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Storage stability of cranberry puree products processed with hydrothermodynamic (HTD) technology

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ABSTRACT

Storage stability of cranberry purees, processed with hydrothermodynamic (HTD) technology was studied for a period of 285 days. Three different formulations of cranberry puree were investigated: pure cranberry (PC); cranberry processed with natural sweetener (SC); and cranberry processed with natural sweetener and diluted with water (SCW). No significant difference in pH and soluble solid content (Brix) of all samples during storage was observed. The degradation kinetics of the bioactive compounds followed first-order reactions. Compared with other bioactive compounds, anthocyanins were the most stable at a 4 °C storage temperature with $t_{1/2}$ from 248 to 330 days depending on the puree formulation. At room temperature, the stability of anthocyanins was significantly smaller than that of PACs and polyphenols. Addition of natural sweetener reduced the storage stability of most bioactive compounds. Colour of processed cranberry puree significantly degraded with time, temperature and addition of sweetener. The study suggested refrigerator storage of HTD processed cranberry products in order to increase their storage stability and shelf-life.

1. Introduction

Cranberries are glossy, scarlet red and tart berries, belonging to the *Vaccinium* genus and are widely cultivated in North America, northern Asia and Europe. Cranberries have long been valued for their superior nutritional properties. It has been reported that more than 150 individual phytochemicals are found in cranberries, such as anthocyanins, flavonoids, flavonols, proanthocyanidins (PAC), vitamins, etc. (Pappas & Schaich, 2009). These notable bioactive phytochemicals have been considered to be linked to the unique health effects of cranberries. Cranberries are traditionally thought to prevent and treat urinary tract infections (UTI) and scientific verification of this pharmaceutical effect has been reported in recent years (Bailey, Dalton, Daugherty, & Tempesta, 2007; Henig & Leahy, 2000; Jepson & Craig, 2007). Besides the UTI prevention effect, recent studies also suggested that the cranberry may also promote gastrointestinal and oral health (Burger et al., 2000; Lin, Kwon, Labbe, & Shetty, 2005), improve cardiovascular health (Dohadwala et al., 2011; McKay & Blumberg, 2007), mitigate neurological problems (Dong et al., 2012), control blood glucose (Shidfar et al., 2012) and even prevent cancer (Neto, 2007; Neto, Amoroso, & Liberty, 2008; Singh et al., 2009).

Cranberries are rarely consumed fresh due to their tart and astringent taste, thus they are normally processed into other more edible forms such as sweetened juice, sauce, puree as well as dried fruits (Pappas & Schaich, 2009). Pasteurization, including both thermal and non-thermal methods, is usually required for processing of cranberry products with high moisture contents in order to prolong their shelf life by inactivating the microorganisms to a safe level (Palgan et al., 2011). The term “shelf life” not only refers to the maximum time for which the products are still safe to eat, but also to the time for which the quality of the foods remains

Abbreviations: HTD, hydrothermodynamic; C3G, cyanidin-3-*O*-glucoside; PAC, proanthocyanidin; UTI, urinary tract infections; GAE, Gallic acid equivalent; PPO, polyphenol oxidase; POD, peroxidase; PC, Pure cranberry puree; SC, Sweetened cranberry puree; SCW, Sweetened cranberry puree with water; k (day^{-1}), kinetic constant rate; $t_{1/2}$ (s), half-life; E_a (kJ/mol), activation energy; Q_{10}, temperature coefficient; R (8.314 J/mol•K), gas constant.

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acceptable (Gyeszly, 1991). In recent decades, consumers have been increasingly interested in the health benefits of foods and thus the nutritional quality of food products during storage has become one of the major concerns of evaluation of food shelf life. Therefore, storage stability is an important criterion for determining the shelf life of food products. Storage stability of physical, biochemical and nutritional qualities of food is affected by several factors including storage conditions (eg. light, heat, oxygen, etc.) and properties of food products (eg. microorganism contaminations, enzyme activity, pH, sugar content, etc.) (Alighourchi & Barzegar, 2009; Kunitake, Ditchfield, Silva, & Petrus, 2014). Thermal degradation of bioactive compounds, such as polyphenols, during storage is mainly caused by oxidation and cleavage of molecular covalent bonds through either an enzymatic or/and non-enzymatic mechanism (Jackman, Yada, Tung, & Speers, 1987). Non-enzymatic reactions of bioactive compounds in food usually include the Maillard reaction, thermal and alkaline degradation and sugar condensation (Kunitake et al., 2014). It has been reported that food composition, especially sugar content and copigments such as ascorbic acid, has a great influence on the storage stability of food. The effects of sugar on stability of anthocyanins and other polyphenols are controversial, where some studies indicate that sugar has a protective effect on polyphenols (Nikkhah, Khayamy, Heidari, & Jamee, 2007; Wrolstad, Skrede, Lea, & Enersen, 1990), while other studies report that sugar decreased storage stability of anthocyanins (Krifi & Metche, 2000; Tsai, Delva, Yu, Huang, & Dufosse, 2005; de Rosso & Mercadante, 2007). The effects of added sugar on the storage stability of foods depend on the concentration and type of sugar, storage conditions as well as structures of bioactive compounds and enzymatic activities in foods (Nicoli, Elizalde, Pitotti, & Lerici, 1991; Wrolstad et al., 1990).

The enzymatic degradation is another mechanism of quality degradation during storage, mostly affecting fruit beverages. Blending or juice extraction results in a release of enzymes, such as peroxidase (POD) and polyphenol oxidase (PPO) from the fruit matrix. These enzymes could initiate and accelerate the enzymatic oxidation of various bioactive compounds (Chisari, Barbagallo, & Spagna, 2007; Vámos-Vigyázó & Haard, 1981). Modern food processing technologies, such as heat treatment, high pressure processing, supercritical carbon dioxide treatment and pulsed electric field, have been widely studied on their ability to inactivate enzymatic activity to extend the storage stability of foods (Buckow, Weiss, & Knorr, 2009; Chen, Balaban, Wei, Marshall, & Hsu, 1992; Riener, Noci, Cronin, Morgan, & Lyng, 2008). Recently developed hydrothermodynamic (HTD) fruit processing technology, was found efficient in inactivation of POD and PPO in blueberry puree and extending its shelf life (Martynenko & Chen, 2016). HTD technology is a novel food processing technique that uses cavitation phenomena in the liquid for crushing and homogenizing of food solid particles (Martynenko, Astatkie, & Satanina, 2015). Due to internal heat generation, cavitation allows single-stage processing involving crushing, homogenization and heating in a closed system with limited exposure to oxygen, which results in minimal degradation of food quality. Our previous studies have demonstrated that HTD processing provided better texture properties and higher nutritional value of blueberries and cranberries purees (Chen & Martynenko, 2016; Satanina, Kalt, Astatkie, Havard, & Martynenko, 2014). The initial hypothesis of this study was that HTD processed cranberry puree has prolonged shelf-life due to the low enzymatic activities.

Shelf life of different berry products, especially storage stability of bioactive compounds, have been extensively studied at different processing and storage conditions, as well as product formulations (Howard, Castrodale, Brownmiller, & Mauromoustakos, 2010; Nikkhah et al., 2007; Tsai et al., 2005; Wrolstad et al., 1990). However, only a few studies assessed the storage stability of cranberry products (Starr & Francis, 1973) and no studies about degradation kinetics of major bioactive compounds in cranberry products are readily available. Furthermore, cranberry products are usually formulated as sweetened products with other food ingredients added which makes it more difficult to predict the shelf life of different commercially available cranberry products. The aim of this study was to assess the storage stability of HTD processed cranberry puree with and without sweetener using degradation kinetics of bioactive compounds, as well as colour changes.

2. Materials and methods

2.1. Materials

Frozen American cranberries (*Vaccinium macrocarpon*), variety Stevens, harvested in Prince Edward Island, Canada in 2014, were supplied from PEI Berries Ltd (Montague, PEI, Canada) with an initial moisture content of 87.8 ± 0.41 g/100 g, a sugar content of 9.57 ± 0.32 Brix and pH 2.72 ± 0.32. The frozen cranberries were stored at −20 °C until processing. All chemicals and reagents with analytical grade were purchased from Sigma-Aldrich (Oakville, Canada) or Fisher Scientific (Ottawa, Canada) and were used without further purification. Gallic acid and proanthocyanidin A2 standards were purchased from Sigma-Aldrich (Oakville, Canada) and Alkemist Labs (Costa Mesa, USA), respectively. Maple syrup purchased from local grocery store (Masstown, NS, Canada) was used as natural sweetening ingredient in this study.

2.2. Preparation of cranberry purees

Individually quick frozen (IQF) cranberries were thawed at room temperature for 12 h and the partially unfrozen cranberries were blended for 30 s with a commercial blender (Ninja Mega Kitchen System MC 1500, Canada). Cranberries were processed with three different formulations of natural sweetener or water: (1) Pure Cranberry (PC): cranberry processed without adding natural sweetener and water; (2) Sweetened Cranberry (SC): cranberry processed with natural sweetener (80 g cranberry/100 g puree); (3) Sweetened Cranberry with Water (SCW): cranberry processed with natural sweetener and water (55 g cranberry/100 g puree). Preblended cranberries were mixed with natural sweetener or/and water prior to HTD processing. HTD processing was carried out using a pilot scale machine (Tekmash, Kherson, Ukraine) according the procedure described previously (Chen & Martynenko, 2016). The prepared cranberry puree was quickly loaded in the tank of HTD processor by reaching the full capacity (5.6 kg) and the stream was circulated by a centrifugal pump. The cranberry was further crushed by cavitation at the cavitation zone of HTD processor. Non-interrupted circular motion of the liquid product in the closed system provided uniform heating with an average heating rate of 1.5 °C/min. Cranberry purees were heated to the temperature of 95 °C and samples were collected with 200 mL glass jars immediately after processing and tightened with caps. The bottles were inverted and cooled overnight.

2.3. Storage conditions

Cranberry purees in glass jars with each formulation were divided into two groups and stored in dark at refrigeration (4 °C) and room (20 °C) temperatures. Samples were periodically removed from storage to be analyzed immediately on day 0, 8, 15, 30, 48, 119, 189 and 285. These sampling times intervals were selected based on the logarithmic scale to minimize the required sampling points and increase the accuracy of the study.

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