LWT - Food Science and Technology 50 (2013) 739–745

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effect of drying method on drying time and physico-chemical properties of dried rabbiteye blueberries

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ARTICLE INFO

Article history:
Received 20 March 2012
Received in revised form
6 July 2012
Accepted 10 July 2012

Keywords:
Rabbiteye blueberry
Cultivar
Impingement drying
Physico-chemical properties
Composition

ABSTRACT

Individually quick frozen (IQF) rabbiteye blueberry cultivars Brightwell and Powderblue were dried in an air-impingement dryer at 85 °C and 107 °C using two different configurations. The effect of cultivar, pick, grade, drying temperature and method on drying time and physico-chemical properties of dried blueberries were determined. Forced air dryer and a fluidized bed dryer were used as controls. Drying times were about 50% longer at 85 °C compared to 107 °C for all drying methods. Among the drying methods; fluidized bed dryer was fastest followed by air-impingement dryer(s) and forced air dryer to achieve a final water activity of 0.55 ± 0.05. Cultivar, drying method and their interaction with drying temperature shown significant effect ($P \leq 0.05$) on drying times. Several tested variables and their specific interactions also showed significant effect on bulk density, color, texture and composition of dried blueberries. Impingement drying showed promise as an alternative to fluidized bed dryer to dry IQF rabbiteye blueberries.

1. Introduction

Blueberries (*Vaccinium* spp.) are native to North America and widely consumed due to their unique flavor and high nutritional value (Shi et al., 2008). In 2009, the United States produced 456 million pounds of blueberries with a value of 508 million dollars (National Agriculture and Statistical Services (NASS), 2009). As a result of continuous increase in production and reported health benefits, the per capita consumption of blueberries in the United States increased more than 70% over the last decade and blueberries are gaining increased popularity in other parts of the world as well (US Highbush Blueberry Council (USHBC), 2010).

Rabbiteye blueberries (*Vaccinium ashei*) are one of the three commercially grown varieties and are highly productive in the southeastern region of the USA. However, high perishability and short shelf life of this fresh fruit is a common problem in the blueberry industry, which limits market availability and consumption (Shi et al., 2008). Blueberries have a brief harvest season and under controlled atmospheric conditions can be stored only 6 wk after harvesting (Prange, Asiedu, DeEll, & Westgarth, 1995). Increase in production as well as rapid machine harvesting quickly saturates the fresh market, and as a result surplus produce needs to be stored frozen for later use.

Adding value in the form of drying has proven to be a good alternative to increase the market potential and availability of many fruits and vegetables. Impingement drying is one popular drying method which uses hot air or super-heated steam at high velocities directly impinging on the product surface. Air-impingement dryers have been used successfully for baking and cooking products such as tortillas, potato chips, pizza crust, pretzels, crackers, cookies, bread and cakes (Rickard, Wuerthner, & Barret, 1993), while impingement drying has been used for coffee, cocoa beans, rice and nuts (Moreira, 2001). Impingement drying has proven to be rapid, simple and efficient, due to the increased heat and mass transfer rates provided by high velocity air. The impact of impingement drying for drying fruits such as blueberries is unknown. Also, there is a dearth of information on the effect of cultivar, pick time and different grades of blueberry on drying time and dried product quality in general. Understanding the effect of these variables on drying performance and dried fruit quality would help to identify significant factors in designing and optimizing a drying method. Therefore, the objective of this study was to determine the effect of cultivar, pick time, grade, drying temperature and drying method on drying time as well as dried product quality.

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http://dx.doi.org/10.1016/j.lwt.2012.07.011

2. Materials and methods

2.1. Blueberries

Individually quick frozen (IQF) rabbiteye blueberry cultivars 'Brightwell' and 'Powderblue' from the first and second harvests of the year 2010 were selected for this study. Blueberries were machine graded as A and C (US Department of Agriculture-Agricultural Marketing Services, 22 FR 3535 §52.613). The frozen blueberries were obtained in 13.6 kg boxes from Alma Pak Industries (Alma, GA) and stored at below −18 °C until used.

2.2. Pretreatment

To speed up the drying process, frozen blueberries were thawed for 20 min at room temperature and subjected to surface scarification using a mechanical scarifier as described by (Yemmireddy, 2011). This method of pretreatment allowed the formation of random pin holes on the surface of partially thawed IQF blueberries so as to increase the drying rate.

2.3. Drying methods

Four drying methods with 1 kg of scarified berries for each drying experiment were conducted. The end point of drying was achieved when dried berries reached a final water activity of 0.55 ± 0.05.

2.3.1. Forced air dryer (control-1)

Scarified blueberries were spread on a stainless steel screen (48 × 18 cm^2), covered with a screen top of the same dimensions and dried in a forced air dryer (Lindberg/Blue M mechanical oven, Asheville, NC, USA) at two temperatures (85 °C and 107 °C). The air velocity of the dryer was measured as 0.4 m/s using an anemometer (No.3132, Taylor Instrument Companies, Rochester 1, NY, USA).

2.3.2. Fluidized bed dryer (control-2)

Drying experiments on a commercial scale fluidized bed dryer (The Jet Zone®, Model: SNB, Wolverine Corporation, Merrimac, MA, USA) was conducted at both 85 °C and 107 °C. Based on previous research experience on this dryer (Pallas, 2011), the air velocity was set at ∼45 m/s.

2.3.3. Air-impingement dryer

An air-impingement dryer (Lincoln®, Model 1452, Food Service Products, Inc., Fort Wayne, IN, USA) (Fig. 1) in which hot air impinges from the top and bottom of the conveyor at an air velocity of ∼1.4 m/s, was used for drying studies.

2.3.4. Modified air-impingement dryer

The air-impingement dryer was modified to only allow air flow from the top of the conveyor, by completely blocking air flow from the nozzles (B1–B4 in Fig. 1 completely blocked). The purpose of this modification was to closely resemble the control-2 method. The air velocity was increased to ∼1.6 m/s to achieve pseudo-fluidization conditions while drying.

2.4. Experimental design

Drying experiments were conducted with a combination of cultivar ('Brightwell' and 'Powderblue'), pick time (pick-1: first harvest of a field in a season, and pick- 2: a subsequent harvest in the same field usually one week after the first harvest), grade (grade A and grade C) and temperature (85 °C and 107 °C). A factorial design based on cultivar, pick, grade and temperature was implemented on each of the four drying methods with a 1 kg sample size. Each combination of drying conditions was conducted in duplicate. Hence a total of 128 ($2^5 \times 4 = 128$) drying experiments were conducted and the dried products were stored in high barrier polyethylene bags for subsequent quality analysis.

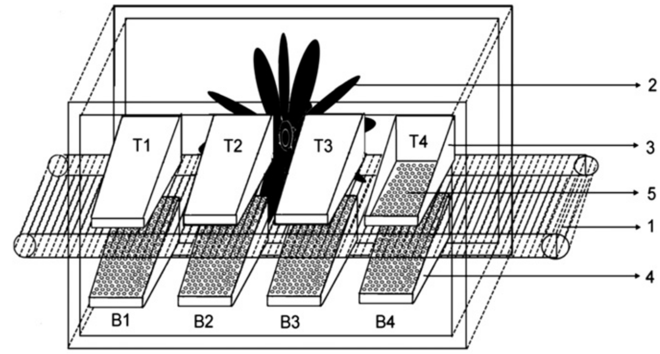

Fig. 1. Schematic diagram of the hot-air impingent dryer 1. A conveyor belt in drying chamber was used to move product trays. 2. Plenum chamber with centrifugal fan. 3. Top air vents (T1–T4) to blow hot air from plenum chamber downward. 4. Bottom air vents (B1–B4). 5. Air distribution chutes in the drying chamber.

2.5. Quality analysis

2.5.1. Water activity

The water activity (a_w) of pretreated blueberries, as well as dried blueberries was determined using an Aqua Lab water activity meter (Series 3, Decagon Devices, Inc., Pullman, WA, USA) at room temperature.

2.5.2. Proximate composition

The dried blueberries were ground into powder using a coffee grinder (Black & Decker, CBG100S, Towson, MD, USA) for composition analysis. Moisture content was determined using AACC method 44-40 (AACC, 2000). A moisture free sample was used to determine crude fat using AACC method 30-26 (AACC, 1976) with a Goldfisch fat extraction apparatus. Moisture and fat free samples were used to determine protein content (N × 6.25) using the AOAC Official method 984.13 (AOAC, 1995). Based on the Kjeldhal nitrogen procedure, analysis was performed by the Agricultural and Environmental Services Laboratories (University of Georgia, Athens, USA). Ash content was determined by muffle furnace using AOAC method 942.05 (AOAC, 2006). Carbohydrate content was calculated by difference. Each drying experiment was conducted in duplicates and two sample measurements were taken in each replicate; hence, the final value is an average of four measurements.

2.5.3. Bulk density

The volume of dried blueberries was measured by a glass beads displacement method in a graduated cylinder of known volume (Hwang & Hayakawa, 1980). Glass beads (30–40 Standard U.S. sieve size, Delong Equipment Co., Atlanta, GA, USA) were used as a displacement medium. The bulk density of dried blueberries were calculated as:

$$\rho_{db} = W_{db} / \left[V_c - \left(W_{gb} - W_{db} \right) / \rho_{gb} \right] \quad (1)$$

where ρ_{db} is the bulk density of dried blueberries (g/ml), W_{db} is the weight of dried blueberries (g), V_c is the volume of the cylindrical container (ml), W_{gb} is the weight of glass beads in the container with the blueberries (g), and ρ_{gb} is the density of the glass