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Development of gluten-free rice bread: Pickering stabilization as a possible batter-swelling mechanism

Hiroyuki Yano [a, *], Akiko Fukui [a], Keiko Kajiwara [a], Isao Kobayashi [a], Koh-ichi Yoza [a], Akiyoshi Satake [b], Masumi Villeneuve [b, **]

[a] Food Research Institute, National Agriculture and Food Research Organization, Tsukuba, Ibaraki 305-8642 Japan
[b] Graduate School of Integrated Arts and Sciences, Hiroshima University, Higashi-Hiroshima 739-8521 Japan

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A B S T R A C T

In this study we sought to develop gluten-free rice bread without using additives. Breads with high specific volume, comparative to wheat bread, around 4 cm^3/g, were obtained when rice flour with low starch damage (<5 g/100 g) was used as an ingredient. Microstructure analyses of the bubble wall in the fermenting batter revealed a "stone-wall" like structure resembling the microstructure of Pickering emulsion rather than that of typical wheat dough. Moreover, the surface tension of the dispersed solution of flour with low starch damage (4.7 g/100 g) was as low as 35 mN/m, while that of flour with high starch damage (9.8 g/100 g) was 47 mN/m. These data with the results of dynamic modulus measurements suggested a hypothetical mechanism in which Pickering stabilization facilitated swelling of the batter/bread. This paper proposes a possible example of Pickering foam/emulsion in food processing.

1. Introduction

Wheat gluten makes a proper network necessary to retain the carbon dioxide produced during fermentation. On the other hand, the wide prevalence of celiac disease (Green & Cellier, 2007) and wheat allergy (Mansueto, Seidita, D'Alcamo, & Carroccio, 2014) has led to a growing demand for gluten-free foods (Lamacchia, Camarca, Picascia, Di Luccia, & Gianfrani, 2014). Rice is considered a suitable substitute for wheat, as it is available worldwide and is less-allergenic. Thus several efforts have been made to produce gluten-free rice bread. Addition of gums (Demirkesen, Campanella, Sumnu, Sahin, & Hamaker, 2014) or hydroxypropyl methylcellulose (HPMC) (Rosell, Yokoyama, & Shoemaker, 2011) produces gluten-like macromolecular network, which improves the rheological properties of the rice batter and increases the volume of the bread. Alternatively, addition of glutathione to rice batter makes the batter/bread swell (Yano, 2010, 2012), and the mechanism is explained by the "barrier theory" (Hamaker & Griffin, 1993). However, further studies are needed to meet the quality expectations of the gluten-free consumers. Besides, some consumers prefer to avoid additives in foods (Devcich, Pedersen, & Petrie, 2007; Varela & Fiszman, 2013). Thus, in this study, we sought to develop gluten-free rice bread without using any additives.

Recently, stabilization of emulsion-based colloidal structures with mixed food ingredients has attracted attentions (Binks & Murakami, 2006; Dickinson, 2013). Solid particles protect emulsion droplets against coalescence by being adsorbed onto the interface between the two phases. The Pickering emulsion, first reported in the early 20th century (Pickering, 1907; Ramsden, 1903), has gained renewed attention as it has potential applications in the food, pharmaceutical as well as cosmetic industries. One of the advantages of the system for food applications is that microparticles of biological origin such as starch granules and cellulose particles work as stabilizers (Dickinson, 2016).

Here, collaboration between food and physico-chemical research groups proposes a hypothetical mechanism in which Pickering stabilization maintain bubble structure of the gluten-free rice batter in fermentation. To our knowledge, this paper describes for the first time a possible application of Pickering stabilization to produce gluten-free bread.

* Corresponding author.
** Corresponding author.
E-mail addresses: hyano@affrc.go.jp (H. Yano), mville@hiroshima-u.ac.jp (M. Villeneuve).

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2. Material and methods

2.1. Bread making

Eleven commercially-available rice flour products (#1–11) produced by different procedures were obtained from various milling companies in Japan. Briefly, flour #1–5 as well as #8 were produced by wet jet-milling of rice grains. Flour #6, 7 and 10 were by dry roll-milling. Flour #9 and #11 were made by dry jet-milling and wet stamp-milling, respectively. The average composition of rice flour #5 was 80.5 g/100 g (80.0–80.9 g/100 g) starch, 6.2 g/100 g (5.7–6.7 g/100 g) protein, 1.0 g/100 g (0.9–1.1 g/100 g) lipid and 0.2 g/100 g (0.2 g/100 g) ash. The composition of flour #7 was 80.6 g/100 g starch, 5.9 g/100 g protein, 1.2 g/100 g lipid and 0.3 g/100 g ash.

Rice batter was prepared using a bread maker SD-BH105 (Panasonic Corporation, Osaka, Japan). In summary, 160 g of rice flour and 140 g of water were mixed by kneading paddles at 160 rpm for 20 min in a bread bin of the bread maker. Then, 15 g of sugar, 5 g of baker's yeast (Nisshin Flour Milling Inc., Tokyo, Japan), 2 g of butter and 1.6 g of salt were added and the batter was mixed again for 20 min. Then, 175 g of the batter was transferred to a square pan case with an 800 mL capacity. Subsequent fermentation (40 °C for about 30 min) and baking (180 °C for 24 min) were done using an EMO-C16C electric oven (Sanyo Electric, Osaka, Japan) by following the supplier's recommendations.

2.2. Determination of bread characteristics

The volume was determined by a 3D laser scanner VM130 (ASTEX, Tokyo, Japan) according to the instruction manual. The weight was measured on a balance. The specific volume was deduced from the ratio. Final moisture of the bread was calculated by drying the pre-weighed bread slice in an oven maintained at 110 °C until constant weight was obtained. The measurements on the loaves were done at least 3 h after baking.

2.3. Damaged starch extent

Damaged starch in flour samples was determined by a spectrophotometric method (AACC Method 76-31) using damage starch assay kit (Megazyme Ltd., Bray, Ireland) following the instruction manual.

2.4. Microstructure analysis of rice bread

A sample of batter in the beginning of fermentation was placed between a microscope slide and a cover slip. After fermentation at room temperature for 30 min, the specimen was observed under a microscope (CKX41, Olympus Corporation, Tokyo, Japan).

Alternatively, a sample of batter in fermentation or baked bread was frozen in liquid nitrogen and the frozen samples were vacuum dried at −20 °C. After drying, the samples were coated with a thin layer (30 nm) of osmium by using an osmium plasma coater (NL-OPC80NS, Nippon Laser & Electronics Laboratory, Nagoya, Japan). The samples were observed by a scanning electron microscope (JSM-6340F, JEOL Ltd., Tokyo, Japan) at an acceleration voltage of 5.0 kV in the secondary electron image (SEI) mode or lower secondary electron image (LEI) mode.

2.5. Preparation of emulsions

A certain mass of rice flour #5 was initially dispersed in 3 mL of water, followed by adding 3 mL of tetradecane. Then the mixture was homogenized at 10,000 rpm for 1 min using a homogenizer

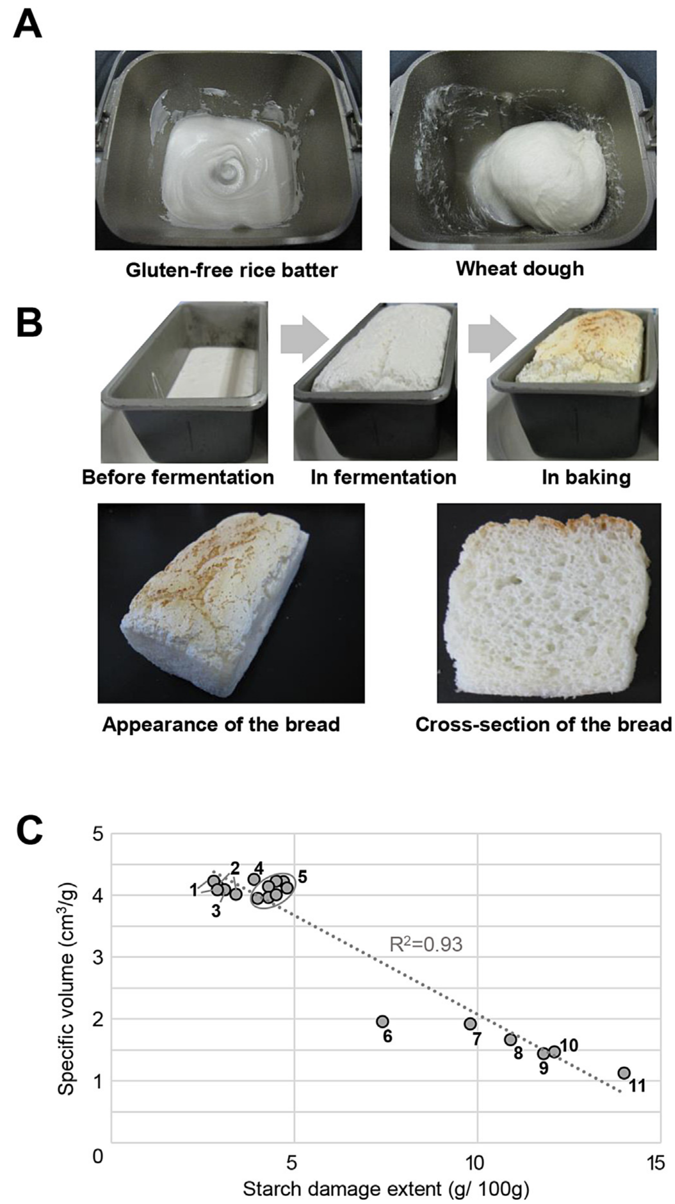

Fig. 1. Comparative photos of gluten-free rice batter (left) and wheat dough (right) (A). Making process of the gluten-free rice bread (B). Specific volume of breads against the starch damage extent of the flour (C).

(Physcotron, Microtec Co., Ltd., Chiba, Japan).

2.6. Surface tension measurements

Surface tension of dispersion of rice flour was measured at 298.15 ± 0.02 K by the pendant drop method with a home-built apparatus. Images of droplets were captured by a CCD camera XC-ST30 (Sony Corporation, Tokyo, Japan) mounted with a macro lens MACRO 50 mm F2.8 EXDG (Sigma Corporation, Tokyo, Japan) through a capture board MTPCI-DMA (MicroTechnica Co., Ltd., Tokyo, Japan). Precise magnification power was estimated by using an image of a reference scale. The drop shape was analyzed using a personal computer Pentium4-2.80C GHz (Intel Corporation, Santa Clara, USA). The shape analysis method based on the modified