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Effects of pulsed infra-red radiation followed by hot-press drying on the properties of mashed sweet potato chips

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ABSTRACT

This study attempted to develop an additive-free dried sweet potato snack. To provide a crispy texture, sweet potatoes were dried by a two-stage process. At the first drying stage, steamed sweet potatoes were semi-dried for 6 h using hot-air convection or pulsed infra-red (IR) radiation, and drying rate was compared under varying sample thicknesses and drying temperatures. The IR exhibited enhanced drying speed, particularly the IR radiation at 60 °C was favorable for application to the drying of sweet potatoes with large thickness. For the secondary drying, the IR-dried sweet potatoes with varying moisture content were applied to hot-press (HP) drying at 180 °C for 2 s. The quality of final products indicated that the crispy texture of the products was generated when the semi-dried sample had a moisture content lower than 0.5 kg/kg dry base (d.b.). When the moisture content of samples prior to HP process was lower than 0.3 kg/kg d.b., the final product was easily broken with discoloration to dark-brown. Considering the entire processing procedure, the present study demonstrated that IR radiation at 60 °C for 5 h followed by HP was an effective combination for the mass production of a crispy sweet potato snack.

1. Introduction

The sweet potato (*Ipomoea batatas* L.), an important root vegetable consumed world-wide, is rich in carbohydrates (~20 g/100 g) and, particularly, starch accounts for ~65% of the carbohydrates. Sweet potato remains as an important staple food in many developing countries (Scott, Best, Rosegrant, & Bokanga, 2000). Recently, the sweet potato has been regarded as a healthy food due to its various constituents such as dietary fiber, vitamins, minerals, and antioxidants (Yang, Chen, Zhao, & Mas, 2010). A common form of processed sweet potato is the French fries. However, more recently consumers are increasingly demanding products that are additives-free (Oke & Workneh, 2013).

The drying of foods provides various advantages such as long shelf-life, convenient application and increased concentration of nutrients (Choi et al., 2015; Kim & Chin, 2016). However, producing dried sweet potato products with acceptable texture is not simple by any means. Traditionally, sun light has been used to produce dried sweet potato, while commercial dried products are made by hot-air (HA) drying. Prior to drying, sweet potatoes are steamed to gelatinize starch which results in increased sweetness. However, the high amount of sugar in the steamed sweet potatoes lowers the drying rate and empirically manifests a very hard texture after complete drying due to crystallization of sugar. For the purpose of accelerating the overall drying rate, alternative techniques have been introduced, which include vacuum-ohmic heating and vacuum-microwave (Oke & Workneh, 2013; Zhong & Lima, 2003). Infra-red (IR) drying is recognized as the effective alternative to HA drying technique (Bondaruk, Markowski, & Blaszczak, 2007). It is well known that IR penetrates drying matter and efficiently generates heat inside the matter (Nowak & Lewicki, 2004). Various fruits and vegetables are dried by IR due to its effective reduction of drying time and improvement in product quality (Nowak & Lewicki, 2004; Sharma, Verma, & Pathare, 2005). However, the IR radiation technique can also cause negative effects such as surface overheating, lipid oxidation, and impingement damage due to generation of intensive heat (Doymaz, 2012; Sheridan & Shilton, 1999). It is important to note that the quality of dried sweet potato is dependent on the IR dosage. More precisely, drying temperature greatly influences the quality of the final product (Hong, Shim, Choi, & Min, 2009).

Hot-press (HP) is a processing technique applied industrially to

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dry plywood, and has the potential for complete drying of materials. Target materials are dried under high temperature usually ranging from 120 °C to 160 °C and a pressure at about 0.4 MPa (Han, Zhan, Xu, Jiang, & Lu, 2015). Under such conditions, materials can be dried instantly (within 1–2 s), but the dryness of HP-treated final products depends on the moisture content of raw materials. During compression, samples are formed to various shapes depending on the mold, hence the HP can be adopted as a secondary or final drying process. In the present study, HP was used to make the dried sweet potato in the form of a chip (<1 mm thickness) with acceptable crispy texture. However, direct application of HP for sweet potato drying is limited because of its high sugar and moisture contents, which result in sticky final products (Bhandari, Datta, & Howes, 1997). Consequently, the steamed sweet potato has to be pretreated to produce an adequately semi-dried form prior to HP process. It is recommended to apply drying the sweet potato in the order of IR as a pretreatment and HP as a final drying process. Therefore, the present study was conducted to optimize IR and HP processing conditions to produce dried sweet potato chips with improved textural and sensorial properties.

2. Materials and methods

2.1. Materials and sample preparation

Sweet potatoes of a domestic cultivar were purchased from a local farm (Jeongeup, Korea). The sweet potatoes were kept in a chilled dark room (~18 °C) for 3 months which increased sweetness of the sweet potatoes. Prior to sample preparation, raw sweet potatoes were cleaned using running water, and steamed at 100 °C for 30 min for saccharification. The steamed sweet potatoes were mashed using a food processor (KMX51, Kenwood Ltd., Havant, UK) for 5 min, and put in a container (210 × 140 × 40 mm) to form a block. After removing from the container, the blocks of mashed sweet potato were manually sliced to 6 mm and 8 mm thickness and used as sample without further storage.

2.2. Drying process

In this study, the drying rate of the two drying methods (HA versus IR radiation) was compared under two sample thicknesses (6 mm versus 8 mm) and three drying temperatures (50, 55 or 60 °C). For HA drying, samples were treated in a commercial HA dryer (LD-918H5, Lequip, Seoul, Korea). Vapor generated during drying was continuously removed by a ventilator located bottom of the device. To monitor drying temperature, a k-type thermocouple was inserted inside the dryer during entire drying, and drying was conducted for 6 h.

The IR drying was applied using a lab-assembled IR dryer (Fig. 1A). In brief, the device consisted of an IR radiator (250 W, Philips, Brussel, Belgium), an air ventilator and a sample holder in a polystyrene housing coated by aluminum foil. The distance from IR ramp to sample was 25 cm, and the IR power was regulated by an electric transformer (500 V A, Hanil Transformer, Seoul, Korea). The temperature of sample surface was monitored by a k-type thermocouple. Since the IR dosage at constant voltage continuously increased the temperature in the dryer, pulsed IR radiation was applied at 220 V. When the sample reached the target temperature, the IR power was turned off until the sample cooled down to 3 °C below the target temperature and then radiated again. This cycle was repeated for 6 h. This entire process of treatments was repeated three times on different days using a new batch of steamed sweet potatoes (n = 3).

2.3. Hot-press (HP) treatment

The dried sweet potatoes with varying moisture contents (0.2–0.6 kg/kg dry base (d.b.)) were applied to HP drying for the purpose of final complete drying and forming as chips. Sample with 6 mm thickness were semi-dried at 60 °C in the pulsed IR radiator for various times. After tempering at ambient for 15 min, the semi-dried samples were subjected to the HP process. The HP consisted of a hot-plate with round shaped mold and pressor (Fig. 1B). The pressing cycle (5 s with intact pressing for 2 s) was regulated by rotor RPM and the plate was ohmically heated to 180 °C. Dried samples were mounted on the hot plate and HP treated. Immediately after HP treatment, the final sample was removed from the plate and analyzed without storage.

2.4. Moisture content and sugar content

The moisture content of samples was measured by the oven method at 105 °C (AOAC, 1997), and expressed as dry weight basis. As an indicator of the sugar content (or sweetness) of the sample, brix of sample was determined. A 5 g sample was homogenized with 45 mL distilled water and kept at ambient temperature for 2 h while stirring gently. The homogenate was centrifuged at 15,000×g for 5 min, and the brix of the supernatant was measured using a refractometer (RHB-55, Lumen Optical, Seoul, Korea). The total brix of the sample was numerically calculated by multiplying the obtained brix with a diluting factor of 10.

2.5. Texture

The texture of both dried and HP treated sweet potatoes was measured using a texture analyzer (CT-3, Brookfield Engineering Laboratories, Inc., Middleboro, USA) but with different fixture. For the analysis of semi-dried sweet potatoes, multiple chip fixture

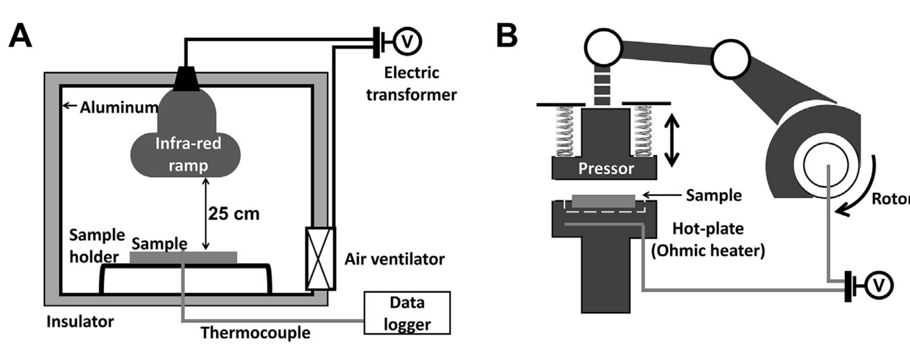

Fig. 1. Schematic diagram of (A) infra-red radiator and (B) hot-press dryer.