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Change of the rheological properties of mango juice by high pressure homogenization

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ABSTRACT

The effect of high pressure homogenization (HPH) on pH, total soluble solid, color, particle size distribution (PSD), microstructure, ζ-potential, water soluble pectin, apparent viscosity, thixotropy, dynamic rheological characteristics of mango juice were investigated in this study. PSD analysis showed the volume peak of mango juice was moved from 138 to 6 μm after 1 HPH pass at 20 °C from 40 to 190 MPa, indicating HPH significantly decreased the particle diameter. Correspondingly, the suspended particles were smaller after HPH observed by optical microscopy, highlighting the effect of HPH in disrupting the fruit juice particles. HPH changed the content of water soluble pectin, and the content was increased with increasing inlet temperature and passes number, whereas no change was found for ζ-potential. The apparent viscosity was significantly enhanced by HPH, meanwhile thixotropy, storage modulus and loss modulus were also altered, and those changes were related to the HPH condition applied. Results showed that HPH significantly changed the rheological properties of mango juice.

1. Introduction

Mango (*Mangifera Indica* L.) is a tropical fruit grown in 85 countries, ranking fifth in global production among other major fruit crops including bananas, citruses, grapes and apples (Santhirasegaram, Razali, George, & Somasundram, 2015). The market for value-added mango products such as juice, puree and nectar has progressively grown due to its perishable nature and limited shelf life (Liu, Wang, Li, Bi, & Liao, 2014). Fruit juices are popular drinks consumed by people of all age for their sensory and nutritional quality. Nowadays, pasteurization and sterilization are commonly treatments used in the juice industry to inactivate microorganisms and enzymes. However, these treatments can cause development of undesirable flavor, loss of cloudiness, nutrient and functional properties in the processed food (Patrignani, Vannini, Kamdem, Lanciotti, & Guerzoni, 2009). Thus, the use of non-thermal technology such as high hydrostatic pressures (HHP) (Liu et al., 2014), pulsed electric field (PEF) (Guo et al., 2014), high pressure homogenization (HPH) (Pathanibul, Taylor, Davidson, & Harte, 2009; Patrignani et al., 2009), have been proposed as an alternative as well as mild thermal processing technology.

HPH is considered to be one of the most promising of these new liquid food processing technologies because of the recent improvements in high-pressure homogenizers and the increasing acceptance by consumers of pressure processed foods (Patrignani et al., 2009). HPH is a process where fluid is forced through a narrow orifice under conditions of high pressure, and allows to process in continuous fluid foodstuffs with proved efficiency inactivating pathogenic and most of the spoiling microorganisms in different kind of foods (Maresca, Donsì, & Ferrari, 2011; Pathanibul et al., 2009). In previous study, HPH also could be used to modify several physical characteristics of the fluid, including change rheology, reducing particle size, reducing phase separation and improving texture uniformity (Augusto, Ibarz, & Cristianini, 2012; Augusto, Ibarz, & Cristianini, 2013; Kubo, Augusto, & Cristianini, 2013; Leite, Augusto, & Cristianini, 2014, 2015, 2016). For example, HPH was successfully applied to reduce the consistency of concentrated orange juice, with a reduction up to 50% on its apparent viscosity (Leite et al., 2014). The rheological characterization of food products plays an important role in process design and optimization (such as pumps, pipelines and equipment), and it also shows correlation with the product stability and quality

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prediction, product formulation, sensory characteristics and consequent consumer acceptance (Rao, 2005). The rheological properties of juice are determined by the level of juice solids (both insoluble and soluble), the particle size and shape of juice tissue pieces, and the degree to which molecules such as pectin or hemicellulose are dissociated from the cells, and so on (Tan and Kerr, 2015).

Several works have focused on the change of rheological properties of juice after HPH (Augusto et al., 2012; Augusto et al., 2013; Kubo et al., 2013). Kubo et al. (2013) found that HPH increased the consistency, thixotropy and viscous of the tomato juice, reduced particle sedimentation and serum separation. However, Tan and Kerr (2015) found that HPH treated tomato puree had lower consistency and were less shear-thinning than the control, explained by the greater homogenization pressures used, different microstructural feature, and lower particle sizes attained in the study. It was reported the rheological properties of fruit juices cannot be only assigned to the serum phase and must be associated with differences in the dispersed phase (Augusto et al., 2012).

Therefore, the aim of present work was to focus on the effect of HPH treatment level on the rheological properties (apparent viscosity, thixotropy, and dynamic rheological characteristics) of mango juice, and the changes of related factors, including particle size distribution, microstructure, ζ-potential, and pectin content were investigated.

2. Materials and methods

2.1. Material

Fresh “Tainong No. 1” Mangos (*Mangifera indica* L.), harvested in Hainan province in June 2015, were purchased from Xiaoying market, Beijing, China. Before further processing, 20 kg of mangos were washed, peeled, deseeded and sliced. Then pulps were immediately frozen by using liquid nitrogen and stored at −40 °C before processing.

2.2. Chemicals

D-(+)-Galacturonic acid and 3-Hydroxybiphenyl were obtained from Sigma-Aldrich Chemical Co. (Beijing, China). All other chemicals were analytical grade and 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 et al. (2013). Blanching pulps were pureed with distilled water in a ratio 1: 3 for 3 min in a blender (Joyong Electric Appliance Co., Shandong, China), and then filtrated twice through four layers of gauze. The juice was stored at 4 °C for around 1 h before processing for high pressure homogenization.

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, according to Guan et al. (2016). The homogenizer is connected with a cooling 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.

The treatment parameters applied in this study were as bellows: the pressure was 40, 70, 100, 130, 160, and 190 MPa, the inlet temperature was 20, 40, and 60 °C, and the number of passes was 1, 3, 5. Before HPH processing, 50 mL of mango juice was heated in a water bath to make its center temperature reach to the required temperature. Meanwhile the cooling circulating system was set to the same value as inlet temperature to cool down the mango juice. 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. Sample after HPH were collected in 150 mL sterile glass bottles, and quickly cooled to room temperature in an ice bath for around 10 min. Each HPH treatment condition was run in triplicate.

2.5. Total soluble solids (TSS) and pH analysis

TSS was determined as °Brix using a digital refractometer (WZB 45, Shanghai electronics and analytical instruments Co., Ltd., Shanghai, China) at 25 ± 1 °C. The value of pH was measured using a portable pH meter (Testo 205, Testo industry corporation, Germany) at 25 ± 1 °C.

2.6. ζ-potential analysis

The particle charge of the mango juice (ζ-potential) was determined using a Zetasizer Nano-ZS (Malvern Instruments, Malvern, Worcestershire, U. K.). All the experiments were carried out at 25 °C.

2.7. Color analysis

Color analysis was carried out using a Color Quest XT colorimeter (Hunter Associates Laboratory, Inc., USA). The data was expressed as Hunter scale parameters L^* (lightness), a^* (redness) and b^* (yellowness) values. The total color difference (ΔE) was calculated using Eq. (1), where L_0^*, a_0^* and b_0^* were the values for control samples.

$$\Delta E = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2} \quad (1)$$

2.8. Particle size distribution (PSD) analysis

The particle size distribution (PSD) was determined by the Mastersizer 2000 (Malvern Instruments, Malvern, U. K.). Laser light diffraction was used to measure particles from 0.02 to 2000 μm. The area-based mean particle diameter (D[3,2]) (μm) and volume-based mean diameter (D[4,3]) (μm) for all samples were calculated by the software provided by the equipment.

2.9. Microstructure analysis

The microstructure was observed using an optical microscope (XSP-BM10A, Shanghai Optical Instruments Manufactory, Shanghai, China) with a 20x lens, digital camera and software (ToupView 3.5), according to Kubo et al. (2013). Thirty microliter of juice after stirring was carefully placed on a glass slide, covered with a coverslip, and carefully rotated at 45° to guarantee the same orientation for the samples. Since the differences among the sample treated by HPH with different pressure, temperature and passes number were not easily distinguishable in a pre-experiment, the treatments with greater pressure intervals (0, 70, 130, 190 MPa) were performed for the microstructure analysis in the study.