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Browning prevention in rehydrated freeze-dried non-blanched potato slices by electrical treatment

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Freeze-drying (lyophilization) has many advantages. The color of the freeze-dried product resembles that of the fresh tissue, in contrast to the frequently darker color resulting from conventional oven-drying. However, freeze-dried non-blanched potato slices suffer from considerable browning following rehydration. Electrical treatment of the fresh tissue (40 V/cm for 1 min) without heating and before lyophilization reduced its browning after rehydration: L^* values (lightness) of the untreated and electrically treated rehydrated tissues were 50.4 ± 0.3 and 84.3 ± 0.8, respectively. Image processing revealed that the porosity of the freeze-dried potato is not significantly influenced by the prior electrical treatment. Compression of any of the treated freeze-dried specimens always yielded characteristic sigmoid stress–strain curves. The freeze-dried blanched potato specimen was tougher than both the freeze-dried fresh potato and its electrically treated counterparts.

1. Introduction

Enzymatic browning in fruits and vegetables is a major reason for decreased shelf life and quality. When the tissue has been bruised, cut, peeled, diseased or exposed to any stressful conditions, it rapidly darkens upon exposure to air as a result of the conversion of phenolic compounds to brown melanins. This discoloration limits the shelf life of many minimally processed foods and also creates a problem in the production of dehydrated fruits and vegetables (Sapers, 1993). Despite the increased demand for fresh foods, dried products have remained popular: consumers find them easy to store and quick to prepare (Kuntz, 1996).

Blanching of fruits and vegetables is extensively used in food processing (Gonzalez-Fesler, Salvatori, Gomez, & Alzamora, 2008; Severini, Baiano, De Pilli, Carbone, & Derossi, 2005; Wang, Zhang, Arun, & Mujumdar, 2010). The most widespread methods of blanching include exposing vegetables to hot water, hot or boiling solutions containing acids and/or salts, steam (Kidmose & Martens, 1999; Mukherjee & Chattopadhyay, 2007; Sapers & Miller, 1995; Severini, Baiano, De Pilli, Romaniello, & Derossi, 2003) or microwaving the product immersed in water or solution for several seconds or minutes (Severini, De Pilli, Baiano, Mastrocola, & Massini, 2001).

In potato processing, blanching is generally performed in a temperature range of 80–100 °C for between 20 s and 15 min. Such temperatures might cause structural damage and decrease the firmness of the vegetative tissue (Anderson, Gekas, Lind, Oliveira, & Oste, 1994). Blanching in the range of 55–75 °C improves the firmness of cooked vegetables and reduces physical breakdown throughout supplementary processing (Verlinden, Yuksel, Baheri, De Baerdemaeker, & Van Dijik, 2000). A blanching method that combines low temperatures with long treatment times followed by a higher temperature for a short time was effective in both minimizing the decrease in vegetables' textural properties and destroying undesirable enzymes. A variety of different favorable blanching conditions, depending upon the size and shape of the pieces, have been described in the literature. For example, an optimum blanching temperature of 60–65 °C for 25–35 min was reported to preserve desirable mechanical properties of fried potatoes (Canet, Alvarez, & Fernandez, 2005a). To produce a freeze-dried snack food, potatoes must be blanched prior to drying. Blanching by heating can result in loss of soluble solids, enzyme denaturation, and air removal from the tissue, hydrolysis and solubilization of structural polymers such as protopectin, and gelatinization of starch granules (Mate, Quartaert, Meerdink, & van't Riet, 1998).

Consumer preference is influenced by a combination of flavor, texture and appearance (Canet, Alvarez, Fernandez, & Tortosa,

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2005b; Canet et al., 2005a). Heat treatment effects chemical, physical and structural modifications of potato tissue texture. The extent of those changes depends on the duration and temperature of the thermal processing, which can consist of blanching, cooking or frying (Moyano, Troncoso, & Pedreschi, 2007). Heating of potato tissue weakens the binding between cells and causes swelling of intracellular starch. Thermal weakening of the potato tissue has been suggested to be controlled mainly by thermal degradation of the middle lamella (Ormerod, Ralfs, Jobling, & Gidley, 2002). Textural degradation of vegetable tissues during blanching has been mostly reported to follow a first-order kinetics reaction, either in one phase for the complete process or divided into an initial rapid step followed by a slower one (Nisha, Singhal, & Pandit, 2006). Another report suggested a kinetics model based on a series of irreversible chemical reactions to fit the experimental data of textural changes throughout thermal processing of a number of potato products (Moyano et al., 2007). Potato strips used for French fries are characteristically blanched at 50–70 °C to activate the enzyme pectin methyl esterase (Ni, Lin, & Barrett, 2005; Nourian & Ramaswamy, 2003). Pectin methyl esterases hydrolyze methyl ester bonds of pectin chains, resulting in free carboxylic groups reacting with divalent bonds (such as Ca^{2+}) and strengthening the texture (Nussinovitch, 2003). As a consequence, addition of calcium cations to the blanching water enhances vegetative tissue firmness (Jaswal, 1970). A second, high-temperature blanch (e.g. in boiling water) improves color by inactivating the enzyme phenolase and provides surface heat treatment of the potato strips (Agblor & Scanlon, 2000).

Over the last few decades, extensive studies have been conducted on the effects of various electrification methods on different tissues, particularly food tissues. Electricity has been applied to foods by ohmic heating, low-electrical field stimulation, high-voltage arc discharge, low-voltage alternating current (AC) and high-intensity pulsed electrical field (PEF) (Barbosa-Canovas, Gongora-Nieto, Pothakamury, & Swanson, 1999; Chen, Barthakur, & Arnold, 1994; Knorr, Geulen, Grahl, & Sitzmann., 1994; Rastogi, Eshtiaghi, & Knorr, 1999; Wang & Sastry, 1997). Several research groups have studied the use of PEFs as an alternative to conventional food-processing methods (Barbosa-Canovas et al., 1999). Other researchers have applied low-density direct current (DC) electrical fields to plant tissues in order to study their effect on solid vs. liquid moieties (Zvitov, Schwartz, & Nussinovitch, 2003b). Electrical fields (PEF or AC) produce a current through the biological tissue and may damage the membranes through volumetric ohmic heating. Strong PEF exposure (high electrical field for long duration) can lead to the formation of large pores, deformation of membranes and cell lysis (Pliquett, Joshi, Sridhara, & Schoenbach, 2007). The damage extent can be defined as the ratio of the damaged cells to the total number of cells. Direct estimation can be performed through microscopic observation of the PEF-treated tissue (Fincan & Dejmek, 2002). We previously reported inhibition of potato browning by application of an electrical field in the range of 43–70 V/cm (DC current of ~0.02–0.2 A) to a potato specimen held between Pt electrodes in a water medium (Nussinovitch & Zvitov, 2008).

Many freeze-dried foodstuffs are rehydrated and reconstituted prior to consumption (Ratti, 2001), and during this process, browning can occur. An additional or alternative treatment is therefore needed to inhibit the browning of such products (Schebor, del Pilar Buera, Karel, & Jorge Chirife, 1999). Rehydration is an important step in the utilization of dried fruits and vegetables. As consumers have shown an increased interest in healthy, ready-to-use foods, convenience, freshness, high quality, flavor and adequate reconstitution are essential in meeting expectations (Marabi, Thieme, Jacobson, & Saguy, 2006). One of the important properties for consumers is color, and thus browning reduction is important for maintaining product quality and acceptance. The aim of this study was to examine the possibility of using low DC electrical fields for electrifying fresh potato slices before freeze-dehydration instead of blanching, to reduce browning of these products upon rehydration.

2. Materials and methods

2.1. Plant material

Fresh potatoes (*Solanum tuberosum* var. Winston) were purchased from a local grocery store. Prior to specimen preparation, potatoes removed from cold storage (4 °C) and allowed to equilibrate to room temperature (~25 °C). They were peeled and halved along their longitudinal axis. Cylindrical specimens, 2.0 mm thick by 6.5 mm in diameter, were trimmed using a cork borer. To achieve an exact thickness, the cylinders were cut with a custom-made cutting device (Zvitov & Nussinovitch, 2005).

2.2. Blanching

Blanching treatments were performed by immersing the potato specimens (2.0 × 6.5 mm, thickness by diameter) in boiling water for 4 min. The product-to-solution ratio was always 1:10 (w/w). After blanching, the samples were cooled in tap water, drained and blotted dry with a paper towel. Unblanched potato samples were used as controls. The control samples were also submerged in tap water to "wash" the free enzyme and substrates from the surface of the potato slice before freeze-drying.

2.3. Drying procedure

All specimens (untreated, blanched and electrically treated) were frozen at −80 °C for 1 h before freeze-drying, which was carried out at −50 °C at a pressure of 1.1 Pa for 30 h (Martin Christ freeze-drying apparatus model ALFA I-5; Osterode am Harz, W. Germany) (Tal, van Rijn, & Nussinovitch, 1999).

2.4. Electrical apparatus

A custom-made apparatus was built to permit electrical treatment of the potato specimens in liquid medium (Fig. 1). The specimens (2.0 × 6.5 mm, thickness by diameter) were sandwiched between a pair of platinum electrodes (Holland Moran Ltd., Yehud, Israel) and the space was filled with distilled water. DC voltage was applied across the electrodes with a DC power supply (Advice

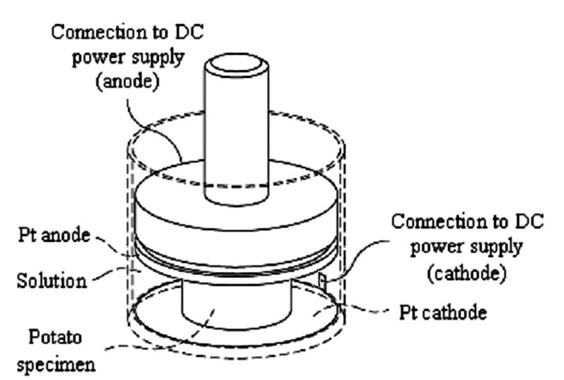

Fig. 1. Custom-made apparatus for application of the DC electrical field to plant tissues. The electrodes were connected to a DC power supply (not shown).