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Characteristics of apple juice and sugar infused fresh and frozen blueberries

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ABSTRACT

Use of apple juice concentrate and standard sugar-based osmotic solution were compared during osmotic dehydration (OD) of fresh and frozen blueberries for solid gain and water loss. Additionally, fresh and frozen blueberries were characterized for moisture desorption using a thermo-gravimetric analyzer (TGA) at an isothermal temperature of 105 °C under dry nitrogen condition. Weight loss-time data generated from the TGA was used to calculate the overall liquid diffusion coefficient during moisture desorption. Results showed that the use of apple juice concentrate as an osmotic solution increased sugar concentration of frozen blueberries to 30.30 °Brix, which was similar to that obtained from the use of sugar-based osmotic solution (32.90 °Brix). Additionally, irrespective of the osmotic solution type, the osmotically dehydrated frozen blueberries reached the desired safe water activity (a_w) range (0.40–0.50) in the 600 min drying time during follow-up drying at 74 °C. Moisture desorption characterization using TGA showed that fresh blueberries took about 53% additional drying time compared to frozen blueberries.

1. Introduction

Blueberries (*Vaccinium Corymbosum* L.) are a high economic value but highly perishable fruit. They are widely consumed for their nutraceutical and nutritive value (Jimenez-Garcia et al., 2013; Martineau et al., 2006; Nile & Park, 2014; Shi et al., 2008a). The United States is by far the largest producer of blueberries, with a total production (wild and cultivated) of 309 kilotons in 2014 (USDA, 2015).

Owning to their short shelf life, blueberries have to be preserved to ensure availability all year round. Direct air-drying, via convection, is one of the widely used methods for preserving blueberries. However, direct air-drying of blueberries requires a prolonged drying time, high energy input, and may lead to non-uniform quality of the final product (Liping, 1998; Vega-Gálvez, Lara, Flores, Di Scala, & Lemus-Mondaca, 2012). To improve the quality, reduce the drying time, and minimize overall energy cost of the dried fruit, direct air-drying is generally preceded by the combination of pre-drying treatments, such as blanching, freezing, osmotic dehydration (OD), enzymes treatments, and chemical treatments (Vega-Gálvez et al., 2012). Osmotic dehydration (OD) is being widely applied as a pretreatment because it minimizes energy consumption and improves the quality of fruit due to reduced heat damage to the fruit's texture, enhanced color, and increased retention of volatiles (Azarpazhooh & Ramaswamy, 2010; Ketata, Desjardins, & Ratti, 2013; Shi et al., 2008a). Water removal and sugar uptake in the fruit during OD process are influenced by size of the fruit (Shi et al., 2008b), pretreatments with chemical agents (Ketata et al., 2013; Kucner, Klewicki, & Sójka, 2013), contact time and temperature (Nsonzi & Ramaswamy, 1998), and type of osmotic agents (Kucner et al., 2013; Shi, Pan, McHugh, & Hirschberg, 2009; Yadav & Singh, 2014).

Traditionally, six-carbon dominant sugars (sucrose) are widely used for making osmotic solutions; however, their use renders dried product sugar-rich, a dietary concern among consumers striving to reduce calorie intake from added-sugar. We visualize substituting sucrose with the 5-carbon sugars present in most fruit-juices, for example, apple juice concentrate. Very sparse scientific data is available on the use of apple juice concentrate as an osmotic agent for osmotic dehydration of sour cherries, blackcurrants, and apples (Konopacka, Jesionkowska, Mieszczakowska, & Płocharski, 2008, 2009) and use of fruit juices during osmotic dehydration of

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blueberries has not been reported. Konopacka et al. (2008) compared the usefulness of selected fruit juices (concentrated apple juice, mixture of concentrated apple juice and sour cherry juices, and de-acidified concentrated apple juice) with traditional sucrose solution during osmotic dehydration of cherry fruit. They reported that the increase in dry matter content of cherry fruit after 2 h of OD using 60 °Brix osmotic solutions, was statistically similar irrespective of type of osmotic solution (fruit juices or sucrose) (Konopacka et al., 2008). However, types of osmotic solution (sucrose, concentrated apple juice, de-acidified and desalted concentrated apple juices, sorbitol, etc.) and types of fruit (sour cherries, blackcurrants, and apples) have significant effect on water loss and dry matter uptake during 1 h long OD performed using 65 °Brix osmotic solutions (Konopacka et al., 2009). However, it is not clear if contact time of 1 h or 2 h were sufficient to reach equilibrium during the OD processes for sour cherries, blackcurrants, and apples fruits. The purpose of this research was to compare the use of apple juice concentrate and sucrose solutions as osmotic agents during osmotic dehydration of blueberries (fresh or frozen) for contact time equivalent to equilibrium period. The equilibrium period is defined as the time from the start of subjecting fruit to the OD process until no further change in °Brix of either fruit or osmotic solution takes place. Additionally, the research characterized fresh and frozen blueberries for moisture desorption behavior.

2. Materials and methods

2.1. Blueberries and osmotic agents

Fresh blueberries (Bleuets, distributed by Sunbelle Inc. Miami FL. USA) and frozen blueberries (Blue Crop and Blue Jay varieties, distributed by Kroger Co. Cincinnati OH. USA) were purchased from a retail store. The fresh blueberries were stored below 4 °C in a refrigerator and frozen blueberries were stored in a freezer below −18 °C prior to use. For the purpose of physical characterization and moisture desorption characterization experiments, the frozen blueberries were thawed at room temperature for 2 h and blotted with tissue paper to remove excess water before use. However, for the osmotic dehydration treatment the frozen blueberries were used without thawing.

To make the various osmotic solutions, granular sugar (Psst brand, distributed by Kroger Co. Cincinnati OH. USA) and apple juice concentrate (Kroger 100% apple juice frozen concentrate, distributed by Kroger Co. Cincinnati OH. USA) were purchased from a retail store. The apple juice concentrate had an initial sugar concentration of 42 ± 2 °Brix. Therefore, osmotic solutions from granular sugar were prepared at the same 42 ± 2 °Brix concentration. About 252 g granular table sugar was thoroughly mixed 348 g of deionized distilled water in a conical flask. For quick solubility of the sugar, the solution was heated to a temperature of 100 °C and then cooled to room temperature prior to use. A cover of poly-film metallic foil was used to prevent solution loss through evaporation during heating.

2.2. Physical characterization measurements

The three significant axial dimensions (Fig. 1) of 100 randomly-selected fresh and frozen (thawed) blueberries were measured using an electronic Vernier caliper (least count 0.02 mm). Effective diameter (D_e), sphericity (φ), aspect ratio (R_A) and surface area (S_A) were calculated using the axial dimensions according to equations (1)–(4) given below (Jain & Bal, 1997; Mohsenin, 1986; Omobuwajo et al., 1999):

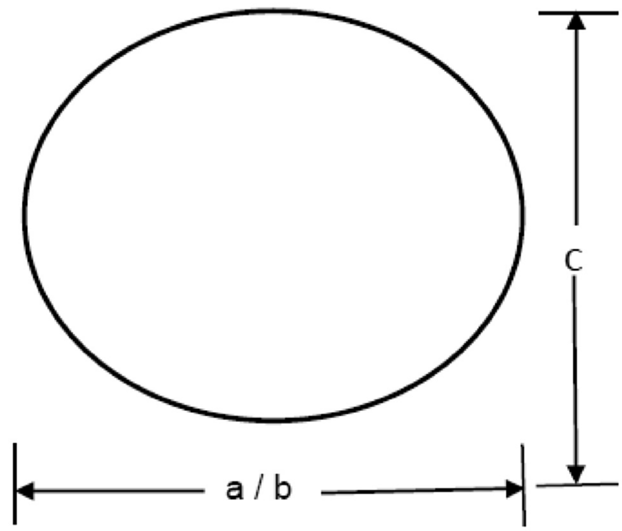

Fig. 1. Schematic diagram of a typical blueberry showing the axial dimensions a (x-axis), b (y-axis), and c (z-axis).

$$D_e = (abc)^{1/3} \quad (1)$$

$$\varphi = \frac{D_e}{a} \quad (2)$$

$$R_A = \frac{b}{a} \quad (3)$$

$$S_A = \frac{\pi a^2 (bc)^{0.5}}{2a - (bc)^{0.5}} \quad (4)$$

where a is the major diameter (mm), b is the intermediate diameter (mm), and c is the minor diameter (mm).

Additionally, the fresh and frozen (thawed) blueberries were characterized for moisture content, bulk density, true density, and volumetric moisture compression. The dried samples of fresh and frozen blueberries were also tested for volumetric shrinkage, bulk density and true density. Both fresh and frozen blueberries were assayed for initial moisture content according to the AACC method 44-15A (Moisture − Air-Oven Methods) (AACC, 2000). The bulk density of fresh as well as oven-dried blueberries was measured according to ASTM standard (ASTM C29/C29M − 2009). To measure the true density, the actual volume of the samples excluding pore volume, was measured using a multipycnometer (Model: MVP.6DC, Quantachrome, Boyton Beach, FL. USA). Volumetric shrinkage was calculated using equation (5).

$$Volumeric\ Shrinkage = \frac{V_{Green} - V_{Oven-dry}}{V_{Oven-dry}} \times 100 \quad (5)$$

Additionally, volumetric compression of water present in the blueberries was calculated by following equation (6).

$$Volumetric\ Compression\ of\ Water = \frac{\left(m_{Green} - m_{Oven-dry}\right)/\rho_{water} - \left(V_{Green} - V_{Oven-dry}\right)}{\left(m_{Green} - m_{Oven-dry}\right)/\rho_{water}} \times 100 \quad (6)$$

In this equation, m_{Green} is the weight of the fresh sample (g),