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Physicochemical and sensory properties of soy bread made with germinated, steamed, and roasted soy flour

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ABSTRACT

For the development of healthful gluten-free soy bread acceptable to consumers, we evaluated the effects of various processing procedures for soy flour on bread quality, in terms of beany flavour and texture. We pretreated soy flour by both non-heating (raw:NS and germinated:GS) and heating (steamed:SS and roasted:RS) methods. In addition, to improve the loaf volume, we added 1% hydroxypropyl-methylcellulose (HPMC) to RS flour. *Lipoxygenase* activity was retained in the non-heat-treated flours (279 U/g for NS and 255 U/g for GS), but was significantly reduced in the heat-treated flours (106 U/g for SS and 69 U/g for RS). Moreover, heat-treated flour had higher isoflavone and ferric reducing antioxidant power than had non-heat-treated flour. However, RS flour had the lowest moisture content and lowest L^* value. The GS bread had the highest specific loaf volume (3.53 cm^3/g), followed by NS (2.96 cm^3/g), RS (2.25 cm^3/g), and SS (1.81 cm^3/g) bread. GS bread had the lowest hardness (1.53 N), followed by NS (1.65 N), RS (2.00 N), and SS (3.75 N) bread. The addition of 1% HPMC to RS increased the loaf volume (2.44 cm^3/g), but decreased the bread's hardness (1.80 N). As to the sensory properties, the bread with heat-treated flour was perceived to have a less beany odour and taste than was the bread with non-heat-treated flour. However, the latter had a better appearance than the former. These results indicated that soy flour pretreatment could enhance the loaf volume and reduce the beany flavour of whole soy bread.

1. Introduction

Breads are basic dietary components in many countries and are mainly prepared from wheat flour containing gluten. Gluten is responsible for the bread's texture quality, but can cause allergic reactions, such as celiac disease. As a bread material, soybeans have attractive functional properties, including their high water-holding, foaming capacity, dough handling properties, and a tenderising effect (Nilufer-Erdil, Serventi, Boyacioglu, & Vodovotz, 2012), as well as a variety of micronutrients and phytochemicals (Siddhuraju & Becker, 2007). In particular, soy protein has been used to mimic the viscoelastic properties of gluten in wheat dough (Ribotta et al., 2004). Therefore, soy flours are partially substituted for wheat flour in a variety of baked goods at contents up to 30% (Shogren, Mohamed, & Carriere, 2003). However, the complete replacement of wheat flour by 100% of soy flour is difficult to achieve in bakery products due to the resulting beany flavour and dense texture.

One of the continuing impediments to the acceptance of soy foods is their beany taste, due to the lipoxygenase-catalysed oxidation of unsaturated fatty acid in soybean oil to volatile compounds. Several studies have investigated the removal of the beany flavour through two types of soybean processing: non-heat treatment, such as germination, and heat treatment, such as steaming, roasting, and baking. Germination processes have been developed in some countries to overcome the disadvantages associated with raw soybean, such as undesirable flavour, as well as the presence of lipoxygenase isozymes (Mostafa & Rahma, 1987). Moreover, sprouts are a way of availing the health benefits of soybeans (Kumar, Rani, Pandey, & Chauhan, 2006). The application of heat, such as in cooking, can change the nutritional and biological activities and the physicochemical properties of soybeans or legumes (Ovando-Martínez, Osorio-Díaz, Whitney, Bello-Pérez, & Simsek, 2011). In particular, heat treatment is the most common method used to inactivate lipoxygenase in soybean. In the study of Kong, Li, Wang, Hua, and Huang (2008), heat-treated soy flour effectively reduced the reaction of lipoxygenase. Moreover, heat treatment also causes the development of cooked and toasted flavours

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(Thakur & Nelson, 1997). On the other hand, Turkmen, Sari, and Velioglu (2005) reported that cooking engenders an increase in phenolics and antioxidant activities in green beans. However, the chemical composition may be altered during processing and heat treatment, negatively affecting the bread quality in terms of loaf volume and texture. In several studies (Kim & Yokoyama, 2011; Kobylañski, Pérez, & Pilosof, 2004; Nishita, Roberts, Bean & Kennedy, 1976), hydroxypropyl-methylcellulose (HPMC) was used for improving the quality of gluten-free bread in terms of high volume and soft crumb texture. In the present study, in an effort to develop an acceptable and healthy bread, pre-treated types of soy flour were substituted in wheat flour samples. We developed a formulation for 100% soybean bread with non-heating (germination) and heating (steaming, roasting) methods. HPMC was added to roasted soy flour in order to improve the texture. To assess the effect of soy treatment on the quality of soy bread, the physicochemical properties and the biochemical and sensory characteristics of the soy flour, dough, and bread were evaluated.

2. Materials and methods

2.1. Pretreatment of soy flour

Soybeans (Taekwangkong; *Glycine max* (L.) Merrill), purchased from Ssalnongbu (Ssalnongbu Co., Gyeongnam, Korea), were processed by the following methods: germination, steaming, and roasting. For germinated soy (GS) flour, the soybeans were held at 25 °C for 2 days in an incubator (BOD incubator, Model HA-1000, Hanil Science Co., Korea), and the sprouts with a length of 5–10 mm were collected and dried at 30 °C for 48 h in a convection oven (SJ Science Co., Korea). For steamed soy (SS) flour, the soybeans were steamed at 95 °C for 1 h in a steam pot (Model STS 304, Chefline Co., Seoul, Korea) and dried at 30 °C for 48 h in an oven. For roasted soy (RS) flour, the soybeans were roasted at 140 °C for 30 min in a convection oven. For HPMC-treated roasted soy (RSH) flour, HPMC (K250 M, Dow Chemical, MI, Michigan, USA) was added to the roasted soy flour on a 1% weight basis, through a pre-test, in order to improve the texture of the bread. All treated soybeans were milled to flour by grinding (Model RT-08, Pulverisser, Rong Tsong Precision Technology Co., Taichung, Taiwan), sieved with a 180 μm screen (Model BS0180, ASTM mesh No. 80, Standard testing sieve, LK Lab Korea Co., Seoul, Korea), and then stored at −20 °C until used.

2.2. Preparation of soy bread

By using a modified formula for the American Association of Cereal Chemists method 10-09 (AACC, 2000) and the rice bread formula (Nishita et al., 1976), soy breads were prepared under four conditions: soy bread with raw soy flour, soy bread with germinated soy flour, soy bread with steamed soy flour, soy bread with roasted soy flour and soy bread with roasted soy flour and added HPMC. The bread formula consisted of 50 g soy flour, 1.5 g dried yeast, 3 g butter, 5 g sugar, 0.5 g salt, 1.5 g defatted milk powder, and a variety of water content according to the flour condition in order to ensure the consistency of the bread (50 g for NS and GS, 60 g for SS and RS, 70 g for RSH). Briefly, the dry ingredients were placed in a mixer (Model 5K5SS, Kitchen Aid, St. Joseph, MI, USA) and mixed, after which the butter was added. The mixture was blended at speed 2 for 15 min. The resultant dough was placed in a baking pan (15 × 6 × 6 cm) and fermented for 35 min in an incubator at 38 °C and 80% relative humidity. It was baked at 150 °C for 20 min. The loaves were removed from the pans and cooled at room temperature. For future studies, the bread was freeze-dried and stored at −18 °C until used.

2.3. Determination of soy flour properties

2.3.1. Moisture, in vitro protein digestibility, and colour value

The moisture content of the soy flour was measured by a moisture meter (HB 42-S Moisture Analyser, Mettler Toledo, Switzerland). *In vitro* protein digestibility (IVPD) was determined according to the procedure of Osman (2004). Briefly, the drop in the pH of casein (control) and of the sample after a 10 min hydrolysis by proteolytic enzymes was measured. IVPD was calculated as follows: %*In vitro* digestibility = 210.46 − 18.10 *X* (where *X* was the pH of the suspension after 20 min of hydrolysis). The colour of the flours was measured using a Minolta Spectrophotometer CR-400 series (Minolta Co., Osaka, Japan). L^*, a^* and b^* values were measured. Chroma (C^*) and hue angle (h°) were calculated using the following equation: $(a^{*2} + b^{*2})^{1/2}$ and the arctangent of b^*/a^*, respectively (McGuire, 1992; Voss, 1992). The total colour difference (TCD∗), which is the parameter of the overall colour difference evaluation between a processed sample and a raw soy flour (indicated by the index 0 in the following equation), was calculated using the following expression: $[(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2]^{1/2}$ (Gonçalves, Pinheiro, Abreu, Brandão, & Silva, 2007).

2.3.2. Lipoxygenase activity

The *lipoxygenase* (LOX) activity was determined by the modified methods of Kong et al. (2008), by measuring the UV absorption from the formation of conjugated dienes from linoleic acid. Briefly, the flour was blended with 50 volumes of deionised water in a blender for 25 min to extract soluble proteins, including lipoxygenase. The mixture was centrifuged at 2000*g* for 15 min and the supernatant was collected. Before use, 1 ml of supernatant was diluted with 50 ml of distilled water. The lipoxygenase substrate was prepared by suspending 1.5 ml of linoleic acid (Sigma Chemical Co., St. Louis, MO. Assay >99.0% (GC)) in a borate buffer (50 mM, pH 9.0). The suspension was neutralised by the addition of 1 ml of a 5 mM NaOH solution, shaken with 10 μl of Tween-20, then diluted to 2.24 mM with a borate buffer (50 mM, pH 9.0) before use. For the assay, 0.3 ml of diluted supernatant of enzyme extract was added to 2 ml of linoleic acid substrate suspension, and the mixture was shaken and incubated in 30 °C water for 3 min. The reaction was terminated by the addition of 5 ml of ethanol; then, 5 ml of distilled water were added to the mixture before the measurement. The conjugated diene oxidation products were determined by measuring absorbance at 234 nm, using a spectrophotometer (UV-2401PC, Shimadzu, Kyoto, Japan). The residual enzymatic activity was expressed as U/g. One unit (U) of activity was defined as the increase in OD per min at 234 nm.

2.3.3. Isoflavone content and ferric reducing antioxidant power

The isoflavone contents of soy flour were measured, based on the method of Wang, Kuan, Francis, Ware, and Carman (1990). 1 g of sample was hydrolysed with 5 ml of 1 N HCl for 2 h at 98–100 °C, and then mixed with an additional 10 ml of methanol for 1 h at 60 °C in a water bath. The extracts were filtered through a 0.45 μm syringe filter and analysed by the HPLC system (SCL 6B, Shimadzu, Japan) with a RP-18 column (4.6 × 250 mm, 5 μm particle size, Waters Co., USA). 20 μl of mixed standard solution were injected into the sample extract, and chromatograms were recorded by the UV detectors at 254 nm. Genistein (G6649, Sigma–Aldrich Co., USA) and daidzein (D7802, Sigma–Aldrich Co., USA) were used as the standards. Ferric reducing antioxidant power (FRAP) analysis was carried out, based on the modified method of Ku et al. (2009). 1 g samples were held overnight at room temperature, extracted with 20 ml of 80% (v/v) ethanol at 60 °C for 1 h, and then concentrated. For the assay, the FRAP reagent (2850 μl) was mixed with 150 μl of soybean extract, and the absorbance at 593 nm was recorded after 4 min. The results were expressed in