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Effects of hot-water blanching on the biological and physicochemical properties of sweet potato slices

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ABSTRACT

Changes in the enzymatic and physicochemical properties of sweet potatoes processed by a combination of pre-heating and high-temperature blanching were investigated. First, the characteristics of the inactivation of peroxidase and pectin methylesterase were analyzed, showing that 112.7 and 119.6 kJ mol^{-1} of activation energy were required for inactivation, respectively. The result also suggested that a temperature of over 94 °C was better to inactivate peroxidase effectively. Second, the optimum conditions for pre-heating treatment were selected through the consideration of quality attributes. Pre-heating at 60 °C and 65 °C produced a stronger effect of enhancing firmness. However, some adverse effects on nutrients and appearance were noted at temperatures over 65 °C. Eventually, pre-heating at 60 °C for 40 min was selected as the best condition for sweet potato slices.

1. Introduction

Blanching is a heating operation applied prior to the freezing, canning, or drying of fruits and vegetables to inactivate enzymes; improve texture; retain color, flavor, and nutritional value; reduce pathogen and bacterial counts; and extend the shelf life of food (Reyes De Corcuera et al., 2011; Yoshida et al., 2017). Because main factor of the quality degradation of the processed fruit and vegetables is due to various enzymes, inactivation of the enzymes is important. In particular, peroxidase (POD) which has high heat resistance is an index for determining blanching time (Imaizumi et al., 2017b). Thus, many researchers investigated characteristics of POD inactivation in several vegetables (Fortea et al., 2009; Neves et al., 2012; Soysal and Söylemez, 2005; Yu et al., 2010). To accomplish POD inactivation effectively, such information is essential.

On the other hand, blanching also causes quality degradation of products. Pectin polysaccharides, which contribute to cell-cell adhesion in plant tissue, are β-eliminated by high temperature heating (Christiaens et al., 2011; Sila et al., 2009). This tissue degradation results in textural loss. To inhibit the degradation, pre-heating before blanching has been studied (Abu-Ghannam and Crowley, 2006; Verlinden et al., 2000; Xu et al., 2015). Pre-heating, usually conducted at 50–80 °C, activates pectin methylesterase (PME), then PME induced demethylation of pectin polysaccharides. The demethylated pectin polysaccharides are hard to β-eliminate and easy to cross-link via divalent ions (Imaizumi et al., 2017a; Sila et al., 2009). Thus, pre-heating before blanching is attractive approach to enhance tissue and texture. To select the optimum temperature and time combination of pre-heating, heat resistance of PME should be known.

Sweet potato is main root vegetable that contains starch, fiber, and is a source for many food applications for humans and animal. However, the shelf life of the fresh product is limited because it is seasonal and it has high moisture content that cannot maintain good quality over a long period. In recent years, modern households prefer to consume semi-finished products, such as frozen products, to prepare meals because of the convenience of use and storage. Hence, blanching methods have become commonly used to inactivate enzymes in order to maintain quality, extend shelf-life of the product during freezing storage, and improve nutritional value (Falade and Solademi, 2010). However, heat resistances of POD and PME in sweet potato has not been investigated enough. Additionally, investigations of the effects of these heating treatments on firmness, ingredients and color are required for comprehensive design of the processes.

In this study, the effect of blanching temperature and treatment time on POD activity was tested to determine the optimum blanching conditions. The effect of pre-heating treatment on PME activation was also estimated. Then, the effect of the combination of pre-heating and high-temperature blanching on the quality of sweet potato slices was evaluated.

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2. Material and methods

2.1. Sample preparation

Sweet potato (*Ipomoea batatas* (L.) Lam.) roots were obtained from a local market in Fukuoka city, Japan. Samples were roots of a similar age, maturity, size, and freedom from defects, and they were delivered immediately to the laboratory. The roots were cut into cylindrical slices (φ29 × 15 mm) using a cork borer and a knife.

2.2. General procedure

A thermostatically controlled water bath (TB-2NC, AS ONE) was used for the pre-heating process, and another water bath (OSB-2000, EYELA) for the blanching process. Six beakers were filled with 200 mL of distilled water for each treatment condition, and 6 samples were dipped into each beaker. Both pre-heating and blanching were conducted by immersing the sweet potato slices fully in the beaker (water: sweet potato = 8:2).

POD activity was assayed after treatment at temperatures of 80 °C, 90 °C, 94 °C, 96 °C, and 98 °C for heating times of 3, 5, 7, and 10 min, and cooled in ice-cold water for 5 min before testing to avoid the effect of remaining heat. PME activity was measured after treatment at temperatures of 50 °C, 55 °C, 60 °C, 65 °C, and 70 °C for heating times of 20, 40, 60, 80, 100, and 120 min. After pre-heating, the sweet potato slices was immersed immediately in ice-cold water for 5 min before measuring PME activity. To evaluate the effect of pre-heating (low-temperature blanching) on firmness and other physicochemical properties such as moisture content, total soluble solid content, ascorbic acid content, and color change, samples were pre-heated at 50 °C, 55 °C, 60 °C, 65 °C, and 70 °C. Time for pre-heating was from 20 to 120 min for measuring firmness and 20, 40 and 60 min for other properties. After pre-heating, the samples were immersed in ice-cold water for 5 min to equalize the sample temperature, then blanched at 96 °C for 5 min, and again immersed into ice-cold water for 5 min before measuring.

2.3. Enzymatic activity measurement

2.3.1. Peroxidase

POD activity was measured in accordance with the method described previously (Neves et al., 2012). To extract POD, samples were homogenized in 30 mL of 0.1 M phosphate buffer (pH 6.5). Then, the homogenate was shaken (15 min, 190 rpm) and centrifuged (15 min, 3500 rpm, 4 °C). The supernatant was filtered and a 0.25 mL aliquot pipetted into 2.25 mL of substrate solution (guaiacol, 30% hydrogen peroxide solution and phosphate buffer in a ratio of 1:1:998). The absorbance at 470 nm was measured using a spectrophotometer (V-530, JASCO).

2.3.2. Pectin methylesterase

PME activity was measured in accordance with the method described previously (He et al., 2014). Samples were homogenized in 30 mL of 8.8% NaCl. Then, the homogenate was shaken (15 min, 190 rpm) and centrifuged (15 min, 3500 rpm, 4 °C). The sample solution was filtered and kept at 30 °C for 15 min before testing. Two milliliters of test solution (0.5% pectin extract, 0.55 mL distilled water, 0.15 mL 0.01 M bromothymol blue) were placed into a glass tube. After mixing thoroughly, 0.3 mL of sample was added to the mixture. The tube was placed into the spectrophotometer and absorbance at 620 nm was measured.

2.3.3. Mathematical analysis

Enzymatic inactivation in vegetables during heat treatment is often represented by a following first-order kinetic model (Imaizumi et al., 2017b):

$$\exp(-kt) = A/A_0 \quad (1)$$

where k is the rate constant (min^{-1}), t is time (min) and A is the enzymatic activity of the treated sample and A_0 is the initial activity (fresh sample). Because heat labile and heat stable fractions exist in both POD and PME molecules (Agüero et al., 2008; Guiavarc'h et al., 2005), the inactivation is often described using a fractional conversion model, which takes into account the nonzero activity of the enzyme after prolonged heating, as described below (Ando et al., 2017):

$$(A - A_\infty)/(A_0 - A_\infty) = \exp(-kt) \quad (2)$$

where A_∞ is the equilibrium activity. Additionally, k can be represented using the Arrhenius equation:

$$k = k_0 \exp(-E_a/RT) \quad (3)$$

where E_a is the activation energy (J mol^{-1}), R is the universal gas constant (8.314 J K^{-1} mol^{-1}), T is absolute temperature (K), and k_0 is k at $T = 0$ K. In this way, the heat-resisting properties of POD and PME were evaluated. Furthermore, D-value is also used as indices of this property. The D-value is defined as the time required for reduction of the activity to 1/10 and generally calculated using the following equation (Ali et al., 2011):

$$D = 2.303/k \quad (4)$$

where D is the D-value (min). To evaluate the inactivation of POD and PME, we determined the parameters described in the above equations using a least-squares method.

2.4. Physiochemical parameters

2.4.1. Firmness

Tissue firmness of sweet potato slices was measured using a creep meter (RE-3305, Yamaden) equipped with cylindrical plunger (diameter: 3 mm). The plunger penetrated from the central point of the top face to a depth 12 mm. The speed of penetration was set at 1 mm per second. The peak force at fracture was determined as the firmness (N).

2.4.2. Moisture content

Moisture content (% wet basis, % w.b.) of samples was measured by the atmospheric heating drying method at 135 °C for 24 h (AOAC).

2.4.3. Total soluble solid content

The sample was homogenized in 30 mL of buffer solution and shaken (15 min, 190 rpm). Then, the homogenate was centrifuged (15 min, 3500 rpm, 4 °C) and filtered. The Brix value of the sample solution was measured as an index of total soluble solid content using a refractometer (IPR-101α, AS ONE) and converted to the sample Brix as follows:

$$sample\ Brix = B \times (W_s + W_b)/W_s \quad (5)$$

where B is the Brix value of the sample solution, W_s is the weight of sample (g), and W_b is the weight of buffer (g).

2.4.4. Color (ΔE*)

The color of sample surface was measured using a chromameter (CR-200, Minolta) and expressed in L^*, a^*, b^* values. Then, color differences of the sample were calculated using the following equation:

$$\Delta E^*ab = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad (6)$$

where subscript 0 indicates the initial value for fresh sample.

2.4.5. Ascorbic acid content

Ascorbic acid content was measured using the method proposed by Rahman et al. (2008), with slight modifications. Sweet potato samples were homogenized in 30 mL of distilled water. Then, the homogenate was shaken (15 min, 190 rpm), centrifuged (15 min, 3500 rpm, 4 °C),