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Relationship between Rice Flour Particle Sizes and Expansion Ratio of Pure Rice Bread

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Abstract: We examined a method to produce bread from crystalline rice flour without using thickening agents such as gluten, polysaccharide thickening, and amorphous rice flour. Rice grains were pulverized by a jet mill to produce flour. Samples of rice flours of various particle size distributions were prepared by using a size shifter. The degree of starch damage and the dynamic viscoelasticity of rice batter were measured in this work. We also baked bread of the flour of each size distribution to study processability for making bread. The batter made by the pulverized flour of rice particle size ranging from 75 to 106 µm had the highest expansion ratio and a good processability for baking breads compared to other particle size batteries. The rice bread with high expansion ratio was produced by controlling particle size of crystalline rice flour without using thickening agents.

Key words: rice bread, starch damage degree, expansion ratio, dynamic viscoelasticity

INTRODUCTION

Various processed foods such as bread, noodle, cake, and so on, are produced from wheat flour. However, those who are allergic to wheat can not eat these common foods. Developments of methods to make these foods without using wheat flour are important issues for them.1,2 In the present paper we focus on how to make bread without using wheat flour.

The wheat is important for viscoelastic properties of bread batter. Kneading of wheat batter generates molecular cross-links of gluten which maintains a batter structure containing large voids. High viscoelasticity caused by gluten cross-links prevents the large voids from breaking. Quality of wheat bread depends on existence of gluten.

Rice bread that does not contain gluten needs alternative agents to fix viscoelasticity. Therefore, rice breads so far include modified starches,3 polysaccharide thickening,4,5 and so on,7 as thickening agents. Recently, we succeeded in producing pure rice bread by adding amorphous rice flour.6,8 We also reported on an instance method to produce amorphous rice flour from rice grains by applying heat and shear simultaneously.9

The amorphous rice flour was a thickening agent for the pure rice bread in this case. In the present paper, we examine possibility of making pure rice bread without using amorphous rice flour. We show that it is possible by adjusting particle size distribution. We studied effect of rice flour of different particle size on viscoelasticity and expansion ratio of rice batter. A jet mill type pulverizer was used in this study to produce crystalline rice flour. We also studied about relationship between particle size and starch damage degree of rice flour.

MATERIALS AND METHODS

Rice flour samples. We produced rice flour by a jet mill type pulverizer (M5-500; Micropowtec Co., Ltd., Fukui, Japan) from raw rice of cultivar Haenuki harvested in Yamagata, Japan in 2011. Obtained rice flour was separated to 4 different particle size samples 150–106, 106–75, 75–45, and < 45 µm using the electric-magnetic sifter (AS200; Retsch Co., Ltd., Haan, Germany). Sample notation 150–106 µm indicates that particle sizes range from 106 to 150 µm, and < 45 µm indicates that particle sizes are smaller than 45 µm.

Measurements for characterizations of rice flour samples.

Wide angle X-ray diffraction (WAXD) analysis for degree of crystallinity on rice flour samples were performed using Cu-Kα radiation source of 0.154 nm wave length (Rint-Rapid; Rigaku Co., Ltd., Tokyo, Japan). A x-ray tube bulb was operated at tube voltage 40 kV and tube current 30 mA. The rice flour samples were scanned at room temperature. Analysis data were obtained by scanning from 5° to 35° at a rate of 1.5°/min. Peaks at 15°, 17°, 18°, and 23° were decomposed by using the peak fit program (PeakFit v4.12 software; SeaSolve Software Inc., Framingham, USA). Degrees of crystallinity were caluculated from fraction of areas of these peaks.

Differential scanning calorimetry (DSC) measurements for degree of gelatinization on rice flour samples were performed (DSC Q-2000; TA Instruments Japan Inc., Tokyo, Japan). The rice flour samples were put into sample pans (High Volume Sample Pans, Lids, and Seals; TA Instruments Japan Inc., Tokyo, Japan). Deionized water was added into...
the pans. Weight ratio of rice flour to water was 1 to 3. Rice flour sample amounting 10 mg and deionized water 30 mg were put into the pan. The samples were heated in temperature range 35–95 °C with a heating rate 5 °C/min using 30 mg water in a pan as reference.

A milling process usually damages starch granules. Damage on starch affects water absorption, gelatinization properties, and viscoelasticity of batter samples. The starch damage degree of rice flour samples were measured using an evaluation kit11) (Starch Damage Assay Kit; Megazyme International Ireland Co., Ltd., Wicklow, Ireland). The evaluation is based on coloration of glucose generated by enzymolysis of damaged starch. A spectrometer (V-630 BIO; Jasco Co., Ltd., Tokyo, Japan) was used to measure absorption of light at wave length 510 nm.

Modal diameters of rice flours after the size selection were obtained by measuring particle size distributions. The measurements of particle size distributions were made by a laser diffractometer (Mastersizer 2000; Malvern Instruments Ltd., Worcestershire, UK)

Mixing, fermentation, baking, and evaluation methods for breadmaking. We mixed 180 g rice flour of each particle size with 180 g water, 18 g sugar, and 2.7 g dry yeast by a mixer (Kitchen Aid KSM90WW; FMI Co., Ltd., Tokyo, Japan) to obtain rice batter sample. We assumed that generation of gas from yeast for this composition did not depend on type of rice flour. Mixing speed of the mixer can be selected from one of eight divisions. After 2 min of low speed mixing at division 2, 20 min high speed mixing at division 8 was performed. The rice batter was fermented using an electronic fermentation machine (SK-15; Taisho Electric Co., Ltd., Kusatsu, Japan) at 40 °C for 30 min. The fermented batter was baked in an oven at 180 °C for 30 min. Evaluation of baked bread was made by measuring expansion ratio. Average of expansion ratios of three points including the center of a sample was calculated. The expansion ratio was defined by the following equation:

Expansion ratio (%) = 100 × (height of baked bread) / (height of fermented batter before baking).

Dynamic viscoelasticity measurement. The dynamic viscoelasticity of batter samples (rice flour/water, 50/50 wt%) were measured using a rheometer (Physica MCR301; Anton Paar Co., Ltd., Graz, Austria) from 35 to 90 °C (rising rate 2.6 °C/min) for 0 = 10 rad/s with strain 0.01 %. Rice flour of each particle size was mixed with water by the mixer to obtain rice batter sample for dynamic viscoelasticity measurement. After 2 min of low speed mixing at division 2, 20 min high speed mixing at division 8 was performed.

RESULTS AND DISCUSSION

Degrees of crystallinity of starch.

Figure 1 shows WAXD measurement results of rice flour samples. From these results, crystalline peak of starch appeared in 15°, 17°, 18°, and 23° on all samples. Degrees of crystallinity on rice flour samples were about 30 % except for rice flour of < 45 μm. Degrees of crystallinity on rice flour of < 45 μm was about 24 %.

Degrees of starch damage.

Figure 2 shows the relationship between modal diameter and degrees of starch damage. Degree of starch damage increased with decreasing modal diameter. We consider that degree of starch damage increases as a function of surface area of starch granules in the system. The solid line of Fig. 2 shows a line of slope -1 which expresses proportionality to surface area. The results show that degree of starch damage for small size particles deviates from the line to a smaller value.

Degrees of gelatinization of starch.

Table 1 shows result of DSC measurement for rice flour samples. From these results, values of peak temperature (Tp) were about the same for all samples. On the other hand, enthalpies (ΔH) of rice flour samples were gradually decreased with decreasing particle size of rice flour samples.
Figure 3 shows the relationship between modal diameters and degrees of starch gelatinization. Enthalpies ($\Delta H$) of rice flour samples were gradually decreased with decreasing modal diameter. Standard deviations of the enthalpy $\Delta H$ and the degree of starch damage divided by their averages are

$$\sqrt{\frac{<\Delta H^2> - <\Delta H>^2}{<\Delta H>}} = 0.14$$  

(1)

$$\sqrt{\frac{<d^2> - <d>^2}{<d>}} = 0.30$$  

(2)

where $<X>$ indicates average of $X$, and $d$ is degree of starch damage. Equations (1) and (2) show that dependence of the degree of starch damage on modal diameter is stronger than that of the degree of gelatinization.

**Average Expansion ratio of baked breads.**

Five photographs of Fig. 4 shows cross sections of baked breads made from flours of different particle size classifications. The void size and processability of bread depended on particle size of flour. Rice bread of particle size 150–106 $\mu$m contained comparatively small voids and its top was dent. The breads of flours 75–45 $\mu$m and < 45 $\mu$m did not keep voids. The processability and void forming property was the best for the flour of particle size 106–75 $\mu$m. The bread made from it contained small and large round voids showing wide range of void size distribution.

Figure 5 shows expansion ratios of baked breads for particle size classifications. The expansion ratios of baked breads made by rice flours of non-classification, 150–106, 106–75, 75–45, and < 45 $\mu$m were, respectively, 216, 233, 269, 177, and 131%.

Addition of thickening agents such as polysaccharide thickening and amorphous rice flour enables bread making from rice batter. Our present results indicate that the batter made by the jet-milled flours 106–75 $\mu$m had the best processability for baking breads among present samples. Bread making is possible by using this crystalline rice flour without amorphous rice flour.

**Dynamic viscoelasticity measurement.**

To examine processability of batter samples, we measured the dynamic viscoelasticity of batters (rice flour/water, 50/50 wt%) at temperature region (35–90°C). Figure 6 shows the temperature dependence of the storage modulus $G'$ for the batters of various size classifications. The storage modulus $G'$ of the batters of rice flour 75–45 $\mu$m and < 45 $\mu$m were larger than those of other batters at fermenting temperature region 35–45°C. Larger value of $G'$ means harder batters. We consider that hardness of batters of rice flour 75–45 $\mu$m and < 45 $\mu$m prevented formation of large voids under fermenting conditions. Batters of rice flour 150–106 $\mu$m and
106–75 µm had suitable soft G′ for void formation under fermenting conditions. Increase of the storage modulus G′ from 45 to 70 °C was caused by starch gelatinization. The G′ value of batter of the flour 106–75 µm was larger than that of the batter of the flour 150–106 µm at baking temperature region 45–90 °C. The G′ value of the batter of the flour 106–75 µm increased from 40 °C, while that of the batter of the flour 150–106 µm increased from 60 °C. We consider that hardness of the batter of the flour 106–75 µm kept void cells from rupture in temperature region 40–60 °C with larger value of G′. These results show that we can adjust G′ of the batter of jet-milled flour by size classification.

Figure 2 shows that starch damage is higher for flour of smaller particle size. We expect that starch damage increases absorption of water in starch granules. Water content in starch granules moves the onset of the gelatinization to low temperature region. Swelling of small particles of high water absorption increases hardness of the batter. Water absorption in batter is also affected by total area of particle surfaces which depend on particle size distribution. These effects together cause size classification dependence of G′ in Fig. 6. Batter of smaller size classification indicated larger value of G′ in the fermentation process and lower onset temperature of gelatinization.

CONCLUSIONS

The following new findings for rice batter were obtained in the present study:

I) The degree of starch damage increased with decreasing the modal diameter of the rice flours produced by a jet mill type pulverizer.

II) The batter made by the pulverized flour (106–75 µm) had the highest expansion ratio of void and a good processability for baking breads compared to other particle size batters.

III) Particle size of crystalline rice flour affected value of G′ in the fermentation process and gelatinization behavior in the baking process.

With these new findings we conclude that the rice bread with high expansion ratio is realized by only controlling particle size of crystalline rice flour without using amorphous rice flour.

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REFERENCES

1) S. Yalcin and A. Basman: Effects of gelatinisation level, gum and transglutaminase on the quality characteristics of rice noodle. Int. J. Food Sci. Technol., 43, 1637–1644 (2008).

2) E. Turabi, G. Sumnu, and S. Sahin: Optimization of baking of rice cakes in infrared-microwave combination oven by response surface methodology. Food Bioprocess Technol., 1, 64–73 (2008).

3) M. Miyazaki, P.V. Hung, T. Maeda, and N. Morita: Recent advances in application of modified starches for breadmaking. Trends Food Sci. Technol., 17, 591–599 (2006).

4) F. Ronda, S. Perez-Quire, A. Lazaridou, and C.G. Biliaderis: Effect of barley and oat β-glucan concentrates on gluten-free rice-based doughs and bread characteristics. Food Hydrocoll., 48, 197–207 (2015).

5) M. Witzak, J. Korus, R. Ziebro, and L. Juszcak: The effects of maltodextrins on gluten-free dough and quality of bread. J. Food Eng., 96, 258–265 (2010).

6) G. Lorentz, N.E. Zaritzky, and A.N. Califano: Rheological characterization of refrigerated and frozen non-fermented gluten-free dough: Effect of hydrocolloids and lipid phase. J. Cereal Sci., 50, 253–261 (2009).

7) H.P. Sivaramakrishnan, B. Senge, and P.K. Chattopadhyay: Rheological properties of rice dough for making rice bread. J. Eng., 62, 37–45 (2004).

8) A. Nishioka and R. Ikeda: Produce method of rice bread, JP Patent 2011–188852 (2011).

9) S. Murakami, A. Ota, T. Nishio, K. Miyata, T. Koda, and A. Nishioka: Effect of strain hardening property on baking productivity of rice batter. J. Soc. Rheol. Jpn. (in press).

10) K. Katsuno, A. Nishioka, T. Koda, K. Miyata, G. Murasawa, Y. Nakaura, and N. Inouchi: Novel method for producing amorphous rice flours by milling without adding water. Starch/Stärke, 62, 475–479 (2010).

11) T.S. Gibson, C.J. Kaldor, and B.V. McCleary: Collaborative evaluation of an enzymatic starch damage assay kit and comparison with other methods. Cereal Chem., 70, 47–51 (1993).