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High pressure processing (HPP) of aronia berry puree: Pilot scale processing and a shelf-life study

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ABSTRACT

Aronia berry puree was subjected to 400 and 600 MPa, 5 min high pressure processing (HPP) and then microbial shelf-life and quality changes of aronia puree during 8-week refrigerated storage were evaluated. HPP reduced the aerobic plate counts (APC) significantly and APC changed insignificantly during the 8-week storage. HPP completely inactivated yeasts and molds, and no regrowth was observed during 8-week storage. In contrast, yeasts in untreated puree increased from 4.7 to 6.1 log CFU/g. Physicochemical properties, total phenolic contents and antioxidant capacities of aronia puree had insignificant changes right after HPP and during 8-week refrigerated storage. Total anthocyanin content of untreated samples and those treated at 400 MPa decreased continuously during the storage. HPP, especially processing at 600 MPa for 5 min, could be an effective preservation technique for microbial population reduction, quality retention, and shelf-life extension of aronia puree.

Industrial relevance: The growing demand for minimal processed and antioxidant-rich aronia berry products has stimulated the interest of food industry. Industrial sector demands methods to extend the microbial shelf-life and maintain its quality and nutritional values of aronia berry products during refrigerated storage. The results of this study demonstrated that HPP is effective in extending the microbial shelf-life, maintaining the quality and preserving the bioactive antioxidants of aronia berry puree during 8 weeks of refrigerated storage.

1. Introduction

Aronia (*Aronia melanocarpa*), commonly known as "black chokeberry", is a woody perennial shrub in the Rosaceae family native to North America (Denev, Kratchanov, Ciz, Lojek, & Kratchanova, 2012). Aronia berry possesses high level of polyphenols, especially anthocyanins and procyanidins, which have substantially beneficial effects on human health, including antioxidant and antiradical activities, anticarcinogenic, anti-inflammatory and antimutagenic effects, and antiproliferative potential (Kokotkiewicz, Jaremicz, & Luczkiewicz, 2010; Kulling & Rawel, 2008). Therefore, aronia berries have attracted great food industry interest when developing health-promoting products (Wangensteen et al., 2014). Fresh aronia berries have a limited harvest window of 4 to 6 weeks and the aronia berries are rarely consumed fresh due to their sour and astringent taste (Błaszczak, Amarowicz, & Górecki, 2017). Aronia berry puree can be combined with other fruit purees, such as banana and apple puree, to make palatable and nutritious mixed fruit products.

Thermal processing is commonly used to extend the shelf-life and to ensure the microbiological safety of fruit purees and other fruit-based products. However, thermal processing can cause detrimental effects on the quality and nutritional values of the fruit-based products. One study showed that 93% of anthocyanins were degraded in thermal pasteurized (90 °C, 10 min) aronia berry juice compared with frozen aronia berries (Wilkes, Howard, Brownmiller, & Prior, 2014). High pressure processing (HPP) is a non-thermal food preservation technique that has been shown to enhance microbiological safety and extend the shelf-life of food products with minimal influence on the sensory, physical, and nutritional properties of foods (Jofré, Aymerich, Bover-Cid, & Garriga, 2010). Hydrostatic pressures of 300 to 700 MPa for 30 s to a few minutes inactivate pathogenic and spoilage microorganism (Munoz, Ancos, Sanchez-Moreno, & Cano, 2007). Compared with traditional heat pasteurization, HPP has much less impact on the low molecular weight nutrients such as vitamins and polyphenols, and compounds related to sensory properties such as pigments and flavoring agents (Landl, Abadias, Sárraga, Viñas, & Picouet, 2010; Marszałek, Woźniak,

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Kruszewski, & Skąpska, 2017). Hence, HPP allows better retention of nutritional values and sensory properties than the traditional pasteurization technologies. HPP has been successfully employed to preserve blueberry juice (Barba et al., 2012), strawberry and its puree (Gao et al., 2016; Marszałek, Woźniak, Skąpska, & Mitek, 2017), pawpaw pulp (Zhang, Dai, & Brannan, 2017), apple juices (Nayak, Rayaguru, & Radha Krishnan, 2017), cantaloupe puree (Mukhopadhyay, Sokorai, Ukuku, Fan, & Juneja, 2017), grape juice (Chang, Wu, Chen, Huang, & Wang, 2017), and so on, extending their shelf-life in 10–60 days range.

Color, texture and flavor are important quality characteristics of fruit-based products and the major factors affecting the consumer acceptance of the products (Oey, Lille, Van Loey, & Hendrickx, 2008). Aronia berries contain 7.2–14.8 g/kg fresh weight anthocyanins (Kulling & Rawel, 2008). The color of aronia puree is dark red and the color can change to purple or even blue with the change of pH due to the characteristics of anthocyanin. During the maturation of aronia berries, contents of anthocyanins and soluble solids increase, whereas the titratable acids decrease (Kaack & Kühn, 1992). Thus, the contents of anthocyanin and total soluble solids, the color, pH and titratable acidity are the key factors to evaluate for the quality of aronia berry products (Jeppsson & Johansson, 2000). In terms of aronia berry purees, the consistency and viscosity are important texture properties, which influence the consumer sensory perception and the manufacturing process involving pumping and mixing of purees (Espinosa et al., 2011; Nindo, Tang, Powers, & Takhar, 2007). Particle size and total soluble solids content play important roles in determining the consistency of puree products (Bi, Hemar, Balaban, & Liao, 2015). In order to develop health-promoting aronia puree based products, the changes in contents of bioactive phenolic compounds and their antioxidant capacities, as well as consumer acceptance related physicochemical properties of aronia purees, are of great importance to evaluate after high pressure processing and during the refrigerated storage period. Evaluation of microbial inactivation after HPP and microbial stability during refrigerated storage is critical to establish the shelf-life of aronia purees.

The objectives of this study were to investigate the effects of HPP and refrigerated storage on microbial loads, physicochemical properties, phenolic compounds, and antioxidant capacities of aronia berry puree, and to evaluate the shelf-life of the high pressure processed aronia puree.

2. Materials and methods

2.1. Chemicals

Tryptic soy agar and dichloran rose bengal chlortetracycline were purchased from ACUMEDIA (Lansing, MI). Sodium hydroxide, sodium carbonate, ferric chloride hexahydrate, hydrochloric acid (HCl), and ethanol were purchased from Fisher Scientific (Hampton, NH). Monopotassium phosphate, Folin-Ciocalteu reagent, 2,4,6-tri (2-pyridyl)-1,3,5-triazine (TPTZ), 2,2-Diphenyl-1-picryl hydrazyl (DPPH), Trolox, and gallic acid were purchased from Sigma-Aldrich (St. Louis, MO).

2.2. Aronia puree preparation

Aronia berries from the cultivar *A. melanocarpa* 'Viking' were harvested at Twist R Farms in Omaha, NE. Before being sent to the University of Nebraska-Lincoln, the berries were destemmed, blast frozen, and stored at −20 °C shortly after they were harvested. The aronia berries were thawed at 4 °C overnight before the preparation of aronia puree. Two batches of 5 kg of thawed aronia berries were homogenized for 10 min using a colloid mill (JM80, Kaiquan Machine Valve Co., Ltd., Shanghai, China), and then the two batches of puree were mixed to obtain a uniform puree sample. After homogenization, 100 g of puree were packed in nylon/polyester vacuum pouches (76 μm thickness with 14.6 cm × 17.1 cm size) and vacuum sealed for high pressure treatment.

2.3. High pressure processing (HPP)

Our previous study has shown that HPP could effectively inactivate aerobic bacteria, molds and yeasts when the pressure was no lower than 400 MPa and dwell time was 5 min (Yuan, Danao, et al., 2018). In this study, vacuum packaged samples were treated at 400 MPa and 600 MPa for 5 min in a 55 L capacity high pressure processing unit (Model 55, Hiperbaric, Burgos, Spain) with water as the pressurizing media. The initial temperature of water in the processing chamber was 15 °C, and the temperature reached approximately 27 and 33 °C when pressure reached 400 and 600 MPa, respectively. Single cycle pressurization with the pressure ramping rate of 300 MPa/min and pressure release time fewer than 2 s was used. The 5-min dwell time reported in this study did not include pressure-come-up or release times. For each HPP condition, high pressure treatment was conducted in three independent runs. All HPP treated and untreated (control) purees were stored in the dark at 4 °C for 8 weeks. Samples ($n = 3$) were drawn from each of the triplicated pressurized aronia purees and subjected to analyses at 0, 1, 2, 4, 6, and 8 weeks.

2.4. Microbial analyses

Microbial analyses were performed on untreated and HPP treated samples. A 10-gram portion was diluted (1:10 w/w) in Butterfield's phosphate solution and homogenized using a stomacher (Model 400, Seward, London, England). The homogenized solution was then serially diluted in 9 mL tubes of Butterfield's phosphate solution and spread plated for aerobic plate counts (APC) using tryptic soy agar (Acumedia, Neogen Corporation, Lansing, MI) followed by incubation at 35 °C for 48 ± 2 h. For yeast and mold counts, samples were spread plated using Dichloran Rose Bengal Chloramphenicol media (Acumedia, Neogen Corporation, Lansing, MI) and incubated at 25 °C for 5 days. The results of the microbial tests were expressed as log colony forming units (CFU) per gram of sample fresh weight (FW).

2.5. Physicochemical property tests

2.5.1. Color

Color was measured in a 100 × 15 mm Petri dish (VMR International) placed on top of a piece of white paper using a colorimeter (CR-300 Chroma Meter, Konica Minolta, Inc., Tokyo, Japan). Aronia puree was poured into the Petri dish until the Petri dish was full (layer of thickness of aronia puree was 12 mm and diameter was 87 mm), and color was measured through the lid. L* (lightness), a* (greenness [−] to redness [+]), and b* (blueness [−] to yellowness [+]) values were recorded (Huang et al., 2016; Sánchez-Moreno, Plaza, de Ancos, & Cano, 2006). Five measurements at different spots of each sample was conducted, and an average value was reported as the result of color of the sample. The values of the absolute color difference (delta E, ΔE) of samples were calculated according to the equation as shown below:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

In this study, ΔE represented the absolute color difference between individual sample and untreated aronia berry puree at week 0.

2.5.2. pH

pH of the puree was measured at ambient temperature using a pH meter (Orion 2-Star, Thermo Electron Corp., Waltham, MA).

2.5.3. Titratable acidity

Titratable acidity (TA) was determined according to Fisk, Silver,