical fruits (Ahmed, Ramaswanmy, & Hiremath, 2005). It is called "the king of the fruit" in the Orient due to its excellent flavor and attractive color with high nutritional value (Ahmed et al., 2005; Vásquez-Caicedo, Schilling, Carle, & Neidhart, 2007a,b). Fresh mango fruit is perishable and has limited shelf-life because of high moisture content, thus its processed products such as juices (Alaka, Aina, & Falade, 2003; Falade, Babalola, & Akinyemi, 2004), pulps (Ahmed et al., 2005; Youssef, Asker, El-Samahy, & Swailam, 2002), purees (Guerrero-Beltrán, Barbosa-Cánovas, Moraga-Ballesteros, Moraga-Ballesteros, & Swanson, 2006; Vásquez-Caicedo et al., 2007a), and slices (Boynton, Sims, Sargent, Balaban, & Marshall, 2002) are of high commercial and economic importance. Currently, thermal processing technologies are applied to inactivate microorganisms and endogenous enzymes in fruit products, and however, since fruits are usually susceptible to thermal processing, this can cause considerable damage to antioxidant activity and color of fruit products (Keenan et al., 2010; Patras, Brunton, Da Pieve, Butler, & Downey, 2009).

High hydrostatic pressure (HHP) is a non-thermal technology that is increasingly studied for the processing of acidic foods such as puree (Landl, Abadias, Sárraga, Viñas, & Picouet, 2010), pulp (Ahmed et al., 2005), nectar (Wang et al., 2012), and juice (Bull et al., 2004). HHP can efficiently enhance the microbial stability of food products while the changes in low molecular weight compounds such as vitamins, pigments, and flavoring agents are minimal when evaluated immediately after pressurization because covalent bonds are not broken during the process (Ramirez, Saraiva, Perez Lamela, & Torres, 2009). However, HHP-processed fruit and vegetable products may exhibit long-term changes in flavor, nutritional properties, and color as a result of the residual activity of endogenous enzymes (Boynton et al., 2002). To reduce enzyme activity and preserve food quality during processing and storage, different methods have been successfully applied in combination with HHP, e.g., low pH conditions, refrigerated storage, high-temperature treatment, and anti-browning agents (Guerrero-Beltrán et al., 2006; Krebbers et al., 2003; Vásquez-Caicedo et al., 2007a).

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1466-8564/$ – see front matter
http://dx.doi.org/10.1016/j.ifset.2013.09.015

Steam blanching has been reported as an excellent technique for inactivating enzymes applied prior to non-thermal processing of food products, to eliminate the possible effects produced by the remainder enzyme activity (Cao et al., 2012; Liu, Wang, et al., 2013; Wang et al., 2012; Youssef et al., 2002). Moreover, Huang reported combined usage of HHP and 0.4% *L*-ascorbic acid to prevent the browning of apricot nectars (Huang et al., 2013) and Guerrero-Beltrán et al. (2006) reported that the addition of ascorbic acid reduced the browning of HHP-treated mango puree. However, literature data on the effects of combination of blanching and HHP on the quality of mango products is very limited. Moreover, no information is available on quality changes of steam-blanched and HHP-treated mango products during storage.

The main objective of this work was to compare the effects of HHP and high temperature short time (HTST) treatments on antioxidant activity, antioxidant compounds, color, and browning degree (BD) of mango nectars immediately after processing and during 16 weeks storage at 4 and 25 °C. Moreover, steam-blanching was implemented prior to HHP or HTST treatment to inactivate endogenous enzymes, including polyphenol oxidase (PPO) and peroxidase (POD).

2. Materials and methods

2.1. Chemicals

Folin–Ciocalteu reagent, *L*-ascorbic acid, sodium erythorbate, gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), (±)-6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylicacid (Trolox), and 2,4,6-tri-2-pyridyl-1,3,5-triazine (TPTZ) were purchased from Sigma Aldrich (St. Louis, USA). Methanol and tert-butyl methyl ether (MTBE) of HPLC-grade were purchased from Honeywell Burdick & Jackson (SK Chemicals, Seoul, Korea). Other chemicals were obtained from Beijing Chemicals Co. (Beijing, China).

2.2. Raw material

Mature green mango fruits (*Mangifera indica* L., *cultivar* Tainong No. 1), were harvested in Hainan province in southern China. The fruit samples were transported by air to Beijing and ripened at room temperature (20–25 °C) for about 7 days until fully mature. Total soluble solid (TSS) and pH of mango fruits were 15.90 ± 0.02 °Brix and 3.95 ± 0.01, respectively.

2.3. Preparation of mango nectars

If endogenous enzymes in mangoes are not inactivated, HHP-treated mango nectars would produce off-flavor during storage and only have a very short shelf life at ambient temperature. To study the quality changes of stabilized mango nectars during long-term storage, and to eliminate the possible effects produced by the remainder enzyme activity, steam blanching treatment was applied prior to HHP and HTST treatments in this study.

Mango fruits were washed, deseeded, and sliced into 3 mm thick slices. Then the slices were steam-blanched (100 °C) for 1.0 min in a steam pan (Zhenghan Stainless Steel Factory) heated though an electromagnetic furnace (Midea RT 2103, Guangdong Midea Electrical Co., LTD) at ambient pressure. Thereafter, 200 g of mango slices was pureed with a juice extractor (Joyong Electric Appliance Co., Shandong, China) and diluted with distilled water (600 mL). In order to obtain maximum consumer acceptance, TSS of mango nectar was adjusted to 8.20 ± 0.10 °Brix with food-grade sucrose (Beijing Sugar Tobacco & Wine Co., Beijing, China), and pH was adjusted to 3.95 ± 0.01 with food-grade citric acid (Beijing Chemical Works, Beijing, China). Furthermore, sodium erythorbate was added for color preservation to reach a final concentration of 0.10% (*w*/*v*). After that, mango nectar was homogenized at 20 MPa (Shanghai Samro Homogenizer Co., Ltd., Shanghai, China) and stored at 4 °C until further analysis.

2.4. HHP and HTST treatments of mango nectars

HHP treatment was carried out using a HHP-650 pressurization unit (Baotou Kefa Co., Ltd., Baotou, Inner Mongolia, China) with a maximum capacity of 30.0 L at an initial temperature of 20 ± 1 °C. Polyethylene terephthalate (PET) bottles of 100 mL with screw-cap closures were filled with mango nectars and placed into the vessel for processing, with distilled water as the pressure-transmitting fluid. The pressurization rate was about 120 MPa/min and the depressurization time was <3 s. It has been reported that the temperature of water increases about 3 °C per 100 MPa at room temperature (Balasubramaniam, Farkas, & Turek, 2008). Furthermore, when the pressurization was finished, the sample temperature quickly dropped to its initial temperature due to heat transfer from samples to the stainless steel of the vessel (Chen & Hoover, 2003). Therefore, in this study, the sample temperature was no more than 38 ± 1 °C during HHP treatment, and its contribution to the quality changes of mango nectars was considered negligible.

HTST treatment was carried out as previously described by Uemura, Kobayashi, and Inoue (2010), using a HTST processing system (FT 74 UHT/HTST, Armfield Inc., Jackson, New Jersey, USA) at 110 °C/8.6 s. Mango nectar entered and exited the heat exchanger at ambient temperature (25 ± 1 °C), and was aseptically transferred into same PET bottles mentioned above.

According to our previous study (Liu, Wang, et al., 2013), after HHP (600 MPa/1 min) or HTST treatment (110 °C/8.6 s), yeasts and molds (Y & M) were not detected in mango pulp, and the counts of total aerobic bacteria (TAB) were less than 2.00 $\log_{10}$CFU/mL, which could meet the requirements of Chinese Drink Standard GB 10789-2007. Therefore, these treatment conditions were applied to mango nectars in this study, to follow antioxidant and color changes immediately after treatment and during storage.

2.5. Storage conditions

All treatments were performed in triplicate, and then three batches of sample were stored at the same conditions at 4 ± 2 °C and 25 ± 2 °C in the dark. Samples were analyzed periodically after 0, 1, 2, 4, 8, 12, and 16 weeks of storage. Every time, one bottle from each batch was collected for duplicate measurement.

2.6. Microbiological analysis

To detect viable natural microorganisms in mango nectars, the total plate count method was used (Liu, Wang, et al., 2013). Untreated and treated samples were serially diluted with sterile 0.85% NaCl solution, and 1.0 mL of each dilution was plated into duplicate plates of appropriate agar. Plate count agar (Beijing Land Bridging Technology Co. Ltd., Beijing, China) was used for counting total aerobic bacteria (TAB) after incubation at 37 °C for 48 ± 2 h. Rose bengal agar (Beijing Land Bridging Technology Co. Ltd., Beijing, China) was used for counting the viable yeasts and molds (Y & M) after incubation at 27 °C for 72 ± 2 h. After incubation, the colonies were counted. Log *N* was calculated to determine the inactivation effect, where *N* is the number of viable microorganisms.

2.7. Measurement of L-ascorbic acid and sodium erythorbate

Twenty milliliters of mango nectars was mixed with 100 mL of 2.5% metaphosphoric acid, incubated at 4 °C for 2 h. Thereafter, the mixture was centrifuged using 9000 × *g* for 15 min at 4 °C, and the supernatant was subsequently used for HPLC measurement. The HPLC system (RF-10AXL, Shimadzu Co., Japan) was equipped with a prominence UV–visible detector (SPD-20AV), a system controller (CBM-20A), an auto sampler (SIL-20A), two pumps (LC-20AT), and a column oven (CTO-20A). The analytical column was a Sunfire™ C_{18} (4.6 × 250 mm