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Comparative study of quality of cloudy pomegranate juice treated by high hydrostatic pressure and high temperature short time

Dong Chen, Huping Xi, Xingfeng Guo, Zihan Qin, Xueli Pang, Xiaosong Hu, Xiaojun Liao, Jihong Wu *

College of Food Science and Nutritional Engineering, China Agricultural University, Beijing 100083, China
National Engineering Research Center for Fruit & Vegetable Processing, Beijing 100083, China
Key Laboratory of Fruit & Vegetable Processing, Ministry of Agriculture, Beijing 100083, China

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ABSTRACT

Inactivation of microorganisms and its kinetic model of high hydrostatic pressure (HHP) processing of cloudy pomegranate juice at different pressures (300 and 400 MPa) and different treatment times (2.5, 5, 10, 15, 20, and 25 min) were studied. Besides, HHP (400 MPa/5 min) and high temperature short time (HTST) (110 °C/8.6 s) treatment were comparatively evaluated by examining their impacts on microorganisms, pH, total soluble solids (TSS), titratable acidity (TA), color, total phenols, anthocyanins, antioxidant capacity and shelf-life characteristics of 90 days at 4 °C.

The inactivation effect of microorganisms by HHP fitted Weibull model well and HHP at 400 MPa/5 min inactivated microorganisms effectively. The microbial safety was ensured in HHP-treated and HTST-treated sample. A greater retention of the original color, anthocyanins and antioxidant capacity and increased total phenols were observed in HHP-treated samples immediately after processing. During storage, color changed and anthocyanins content, total phenols and the antioxidant activity decreased, where the changes depended on the applied treatments. The pH, TSS and TA did not show significant change immediately after HHP or HTST treatment and during storage.

Industrial Relevance: Cloudy pomegranate juice is one of the most popular fruit juice and requires strict processing and storage conditions to keep the safety and quality. Our research presents a fair comparison between HHP and HTST treatment. The available data shows the different impacts on cloudy pomegranate juice of HHP and HTST treatment and the changes of quality during storage. This study would provide technical support for commercial application, evaluation and the criteria establishment for commercial production of HHP and HTST treatment in juice industry, and also provide a non-thermal treatment to meet the growing demand from consumers for healthier food products.

1. Introduction

Pomegranate (*Punica granatum* L.), one of the important fruits grown in Turkey, Iran, USA, Middle East, Mediterranean and Arabic countries, is originated from South-East Asia and has two thousand years of cultivation history in China (Maskan, 2006). Pomegranate is consumed as fresh fruit and juice, also used in desserts and salad (Al-Maiman & Ahmad, 2002). The richly colored grains in pomegranate contain considerable amount of acids, sugars, Vitamin A, Vitamin E, polysaccharides, important minerals and phenolic compounds such as catechins, ellagic tannins and anthocyanins such as 3-glucosides and 3,5-diglucosides of delphinidin, cyanidin, and pelargonidin and give a delicious and nutritional juice (López-Rubira, Conesa, Allende, & Artés, 2005). Several studies have highlighted the nutritional and bioactive compounds and the antioxidant activity of pomegranate juice. For instance, Gil, Tomas-Barberan, Hess-Pierce, Holcroft, and Kader (2000) and Seeram et al. (2008) have reported the pomegranate juice contained much more antioxidant compounds than other fruit juices and beverages and had the greatest antioxidant activity among the commonly consumed polyphenol-rich beverages in the US market. Braga et al. (2005) and Malik and Mukhtar (2006) found that attributed to its phenolic fraction, pomegranate juice had anticarcinogenic, antimicrobial, antioxidant, antiviral and anti-atherogenic effects. Some clinical research studies suggested that pomegranate juice changed the blood parameters, increased the prostate specific antigen, improved sperm quality and was helpful against heart disease, Alzheimer's disease and cancer (Khan, Afaq, Kweon, Kim, & Mukhtar, 2007; Turk et al., 2008). As reported, a glass of pomegranate juice contained about 40% of the Recommended Daily Allowance (RDA) of Vitamin C and pomegranate juice was sometimes regarded as a functional food (Du, Wang, & Francis, 1975).

Owing to its nutrition and taste, the demand for pomegranate juice has increased. Pomegranate has a brief harvest season and fresh

* Corresponding author at: College of Food Science & Nutritional Engineering, China Agricultural University, No.17, Qinghua East Road, Haidian District, Beijing 100083, P.R of China. Tel./fax: +86 10 62737434.
E-mail address: wjhcau@yahoo.com.cn (J. Wu).

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pomegranate juice is susceptible to spoilage, therefore further processing is desirable to extend shelf-life. Thermal processing is the most commonly used preservation technique. However, many reactions such as pigment degradation, especially carotenoids or anthocyanins, and browning reactions such as the Maillard reaction, enzymatic browning and oxidation of ascorbic acid take place during thermal processing, which induce adverse effects on sensory and nutritional values (Ibarz, Pagan, & Garza, 1999; Suh, Noh, Kang, Kim, & Lee, 2003). It has been reported that thermal processing caused the loss of nutritional components and changes of color in strawberry juice (Patras, Brunton, Da Pieve, & Butler, 2009). It also has been found that the more severe the heat treatment was, the more destruction of carotenoids occured (Chen, Peng, & Chen, 1995). Dede, Alpas, and Bayindirli (2007) found that heat treatments at 60 °C for 5–15 min and 80 °C significantly ($p < 0.05$) reduced the ascorbic acid content and the free-radical scavenging activity of carrot juice. Patras et al. (2009) found that anthocyanins readily degraded and color quality lost in anthocyanins containing juices due to thermal process. Therefore, in order to preserve the sensory and nutritional quality,there is a real need to find a novel method to destroy undesirable microorganisms and minimize the degradation of the functional molecules.

Non-thermal processes, including high hydrostatic pressure (HHP), high pressure carbon dioxide, high-intensity pulsed electric fields, oscillating magnetic fields, light pulses, and irradiation, can meet the demand of consumers for natural, fresh-like and safe food (Barbosa-Canovas, Pothakamury, Palou, & Swanson, 1998). HHP, one of the most promising methods, uses water as pressure transmitting medium to subject foods to 100–1000 MPa at room or mild process temperatures (<60 °C) and instantaneously transmits isostatic pressure to the product, independent of size, shape and food composition yielding highly homogeneous products (Bala, Farkas, & Turek, 2008; Oey, Lille, Van Loey, & Hendrickx, 2008). Structure of high-molecular-weight molecules such as proteins and carbohydrates are altered, harmful pathogens and vegetative spoilage microorganisms are inactivated by HHP treatment. However, owing to the limited impacts of HHP treatment on the covalent bonds of low molecular-mass compounds, smaller molecules such as volatile compounds, pigments, vitamins, and other compounds connected with the sensory, nutritional, and health promoting are unaffected or affected very minimally (Bala et al., 2008; Oey et al., 2008; Zabetakis, Leclerc, & Kajda, 2000).

HHP has been applied to fermented foods such as cheeses, ham and yogurt, and some fruit and vegetable products such as tomato puree (Rodrigo, Van Loey, & Hendrickx, 2007), apple juice (Baron, Dénes, & Durier, 2006; Valdramidis et al., 2009), mango pulp (Ahmed, Ramaswamy, & Hiremath, 2005), orange juice (Katsaros, Tsevdou, Panagiotou, & Taoukis, 2010), and strawberry puree (Cao et al., 2011), some of which are currently available on market. However, there has not been pomegranate juice processed by HHP on the market. Only did Varela-Santos et al. (2012) and Ferrari, Maresca, and Ciccarone (2010) study the effect of HHP on pomegranate juice. Ferrari et al. (2010) has studied the application of HHP for the stabilization of clear pomegranate juice and the different effects of processing variables (pressure, temperature and time) on the microbiological stability and properties. Varela-Santos et al. (2012) has studied the effect of HHP processing (350~550 MPa for 30, 90 and 150 s) on microorganisms, physicochemical properties, bioactive compounds of pomegranate juice and its shelf-life during 35 days of storage at 4 °C. However, there has been no comparative study on the microorganisms, quality attributes and shelf-life of cloudy pomegranate juice (CPJ) treated by HHP and thermal treatment, especially high temperature short time (HTST).

Therefore, the study was undertaken to investigate: (1) the effectiveness and kinetic model about microorganisms inactivation of HHP processing on CPJ; (2) the comparison of microorganisms, color, pH, TSS, TA, total phenols, anthocyanins, and antioxidant capacity between HHP-treated and HTST-treated CPJ; (3) the comparison of the microbiological safety and the quality characteristics between HHP-treated and HTST-treated CPJ during storage of 90 days at 4 °C.

2. Materials and methods

2.1. Preparation of CPJ

Pomegranates (Pyaman, Hetian, Xinjiang, China) were purchased from the wholesale market in Urumqi (Xinjiang, China) and stored at about 8 °C in the market. The pomegranates were transported to Beijing by air and stored at an average temperature of 4 °C. The pomegranates were washed with tap water and manually separated into sacs. The juice in the sacs was manually pressed and extracted, then filtered with 400 mesh filter cloth, centrifuged in 9000 rpm, mixed to ensure its uniformity. The CPJ was stored at the cold warehouse about 4 °C until the experiment started.

2.2. HHP process system

HHP treatment was carried out by a hydrostatic pressurization unit with a 7 L capacity (HHP-650, 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 pressure level and treatment time were continuously recorded during the pressurization cycle. The initial temperature in the processing vessel was nearly 20 °C and when 300 MPa and 400 MPa were applied, the temperature reached approximately 29 °C and 32 °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).

2.3. HHP processing

Freshly squeezed CPJ was filled into the bottles identical to the ones used for the control samples, and then placed into the vessel for HHP treatment. Samples were subjected to pressures of 300, 400 MPa for 2.5, 5, 10, 15, 20, and 25 min at ambient temperature. Based on microbiological analysis results of these treatments, 400 MPa/5 min was selected as the sterilized condition for shelf-life study of CPJ.

2.4. HTST processing

A tubular heat exchanger unit (Armfield FT74, HTST/UHT Processing Unit, Hampshire, England) was used for high temperature short time (HTST) pasteurization (110 °C/8.6 s). The juice entered and exited the heat exchanger at ambient temperature, and then was transferred into packages identical to the ones used before.

2.5. Storage conditions

The treated samples were stored at 4 ± 2 °C in the dark. Sample analysis was carried out after 0, 10, 20, 30, 45, 60, 75 and 90 days storage. Before each measurement, samples were equilibrated at an ambient temperature (20 ± 1 °C).

2.6. Microbiological enumeration

To detect the viable natural microorganisms in CPJ, the total plate count method was used (National Food Hygienic Standard of China