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Combination of hydrothermodynamic (HTD) processing and different drying methods for natural blueberry leather

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ABSTRACT

The effects of two-stage fruit processing on the quality of natural blueberry leather are reported. Different combinations of pureeing methods, including hydrothermodynamic vs. conventional blending and drying technologies, including freeze, forced-air and electrohydrodynamic drying, were studied. At the first stage, hydrothermodynamic processing provided better quality compared to conventional blending due to full enzymes inactivation and less degradation of bioactive compounds. This was beneficial for the next stage of drying, where hydrothermodynamic processed puree did not degrade under forced-air drying below 65 °C, while conventional blended puree demonstrated rapid degradation of anthocyanin (23% loss) and formation of polymeric colour (20%). Electrohydrodynamic drying showed partial inactivation of enzymes, but negatively affected leather quality (15.6–20.6% loss of anthocyanin, 17.3–27.9% loss of polyphenols), which may be due to oxidation by ozone, generated in corona discharge. The current study suggested hydrothermodynamic pureeing for inactivation of enzymes and forced-air drying at 65 °C for maximum preservation of nutritional quality.

1. Introduction

In recent decades, consumers are increasingly interested in the health benefits of foods and have begun to look beyond the basic nutritional benefits to the potential disease prevention and health enhancing compounds contained in many foods. Fruits are natural sources of healthy bioactive compounds and mineral nutrients, exhibiting significant health benefits (Agudo et al., 2007). Thus, demand in value-added fruit products, such as 100% fruit juice and puree, is increasing and both fruit growers and processors are trying to create value-added products for maximum revenue (Hu, Woods, & Bastin, 2009; Hu, Woods, Bastin, Cox, & You, 2011). In addition to juice and puree, fruit leather has been seen as an economical and convenient value-added substitute for natural fruits as a source of various nutritional elements including dietary fibers, carbohydrates, minerals, vitamins and antioxidants (Diamante, Bai, & Busch, 2014).

Preparation method is critical for both physical and nutritional quality of fruit leather (Diamante et al., 2014; Maskan, Kaya, & Maskan, 2002). Two steps are usually involved in a fruit leather production process: puree preparation and dehydration. Cooking of puree is usually required to inactivate the enzymes and reduce the level of microbiological contamination (FAO, 2007). However, thermal processing of fruit puree usually results in significant degradation of nutrients and colour (Brownmiller, Howard, & Prior, 2008; Sablani et al., 2010). Recently developed pureeing technology, namely hydrothermodynamic (HTD) processing, was found to be beneficial in thermal treatment of fruit pulps without oxidation (Martynenko, Astatkie, & Satanina, 2015). Due to the single-stage multiple mode operation, i.e. crushing, homogenization and heating in a closed system, it is able to produce high quality fruit puree with minimal quality degradation (Martynenko et al., 2015; Satanina, Kalt, Astatkie, Havard, & Martynenko, 2014). Our most recent research showed that HTD could completely inactivate the enzymes in blueberries, including polyphenol oxidase and peroxidase (Martynenko & Chen, 2016). These results indicate that HTD could be potentially used for the first stage of blueberry leather production.

Drying of fruit puree is the second and most critical step in

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natural leather production. The most commonly used drying methods are convective and solar drying. Solar drying is popular in tropical countries due to abundance of solar energy and simple construction (Maskan et al., 2002). However, sun-dried leather has low quality due to the long drying time and associated loss of colour pigments and aroma compounds (Okilya, Mukisa, & Kaaya, 2010). Convective drying is the most commonly used industrial method of fruit leather production (Lee & Hsieh, 2008; Man, Jaswir, Yusof, Selamat, & Sugisawa, 1997; Maskan et al., 2002). However, convective drying is not ideal due to significant effect of temperature on the physical-chemical properties of fruit leather, such as enzymatic and non-enzymatic browning, texture, vitamin, colour and polyphenols (Man et al., 1997). The need in novel technology for high quality fruit drying is commonly recognized in recent years (Mujumdar, 2015). One of the novel drying technologies of fruit leather production is combined convective-infrared drying (Jaturonglumlert & Kiatsiriroat, 2010). It significantly reduces drying time, however effect on quality was not reported. It is quite possible that high temperature 300–400 °C damaged quality of the product. The application of microwave (MW) drying for mango fruit leather production was reported by Pushpa, Rajkumar, Gariepy, and Raghavan (2006). They concluded about undesirable effects of high MW power on the fruit leather quality. In both cases effects of novel technologies on the bioactive compounds of fruit leather was not investigated.

Electrotechnologies such as high voltage electrical discharge (HVED) and pulsed electric field (PEF) and electrohydrodynamic (EHD) have been intensively researched for their application in food processing due to their non-thermal property (Misra, Martynenko, Chemat, Paniwnyk, Francisco, Barba and Jambrak, 2017). HVED and PEF are high-power electrotechnologies, working close to electrical breakdown, which occurs when a high voltage pulse comes in contact with water (Puértolas, Koubaa and Barba, 2016; Puértolas & Barba, 2016). The novel electrohydrodynamic (EHD) drying is one of the promising applications of electrotechnologies for non-thermal food dehydration. The EHD exploits the effects of high-voltage corona discharge from thin wire of needle electrode on water evaporation (Kudra & Martynenko, 2015). One of the advantages of EHD corona discharge is direct converting the electrical energy into kinetic energy of ionic wind (Fylladitakis, Theodoridis, & Moronis, 2014). Different from other electrotechnologies, such as high voltage electrical discharge (HVED) and pulsed electric field (PEF), the EHD drying works in conditions of low-power glowing discharge, which is not strong enough to cause electric breakdown or arching (Misra et al., 2017). On the other hand, the thermodynamic considerations regarding the lowering of temperature under EHD drying include rapid rates of evaporation and exothermic interaction of the electric field with a dielectric material. Compared to convective or freeze drying, EHD offers lower production cost along with superior quality (Singh, Orsat, & Raghavan, 2012). In addition, considering simple design and less energy requirements of EHD drying, they could have great potential for industrial drying (Zhao & Adamiak, 2016). Previous research showed the efficiency of EHD drying technology for potato, apple, tomato, mushroom slices, spinach, rapeseed, okra and wheat drying (Singh et al., 2012). However, EHD technology has never been studied for fruit leather production and its effect on biochemical quality of food in unknown.

This study aims to develop a novel two-stage process of pureeing and drying for the production of a natural blueberry leather with high quality. Design of the two-stage processing of blueberry leather included testing the different processing methods and their combinations as presented in Fig. 1.

At the first stage the effect of HTD vs. CB on the biochemical quality of puree was compared. At the second stage the effects of three different drying technologies, namely FD, AD and EHD, on the blueberry leather quality were compared. Additionally, the direct effect of electric field introduced by EHD on enzymatic activity of blueberry puree was also investigated.

2. Materials and methods

2.1. Materials

IQF frozen blueberries, harvested in 2015, were supplied from PEI Berries Ltd (Montague, PEI, Canada). The frozen blueberries were stored at −20 °C and thawed at room temperature for 12 h just before puree processing. All chemicals and reagents of analytical grade (Sigma-Aldrich, Oakville, Canada) were used without further purification.

2.2. Blueberry puree preparation

Blueberry purees used for natural leather production were prepared by either HTD or CB technology. HTD processing of blueberries were carried out using a pilot scale HTD processor (Tekmash, Kherson, Ukraine) according to the procedure described previously (Martynenko & Chen, 2016). Approximate 5.6 kg of thawed blueberries were quickly loaded in the tank of HTD processor by reaching the full capacity and the blueberry stream was circulated by a centrifugal pump. Blueberries were continuously 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. Blueberry puree was processed until the temperature reached 90 °C and were collected with 200 mL glass jars immediately after processing and tightened with caps. The bottles were inverted and cooled overnight.

Conventional blending of blueberry was conducted by a commercial blender (Model: BL 740C, SharkNinja Operating LLC, USA). One kilogram of thawed blueberries were blended for 12 min to achieve the same particle size as HTD processed blueberry puree and stored in 200 mL jars. The above CB parameters were used in order to obtain similar physical properties with HTD processed blueberry puree. Both HTD and CB processed blueberry purees were stored at −20 °C before further drying process to prevent quality degradation.

2.3. Blueberry leather drying

Prepared blueberry purees were subjected to three different drying methods for producing fruit leathers: forced-air cabinet drying (AD), electrohydrodynamic (EHD) drying and freeze drying (FD). Approximate 50 g of blueberry puree was poured in a petri dish (diameter: 10 cm) to a depth of 0.8 cm and put into the dryers for drying. AD was carried out using an Excalibur food dehydrator (Excalibur, USA) at three temperature settings: 50, 65 and 80 °C and 1.5 m/s air velocity.

EHD drying was carried out using a laboratory scale EHD dryer consisted of a multiple points-to-plate electrode, real-time mass measurement system, an industrial blower (Fantech, Model K4, Canada), and a AC/DC high voltage converter (Universal Voltronics, Model Labtrol BAP-2-40, USA). The multiple-point discharge electrode 10 × 9 cm was formed from 1.5 cm long sharp carbon steel needles located in the nodes of the rectangular grid arranged in 10 × 9 rows with 2 cm square cells and was connected to the positive pole of the high voltage converter. A 20 × 10 cm aluminum plate electrode was connected to the ground of the high voltage source and the gap between the positive and ground electrodes was 35 mm. A modified petri dish with an aluminum plate as bottom