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Comparing the effects of high hydrostatic pressure and high temperature short time on papaya beverage

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ABSTRACT

Inactivation of microorganisms in papaya beverage (PB) by high hydrostatic pressure (HHP) at different pressures (350, 450, 550 and 650 MPa) and for different times (5 and 10 min) was studied. Besides, the effects of HHP (550 MPa/5 min) and high temperature short time (HTST) (110 °C/8.6 s) on microorganisms, total soluble solids (TSS), pH, color, total carotenoids, total phenols, antioxidant capacity, viscosity and sensory characteristics were comparatively studied immediately after treatments and during storage of 40 days at 4 °C.

HHP at 550 MPa/5 min inactivated microorganisms totally. The microbial safety in samples treated by HHP (550 MPa/5 min) and HTST (110 °C/8.6 s) was ensured immediately after treatments during storage. TSS, pH, total carotenoids and viscosity experienced no significant impacts immediately after HHP and HTST treatments, while change of the original color and significant decreases of total phenols and antioxidant capacity were observed after HTST treatment. During storage, color changed and total carotenoids, total phenol, antioxidant capacity, viscosity and sensory evaluation decreased, whereas TSS and pH did not change. Kinetic data of changes in L^*, a^*, b^*,ΔE^* and antioxidant capacities measured by DPPH and FRAP methods fitted well into the combined model, while kinetic data of changes in total carotenoids and total phenols fitted well into the zero-order model. In both samples, total carotenoids and total phenols were positively and significantly correlated to antioxidant capacity. The HHP-treated sample showed higher total carotenoids content, total phenols content and antioxidant capacity, compared with the HTST-treated sample during 40-day storage.

Industrial relevance: Papaya beverage, one of the most popular fruit juice products, is of high nutrition and economic value. This study presents a fair comparison between HHP- and HTST-treated papaya beverages immediately after processing and during storage. The available data show the different effects of HHP and HTST on quality and storage stability of microorganisms, color, antioxidant compounds, antioxidant capacity and other quality-related aspects. This study would provide technical support for the application of HHP or HTST in papaya beverage industry and the criteria establishment for commercial production of high quality papaya beverage. Besides, a non-thermal technique to meet consumers' growing demand for healthier food products is provided in this study.

1. Introduction

Papaya (*Carica papaya* L.), a member of the Caricaceae family, is widely cultivated in tropical and subtropical regions and popular for its milky juice, palatable taste, high digestibility and nutritive value (Juárez-Rojop et al., 2014; Julianti et al., 2014; Monti, Contiero, & Goulart, 2004; Nunes, Santana, Sampaio, Lemos, & Oliva, 2013). Several studies have highlighted its great health-care values, since the fruit not only contains protein, fat, carbohydrates, minerals and vitamins, but also is naturally rich in beneficial antioxidant compounds, such as phenols and carotenoids (Kelebek, Selli, Gubbuk, & Gunes, 2015; Krishna, Paridhavi, & Patel, 2008; Rivera-Pastrana, Yahia, & González-Aguilar, 2010; Sancho, Yahia, & González-Aguilar, 2011; Udomkun et al., 2015). Phenols are important characteristic of papaya and have been proved to have high antioxidant activity to neutralize reactive species and prevent chronic diseases (Rivera-Pastrana et al., 2010; Saeed et al., 2014; Sancho et al., 2011). Papaya also contains more carotenoids than other fruits such as guavas, apples and plantains, which play an important role to prevent aged related macular, cardiovascular disease and heart disease (Krishna et al., 2008; Rivera-Pastrana et al., 2010; Sancho et al., 2011). Cano, De Ancos, Lobo, and Monreal (1996) and Furtado, Siles, and Campos (2004) have reported that Carica papaya is an important dietary source of Vitamin

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A carotenoids, which can prevent Vitamin A deficiency, a serious global nutrition problem.

Now papaya is becoming more and more popular, as people are attaching more attention to health (Kelebek et al., 2015). World papaya production has been continually increasing (FAOSTAT, 2013). However, fresh papaya has limited shelf-life, because post-harvest losses of papaya occur along the entire value chain due to rapid deterioration (Udomkun et al., 2015). Thus, further processing and its processed product are of high commercial and economic importance.

Papaya beverage (PB) is a popular papaya juice product for its great taste and nutrients. Thermal processing is usually applied to prevent fresh products from spoilage and extend shelf-life. However, fruit and vegetable juice products are susceptible to thermal processing, which often causes nutrient compounds degradation, color changes, antioxidant capacity loss and adverse effects on sensory and nutritional values eventually (Ibarz, Pagan, & Garza, 1999; Keenan et al., 2010; Patras, Brunton, Da Pieve, Butler, & Downey, 2009; Suh, Noh, Kang, Kim, & Lee, 2003). Patras, Brunton, Da Pieve, and Butler (2009) found that thermal processing lead to degradation of anthocyanins and loss of color in strawberry and blackberry purees. Dede, Alpas, and Bayindirli (2007) found that heat treatments at 60 °C for 5–15 min and 80 °C significantly reduced free-radical scavenging activity of carrot juice. Nowadays, high temperature short time (HTST), a new thermal processing, has been used for fruit juice products in food industry, since it has a greater retention of quality factors than pasteurization (De Oliveira, Borges, Furtado, Della, & Godoy, 2011).

Besides HTST, high hydrostatic pressure (HHP) has gained more and more attention. HHP is a promising non-thermal processing to inactive harmful pathogens and spoilage microorganisms in food by instantaneously transmitting isostatic pressure (100–1000 MPa) at room or mild processing temperatures (<60 °C) (Bala, Farkas, & Turek, 2008; Oey, Lille, Van Loey, & Hendrickx, 2008). HHP exerts limited effects on smaller molecules such as volatile compounds, pigments, vitamins, and antioxidant compounds, owing to its limited impacts on the covalent bonds and its low processing temperature (Norton & Sun, 2008; Ramirez, Saraiva, Perez Lamela, & Torres, 2009; Zabetakis, Leclerc, & Kajda, 2000). HHP has been studied for processing some fruit and vegetable products such as blueberry juice (Barba, Esteve, & Frigola, 2013), tomato puree (Krebbers et al., 2003; Rodrigo, Van Loey, & Hendrickx, 2007), apple juice (Baron, Dénes, & Durier, 2006; Valdramidis et al., 2009), mango pulp (Ahmed, Ramaswamy, & Hiremath, 2005; Liu, Wang, Li, Bi, & Liao, 2014), and pomegranate juice (Chen et al., 2013; Ferrari, Maresca, & Ciccarone, 2010; Varela-Santos et al., 2012). HHP has been adopted at a fast rate as one of novel alternatives to thermal processing (Mújica-Paz, Valdez-Fragoso, Samson, Welti-Chanes, & Torres, 2011). Moreover, there have been comparative studies of HHP and HTST-treated strawberry juices, mango nectars, pomegranate juices, apricot nectars and purple sweet potato nectars (Cao et al., 2012; Chen et al., 2013; Huang et al., 2013; Liu et al., 2014; Wang, Liu, Cao, Chen, & Liao, 2012). These studies have shown that the two techniques have their own advantages in protecting different quality attributes, which dependents on the applied conditions and the kinds of processed products. However, up to now, there is no literature data on the effects of HHP on PB and on comparative study of HHP and HTST on the microorganisms, quality attributes and shelf-life of PB, so that there is no technical support for the application of HHP or HTST in papaya beverage industry.

Therefore, the study was undertaken to investigate: (1) the inactivation of microorganisms in papaya beverage by HHP treatment; (2) the comparison of the effects of HHP and HTST on color, pH, total soluble solid (TSS), total carotenoids, total phenols and antioxidant capacity of PB immediately after treatments; (3) the comparison of the microbiological safety and the quality characteristics between HHP-treated and HTST-treated PBs during storage of 40 days at 4 °C.

2. Materials and methods

2.1. Preparation of PB

If endogenous enzymes in papaya were not inactivated, they would induce the deterioration to PB during processing and storage, especially the HHP-treated PB during storage, and PB would have a very short shelf-life. Therefore, steam blanching treatment was applied prior to pulping and HHP or HTST treatment in this study, in order to eliminate the possible effects produced by the remainder enzyme activity, extend the shelf-life and study the quality changes of stabilized PB during storage.

In this study, the papayas (*Carica papaya* L.) were obtained from a local market (Xinfadi) in Beijing (China) and were fully mature (TSS was 11.8 ± 0.03°Brix and pH was 5.85 ± 0.01). Fresh papayas were rinsed in tap water, peeled and cut into slices 4 mm in thickness.

The slices were blanched by steam (100 °C) for 3 min on the basis of the results of our previous experiment (data not shown) in a steam pan (Zhenghan Stainless Steel Factory) heated though an electromagnetic furnace (Midea RT 2103, Guangdong Midea Electrical Co., Ltd.), in order to totally inactivate polyphenol oxidase (PPO),peroxidase (POD), and especially pectin methyl esterase (PME) which would induce gelation or precipitation of juice product and was the main reason of quality deterioration (Sila et al., 2008). Then the slices were cooled quickly in cold water.

Thereafter, 200 g of the slices was pulped with a juice extractor (Joyong Electric Appliance Co., Shandong, China) and diluted with distilled water (800 mL) on the basis of initial sensory analysis. In order to obtain maximum consumer acceptance, the TSS was adjusted to 10.63°Brix by adding food-grade sucrose (Beijing Sugar Tobacco &Wine Co., Beijing, China), and the pH was adjusted to 3.46 with citric acid (Beijing Chemical Works, Beijing, China). Then, the PB was homogenized at 25 MPa (Shanghai Samro Homogenizer Co., Ltd., Shanghai, China) and kept at 4 °C until use. Furthermore, there was no oxygen scavenger added to the PB.

The PB that was obtained by the above processes was the control sample and would be treated by HPP or HTST treatment to produce HHP-treated or HTST-treated PB.

2.2. HHP processing

The PB obtained by the processes in 2.1 was filled into plastic bottles (PET) of 60 mL capacity with thickness of 0.065 cm and the lids were manually screwed, and the headspace volumes in the bottle were nearly 1.47 cm^3, and then placed into the vessel for HHP treatment.

HHP treatment was carried out by a hydrostatic pressurization unit with a 7.0 L capacity (HHP-700, Baotou Kefa Co., Ltd., Inner Mongolia, China). The pressure-transmitting fluid was distilled water. The pressurization rate was about 120 MPa/min and the depressurization was immediate (<3 s). The treatment time reported in this study did not include the pressure increase and release time. A pressure transducer (PPM-T229A, Changsha Taihe Electronic Equipment, Co., Ltd., Fujian, China) was attached to the vessel and used to measure the pressure in the vessel. The hysteresis for pressure level measurement was 10 MPa. The pressure level and treatment time were continuously recorded during the pressurization cycle.

Samples were subjected to pressures of 350, 450, 550, 650 MPa for 5, 10 min at almost ambient temperature (20 ± 1 °C). The initial temperature in the processing vessel was nearly 20 °C and when 350, 450, 550, 650 MPa were applied, the temperature reached approximately 30.5, 33.5, 36.5, 39.5 °C due to the adiabatic compression, which was calculated as 3 °C/100 MPa, since there was no temperature monitoring and recording system (Bala et al., 2008). When the pressurization was finished, the temperature quickly dropped to its initial temperature due to heat transfer from the samples to the stainless steel of the vessel (Chen & Hoover, 2003).