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Effect of ovalbumin on the quality of gluten-free rice flour bread made with soymilk

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ABSTRACT

The use of soymilk instead of water affects the rising of gluten-free rice flour bread into the shape of a muffin. However, when baking bread into a loaf, gas cells at the center of the crust, where thermal conduction is lowest, collect to form a hollow in the loaf. The goal of this study was to assess the components that affect the quality of gluten-free rice flour bread made with soymilk. Adding more than 1.25% of ovalbumin (OVA) to the rice flour prevented formation of this hollow. In addition, OVA levels greater than 2.5% helped the bread rise further through oven spring, which increased specific loaf volume. These improvements resulted from an increase in thermal coagulation of gas cell membranes and an increase in batter viscosity due to interactions between soy globulins and OVA that promoted starch granule aggregation. Thus, even though OVA levels greater than 2.5% increased the specific loaf volume, they also made the crust harder. As a result, the optimum OVA level is 1.25% of the rice flour.

1. Introduction

Gluten is a fundamental component for making bread dough (Wieser, 2007; Barak, Mudgil, & Khatkar, 2013), but genetic factors or excessive intake can lead to health problems such as celiac disease (Biesiekierski, Muir, & Gibson, 2013; Sabatino & Corazza, 2009), baker's asthma (Salcedo, Quirce, & Diaz-Perales, 2011; Wang et al., 2010), and gluten sensitivity (Fasano et al., 2008). Concern over these diseases has created the need for diets with reduced or no gluten (Cosnes et al., 2008; Gallagher, Gormley, & Arendt, 2004; Norström, Sandström, Lindholm, & Ivarsson, 2012).

Variants of gluten-free rice bread, made with rice flour instead of wheat flour, have been developed, but usually require the addition of thickeners such as xanthan gum (Demirkesen et al., 2014; Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007), guar gum (Schwarzlaff, Johnson, Barbeau, & Duncan, 1996), or hydroxypropyl methylcellulose (Cornejo & Rosell, 2015; De La Hera, Rosell, & Gomez, 2014; Mariotti, Ambrogina, & Lucisano, 2013) to trap the CO_2 released by the yeast in the batter. All of these thickeners are approved food additives in many countries. Thus, developing a rice flour bread that rises properly using approved food ingredients is beneficial.

A previous study (Nozawa, Ito, & Arai, 2014) reported that replacing water with soymilk in the dough was an effective way to produce gluten-free rice flour bread that would rise properly without the use of thickeners. Replacing the water in the rice flour batter with the same weight of soymilk reduced the water content of the batter to 90% of the original amount, increasing the batter viscosity. The sucrose in the soymilk also stimulated yeast fermentation, which increased the amount of CO_2. These effects created more gas cells (CO_2) in the soymilk batter compared to batter with water, and significantly increased the volume after fermentation. Additionally, glycinin and β-conglycinin contained in the soymilk formed a membrane that prevented gas cells from escaping the batter or joining together. The gas cells remained intact, even during the baking process, allowing the bread to rise significantly more compared to bread made from batter containing water.

These results, however, were achieved by baking a small amount of batter in a muffin mold. For gluten-free rice flour bread to be a useful replacement for wheat flour bread, the bread must be able to form loaves similar to those of wheat flour bread. Marston and Wannan (1976) reported that the temperature increase at the center of a wheat flour loaf at the start of heating is significantly slower than that at or near the sides of the loaf when baking. During baking of a loaf of bread made from batter containing soymilk, gas cells at the center of the loaf, where the heat transfer is

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slowest, need to remain stable.

Earlier studies on gluten-free bread have used rice flour as the main ingredient with the addition of soy protein isolates and dried egg white solids (Crockett, Ie, & Vodovotz, 2011). However, in most of these studies, hydrochlorides were used as additives. Consequently, the contribution of soybean and egg proteins to the formation and stabilization of gas cells in gluten-free bread has not yet been clarified.

The objective of the present study was to investigate the ability of albumin (which has a high capacity for thermal coagulation among dietary proteins) to improve gas cell stability and increase the leavening ability of the bread by preventing the breakdown and merging of gas cells formed by soy globulin during baking. Three types of albumin with different thermal denaturation temperatures were used: ovalbumin, bovine serum albumin, and lactalbumin. The effect of albumin addition on the quality of gluten-free rice flour bread made with soymilk also was determined.

2. Material and methods

2.1. Materials

Gluten-free bread was made using rice flour (powder rice type D; Niigata Seifun Co., Ltd., Niigata, Japan; Koshihikari cultivar; mean particle size, approximately 55 μm), organic soymilk (Marusan-AI Co., Ltd., Aichi, Japan; protein, fat, ash, and water contents were 4.6%, 2.8%, 0.5%, and 90.7%, respectively), granulated sugar (Fuji Nihon Seito Corporation, Tokyo, Japan), refined salt (Salt Industry Center of Japan, Tokyo, Japan), freeze-dried instant yeast (Nisshin Foods Inc., Tokyo, Japan), ovalbumin (OVA, Wako Pure Chemical Industries, Ltd., Osaka, Japan), bovine serum albumin (BSA, Nacalai Tesque, Inc., Kyoto, Japan), and bovine α-lactalbumin (BLA, LKT Laboratories, Inc., Minnesota, US). Other components included soybean (*Glycine max* L., Hukuyutaka cultivar) seeds and non-glutinous rice starch (Joetsu Starch Co. Ltd., Niigata, Japan).

2.2. Methods

2.2.1. Bread-making procedure

Gluten-free rice flour bread using was prepared in a muffin mold as described previously (Nozawa et al., 2014). Preparation of bread using a half-loaf mold was performed according to a modified muffin mold method. The batter ingredients were: 200 g rice flour (baker's percentage of 100%), 220 g soymilk or water (110%), 4 g sugar (2%), 2.5 g salt (1.25%), 2.5 g yeast (1.25%), and 1.25, 2.5, 5.0, or 10 g albumin (0.625%, 1.25%, 2.5%, or 5%, respectively). After adjusting the temperature of the ingredients to a batter temperature of 10 °C, the ingredients were placed in a bowl with ice water and mixed for 5 min with an electric mixer (THM 26M; Tescom Co. Ltd., Tokyo, Japan) at a mixing rate of 800 rpm. The resulting batter was poured in 300-g portions into a half-loaf mold made of aluminum (length, 95 mm; width, 95 mm; height, 95 mm) and yeast-fermented at 38 °C with 80% RH for 120 min in an incubator. After yeast fermentation, the batter was baked at 170 °C in a household electric oven (RE-WB30-S; Sharp Corporation, Tokyo, Japan) for 40 min. After baking, the bread was removed and cooled in an incubator at 20 °C and 60% RH for 2 h.

2.2.2. Rate of batter volume increase

A 50-g portion of batter was added to a graduated cylinder (200 mL) and yeast-fermented at 38 °C with 50% RH for 80 min. The rate of volume increase (%) of the batter was calculated using the formula: [volume after fermentation (mL)/volume before fermentation (mL)] × 100.

2.2.3. Specific loaf volume (SLV)

Bread using the half-loaf mold was weighed and the volume measured using a rapeseed displacement method. The SLV (cm^3/g) value and the ratio of the volume (cm^3) to the mass of the bread (g) also were calculated.

2.2.4. Thermal coagulation of soymilk foam with added albumin

Soymilk (220 g) with added OVA, BSA, or BLA (10 g, in the same ratio as for bread-making with 5% albumin) was mixed for 5 min with an electric mixer at a rate of 800 rpm to produce soymilk foam. The foam was added to a Pyrex glass cup (diameter, 75 mm; height, 57 mm; content, 150 mL), and heated at 170 °C in a household electric oven for 10 min. After heating, an image of the soymilk foam was obtained using a digital camera.

2.2.5. Differential scanning calorimetry (DSC) measurements

DSC measurements were obtained using an EXSTAR 6000 calorimeter (Seiko Instruments Inc., Chiba, Japan). Prior to the DSC measurements, 10 mg of protein (glycinin, OVA, BSA, or BLA) was placed in a silver cell (70 μL) and 30 μL of distilled water was added, while the reference cell contained 50 μL of distilled water. Glycinin was prepared from soybean seeds using a method described previously (Nozawa et al., 2014). After sealing, the sample was scanned at temperatures from 20 to 150 °C at a heating rate of 5 °C/min. The thermo compensation curves were evaluated using the software package provided with the equipment (Muse, Seiko Instruments Inc., Chiba, Japan) to calculate parameters, including peak temperature (PT) and enthalpy (ΔH).

2.2.6. Viscosity of gelatinized rice flour-soymilk slurry

The viscosity of a gelatinized rice flour-soymilk slurry was measured using a Rapid Vicso Analyzer (RVA-4, Newport Scientific, Inc., Warriewood, Australia). Rice flour (3.06 g) was transferred into a canister and water (24.94 g) or soymilk (27.49 g) was added. The amount of soymilk used was equal that of the amount of water added to the rice flour. Then, OVA, BSA, or BLA was added to the slurry in the proportions to rice flour of 0% (no additive), 0.625% (19 mg), 1.25% (38 mg), 2.5% (76 mg), and 5% (152 mg). The slurry obtained was held at 50 °C for 1 min, heated to 95 °C in 3.8 min, and then held at 95 °C for 2.5 min. The slurry then was cooled to 50 °C in 3.8 min and held at 50 °C for 1.4 min. The paddle rotation speed was 960 rpm for the first 10 s and then was reduced to 160 rpm throughout the remainder of the experiment. The peak viscosity was obtained from the Rapid Visco Analyzer (RVA) curve.

2.2.7. Fractionation of soy globulin from soybean seeds and preparation of soy globulin solution

Soybean seeds were powdered with a grinder mill (IFM-720G-W/Y; Iwatani Corporation, Tokyo, Japan) and then soaked in hexane at 20 °C for 3 h. The residue was filtered and air dried (defatted soybean powder). Glycinin and β-conglycinin were fractionated from the defatted soybean powder using the method described by Thanh and Shibasaki (1976). The glycinin fraction, which precipitated at pH 6.4, and the β-conglycinin fraction, which precipitated at pH 4.2, were mixed, suspended in 60 mM Tris–HCl buffer (pH 6.4), and adjusted to pH 7.8 with sodium hydroxide. The solutions were dialyzed against water at 4 °C for 48 h and freeze-dried using a lyophilizer. The soy globulin solution was prepared by dissolving the lyophilizates in water at a concentration equivalent to the protein content of soymilk (4.6 g/100 g). The composition of proteins in the glycinin and β-conglycinin fractions was confirmed by SDS-PAGE (Laemmli, 1970) using a 5–20% gradient acrylamide gel (E-T/R/D5201, ATTO Corp., Tokyo, Japan). Samples used for electrophoresis were prepared by dialysis of the precipitates of the glycinin and β-conglycinin fractions before they were combined,