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Effects of Soaking and Particle Sizes on the Properties of Rice Flour and Gluten-free Rice Bread

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Abstract To investigate the effect of soaking and particle sizes on the properties of rice flour and gluten–free rice bread, wet-milled (WRF, dried at 20°C) and dry-milled rice flours (DRF) were passed through sieves (45 or 100 mesh). Soaking of the rice grains affected the particle size distribution of flour passed through the same size screen. The L and b values of WRF were higher than those of DRF and were not changed with decreasing particle sizes, but DRF increased L and decreased b values. The initial pasting temperatures and setback viscosities of both flours decreased with decreasing particle sizes. The swelling powers at 100°C increased with decreasing particle sizes in DRF, but maintained in WRF. Starch granules were observed on the surface of flour particles in WRF. The apparent viscosity of WRF paste exhibited 3-5 times higher than that of DRF. Thus, wet milled rice flour with smaller particle sizes (ϕ<150 μm) showed better properties for making gluten-free rice bread.

Keywords: rice flour, soaking, particle size, property, gluten-free rice bread

Introduction

Rice is a very important worldwide crop, and is used as a staple food, in both grain and flour forms. Rice flour is consumed principally in Asia, and has been used in the preparation of a variety of traditional oriental foods, including rice cakes, rice noodles, rice cookies, and others. Rice flour is also increasingly utilized in developed countries, as well as countries in Asia, and therefore, the market for rice flour is growing (1).

Three methods, dry-, wet-, and semi-dry-milling, have been used to grind milled rice kernels into flours. In general, wet-milled rice flour (WRF) is better than dry-milled rice flour (DRF) with regard to the preparation of rice products (1, 2), but the reason for it is not well known. The particle size distribution and damaged starch content in flour are two key factors that affect the physical properties and applications of rice flour (3-6). Some scientists have studied to make rice bread using rice flour with different milling methods (7-10). Bean *et al.* (7) reported a noticeable improvement in bread texture when they substituted WRF for DRF in 100% rice bread. Soaking constitutes an essential step in wet milling, and both soaking temperature and time have affected the properties of rice flour, such as particle sizes and starch damage (8). Dry rice flour is needed to make bread, because the recipe for it requires dry flour instead of wet flour. However, WRF has a high degree of water content and is difficult to handle and supply to the market or stores. To make dry rice flour commercially, the soaked rice grain is milled by the roller mill and wet flour is dried using hot air commonly (1, 11). WRF dried at room temperature after wet-milling of soaked rice kernel showed the similar processing properties of wet flour.

Recently, the studies on the gluten-free bread have been reported that it can be used for sufferers of coeliac disease that is inflammation of the small intestine leading to the malabsorption (11-13). Rice might provide a good basis for gluten-free bread, because rice has properties such as the absence of gluten, low levels of sodium, protein, and fat (10).

Therefore, the objectives of this study were to investigate the effects of soaking and particle sizes on the properties of rice flour and the possibility for making gluten-free bread by using rice flour.

Materials and Methods

Materials 'Ilmibyeo', non-waxy milled rice, was purchased from Jeonnam Agricultural Research and Extension Services in 2003.

Preparation of rice flours Two types of milled rice flours were prepared from dry grain and wet grain, which were soaked for 12 hr at room temperature. The milling of rice grain was done using a food mixer (HR2835; Philips, Mexico City, Mexico) with a stainless steel blade. Wet-milled rice flour (WRF) was dried for 3 days in the cold room at 15±3°C. Rice flour samples were then passed through 45 and 100 mesh screens, respectively, to obtain rice flour with different particle sizes using ASTM sieves, such as <355 or <150 μm, then stored in a -20°C freezer until used for further analyses.

Determination of physicochemical properties Moisture (method 44-15A), protein (method 46-11A), ash (method 08-01), and crude lipid (method 30-10) contents were measured by AACC methods (14). The amylose content of rice flour was measured by the method of Song *et al.* (15). To obtain the standard curve for determination of amylose content, the rice starch was separated into amylose and amylopectin using the method of Montgomery and Senti (16). A mixture of certain ratios for isolated amylose and amylopectin was used for

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measuring of amylose content by the method of Williams *et al.* (17). The color values of the flour samples were assessed using a Chroma meter (CR-300 series; Minolta, Tokyo, Japan) and the Hunter L (lightness), +a (redness), and +b (yellowness) values were measured. The L, a, and b values of standard white plate used were 96.90, 0.21, and 2.21, respectively. Water binding capacity was determined by Medcalf and Gilles' method (18). Swelling power and solubility were determined at 100°C (15).

Scanning electron microscopy In order to observe the shape and size of the rice flour particles, a scanning electron microscope (SEM) was used. Scanning electron microphotographs were obtained using a Joel, JSM-5400 (Tokyo, Japan) microscope, at an accelerating potential of 20 kV at 50 and 1,000× magnification. The flour samples were attached to an SEM stub, using double-sided cellophane tape. The stub and sample were then coated with gold-palladium, examined, and photographed.

Measurement of particle size distribution The particle size distribution of DRF and WRF passed through different size screens was measured using an LS particle size analyzer (model LS 100Q; Beckman Coulter, Inc., Fullerton, CA, USA). The rice flour was dispersed in ethanol and measured at room temperature.

Rapid Visco-Analyzer The pasting behaviors of rice flours were investigated with a Rapid Visco-Analyzer (RVA, model 3D; Newport Scientific Pty., Ltd., Narranbeen, Australia) according to the AACC standard method (19). Rice flour (4 g, on 14% moisture basis) was transferred into distilled water (25 mL) in the canister and then mixed thoroughly. The temperature was maintained at 50°C for 2 min and then raised to 95°C for 6 min. The sample was maintained at 95°C for 2 min, cooled to 50°C for 6 min, and maintained at 50°C for 2 min. A plot of paste viscosity in arbitrary RVA units (RVU) versus time was then used to determine the initial pasting temperature, peak viscosity (P), trough viscosity (T), final viscosity (F), breakdown viscosity (P-T), and setback viscosity (F-T).

Flour paste viscosity by Brookfield viscometer The changes in the viscosity of the rice flour paste were measured with a Brookfield viscometer (Brookfield Engineering Lab. Inc., Stoughton, MA, USA) (15). The rice flour (2.0 g, d.b.), distilled water (30 mL), and a magnetic bar (ϕ 3.2×13 mm) were placed into a 50 mL centrifuge tube with a screw cap. These tubes were then heated in a boiling water bath for 10 min with stirring. The flour paste was then poured immediately into vials (ϕ 2×4 cm) without air, and maintained for 1 min with its apparent viscosity being measured every 1 min for 20 min. An LV No. 4 spindle was used at 12 rpm.

Making gluten-free rice bread DRF and WRF passed through 100 mesh sieve were prepared for making rice bread using transglutaminase (20). It was hard to prepare batter for rice bread with coarse particle rice flours (above 355 μm). The ingredients for the gluten-free rice bread were, rice flour (100 g), yeast (Jenico Foods Co., Jeonbuk Korea) (3 g), sugar (7.5 g), skim milk powder (10 g), butter (6 g), salt (2 g), transglutaminase (TGase, ACTIVA-TG, STG-M from *Streptoverticillium* sp., Ajinomoto Co., Inc., Tokyo, Japan) (0.01 g), and water (110 g). Rice flour mixture was prepared by mixing and sifting 5 times using rice flour, TGase, sugar, salt, and skim milk powder. It was mixed by Hobart mixer (2nd speed for 15 sec and 3rd speed for 10 sec). Yeast dispersion (in 110 g water) was added into bowl in flour mixture and mixed well at the same speed and time. The first and second proofing was carried out for 30 and 45 min, respectively at 35°C and RH 75%. Baking was done in an oven (Turbofan Back Bar Co., New Zealand) at 175°C top and bottom heat for 25 min. After baking the loaf was depanned and cooled on a cooling rack at room temperature for 4 hr.

Statistical analysis All the samples were analyzed at least in duplicate, unless otherwise indicated, and the mean values and standard deviations were reported. Statistical analyses were conducted via Duncan multiple range test using the SAS software package (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Compositional analysis and physicochemical properties of rice flours The moisture, protein, ash, and crude lipid contents of DRF and WRF were 12.21±1.10 and 12.11±0.87%, 7.47±0.31 and 6.76±0.37%, 0.71±0.01 and 0.31±

Table 1. Apparent amylose content and physical properties of dry- and wet-milled rice flours with different particle sizes

Maximum particle size	Water binding capacity (%)	Apparent amylose content (%)	Swelling power at 100°C	Solubility (%) at 100°C
DRF[1]				
<355 μm	290±10$^{b2)}$	16.04±0.55^{b}	19.46±1.66^{b}	18.55±1.51^{c}
<150 μm	348±39^{a}	16.53±0.01^{b}	20.72±1.41^{a}	25.43±1.65^{a}
WRF[1]				
<355 μm	349±14^{a}	17.65±0.08^{a}	21.73±1.29^{a}	25.07±0.70^{ab}
<150 μm	343±7^{a}	17.72±0.08^{a}	21.48±2.12^{a}	26.13±0.50^{a}

1)DRF and WRF mean dry- and wet-milled rice flours, respectively, and DRF and WRF used for determining all properties were based on dry basis.
2)Means within a column with different superscripts are significantly different at $p<0.05$ by Duncan's multiple range test.

0.02%, 1.04±0.01 and 1.02±0.02%, respectively. Protein and ash contents of DRF were higher than those of WRF, because protein and ash were leached out from rice grain during soaking (1). Table 1 shows apparent amylose content and physical properties of rice flours with different particle sizes. The amylose content of the DRF was lower than that of WRF. During the process of alkali gelatinization of starch to determine apparent amylose content, it was hard for alkali solution to penetrate into inside of DRF particles and to react with iodine solution. WRF prepared from wet grain might separate starch granules from cell wall material and absorbed alkaline solution rapidly. Soaking, milling, and passing through screens could help to easily detach starch granules from flour particles. These trends revealed the difference of apparent amylose contents between them. Soaking before milling of rice grain was an important factor to penetrate water into flour particle and helped to gelatinize starch granules in flour particles. Water binding capacity of DRF was lower than that of WRF. The swelling power and solubility of DRF and WRF at 100°C were 19.5-20.7 and 21.5-21.7, 18.6-25.4 and 25.1-26.1%, respectively. The swelling power and solubility of WRF remained similar, regardless of particle sizes, but those of DRF decreased along with increasing particle sizes. Water binding capacity and swelling power contributed to the increasing consistency of batter.

The color values of DRF and WRF with different particle sizes are shown in Table 2. The lightness L values of DRF increased with decreasing particle sizes, and the yellowness +b evidenced an opposite trend. The color of WRF was judged to have a higher L value and a lower b value, regardless of particle sizes, and WRF (95.4-95.9) was consistently whiter than DRF (92.7-94.6). Yoon and Kim (21) reported that whiteness and lightness of milled rice were negatively correlated with protein, fat, and ash contents. The fact that lightness was higher in WRF than DRF had to do with that the former had lower protein, lipid, and ash contents than the latter. Color measurement revealed that the finer the flour was, the brighter and whiter its color became. Kum *et al.* (22) also reported that L values increased and b values decreased as particles became finer.

Table 2. Hunter color values of dry- and wet-milled rice flours with different particle sizes

Maximum particle size	Hunter color values		
	L (Lightness)	±a (Redness/ greenness)	±b (Yellowness/ blueness)
DRF			
<355 μm	92.68±0.94^{c}[2)]	-1.01±0.02^{b}	5.10±0.02^{a}
<150 μm	94.66±0.14^{b}	-1.04±0.02^{c}	3.80±0.00^{b}
WRF			
<355 μm	95.44±0.05^{ab}	-0.93±0.01^{a}	3.23±0.01^{c}
<150 μm	95.89±0.03^{a}	-0.93±0.02^{a}	2.87±0.02^{d}

[1)] DRF and WRF mean dry- and wet-milled rice flours, respectively.
[2)] Means within columns with different superscripts are significantly different at $p<0.05$.

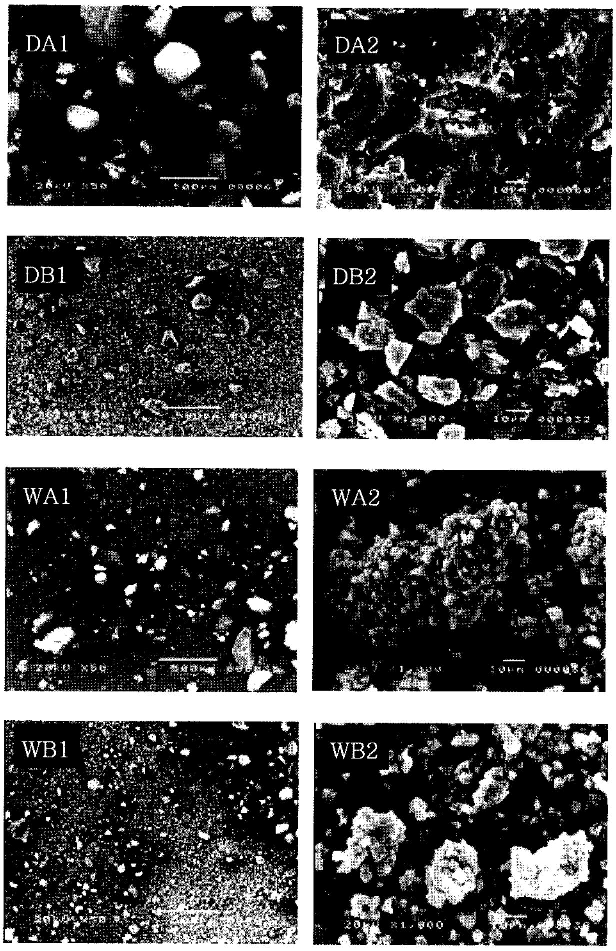

Fig. 1. Scanning electron microphotographs of dry-milled (D) and wet-milled (W) rice flours with different particle size and magnification. Particle sizes of flours were <355 μm (A), and <150 μm (B), and magnification were 50× (1) and 1,000× (2), respectively.

Shape by using SEM The shape of DRF and WRF particles was observed via SEM. These photographs are shown in Fig. 1. DRF showed some lumps and coarse flour with smooth surface of particles and did not display starch granules on the surface of cell wall material. But starch granules were observed on the surface of WRF particles and the granular shape was shown obviously. Some starch granules separated from flour particles were also observed on DRF with smaller particles (<150 μm) compared to DRF with coarse particles (Fig. 1, DB2). The separation of protein body and cellular materials from starch granules in cells affected the structure and properties of flour particles. Such protein-starch and fiber-starch interactions would be weakened due to the loss of the protein bodies during soaking or milling with fine particles (1). Those starch granules might be separated from cells not only during the milling process but also during the sifting process.

Particle size distribution The particle size distribution patterns of DRF and WRF are shown in Fig. 2. As the standard sieve number increased, the fraction of small size

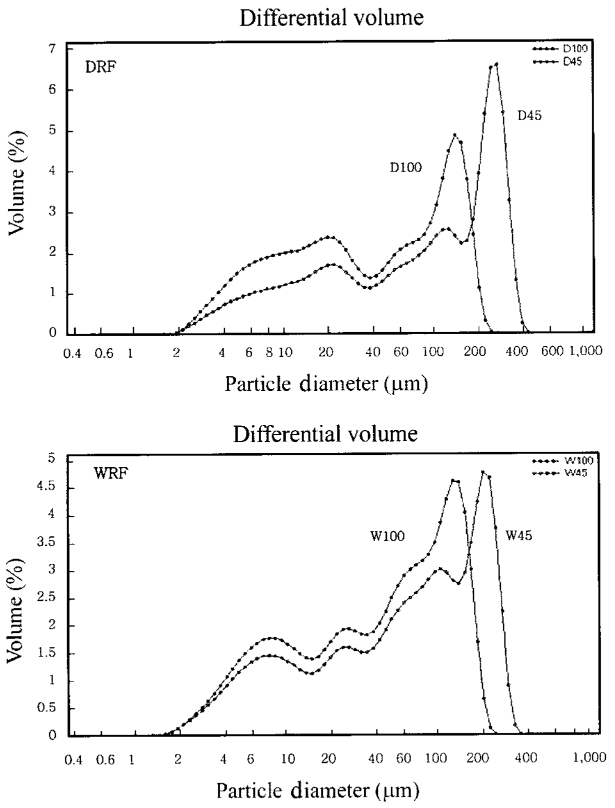

Fig. 2. Particle size distribution patterns of dry- (D) and wet- (W) milled rice flours with different particle sizes. Particle size of flours were <355 µm (D45, W45), and <150 µm (D100, W 100), respectively.

particles (<80 µm) increased. WRF passed through 45 or 100 mesh screen showed similar patterns, especially binominal distribution under 40 µm of particle sizes. Their volume percent ratios were 22.0 and 27.4% in 2-15 µm fraction, 13.7 and 17.8% in 15-37 µm fraction. However, DRF was broadly distributed under 40 µm particles. In DRF, the percent ratios in 3-37 µm fraction were similar to those of flour with <150 µm, but lower in flour with <335 µm. In the case of the same particle sized flours, WRF showed a higher volume percent ratio of 37-80 µm fraction than DRF.

Chiang and Yeh (1) reported that during soaking, the more water was diffused into the rice kernel, the softer the kernel became and the smaller particles became. The sizes of rice starch granules usually ranged between 1.6 and 8.7 µm (23), and therefore the fraction, ranged from 2 to 10 µm in the particle size distribution was considered as isolated starch granules in the flour. The ratio and pattern of smaller particles (2-37 µm fractions) of small sized DRF and WRF showed almost similar patterns and the physicochemical properties of their flours, such as water binding capacity, swelling power, solubility, and lightness, exhibited the same trends.

Pasting properties by RVA Pasting properties for DRF and WRF measured by RVA are shown in Table 3. The initial gelatinization temperatures of DRF and WRF were 68.6-71.1 and 62.4-65.3°C, respectively, and DRF had higher initial gelatinization temperatures than WRF. Soaking conditions and particle sizes affected all parameters, and initial gelatinization temperatures were determined to decrease with decreasing particle sizes. Chen *et al.* (2) reported the same results as ours; namely, that the initial gelatinization temperature decreased along with decreasing particle sizes. The peak viscosity, breakdown, and setback viscosity trends associated with WRF were opposite to those observed in conjunction with DRF, and those of WRF decreased with increasing particle sizes. Lee and Kim (24) reported that the initial gelatinization temperature of non-waxy rice flour decreased and peak viscosity increased, along with decreasing particle sizes. Kum and Lee (25) reported similar results of amylograms in which the initial pasting temperature was observed to decrease, and the peak viscosity was observed to increase, with decreasing particle sizes in the rice flour. The same results were found in a study conducted by Marshall (26). The initial pasting and peak temperature and enthalpy decreased along with decreasing particle sizes when DSC was used. This result was similar to that observed with DRF, but was different from that observed with WRF. Kum *et al.* (22) reported that as particles became finer, initial pasting temperatures tend to decrease and the peak viscosity tends to be reduced. Hamaker and Griffin (27) reported that proteins with disulfide bonds in the rice flour restrict the swelling of starch granules during gelatinization, and render the swollen granules less susceptible to disruption by shearing.

Table 3. Pasting properties of dry- and wet-milled rice flours with different particle sizes by Rapid Visco-Analyzer

Maximum particle size	Initial pasting temperature (°C)	Viscosity (RVU)				
		Peak (P)	Trough (T)	Final (F)	Breakdown (P-T)	Setback (F-T)
DRF[1]						
<355 µm	71.1	530.3	238.8	385.5	291.5	146.7
<150 µm	68.6	517.5	246.2	382.8	271.3	136.6
WRF[1]						
<355 µm	65.3	430.3	200.0	327.2	230.3	127.2
<150 µm	62.4	317.9	160.8	259.4	157.1	98.6

[1] DRF and WRF mean dry- and wet-milled rice flours, respectively.

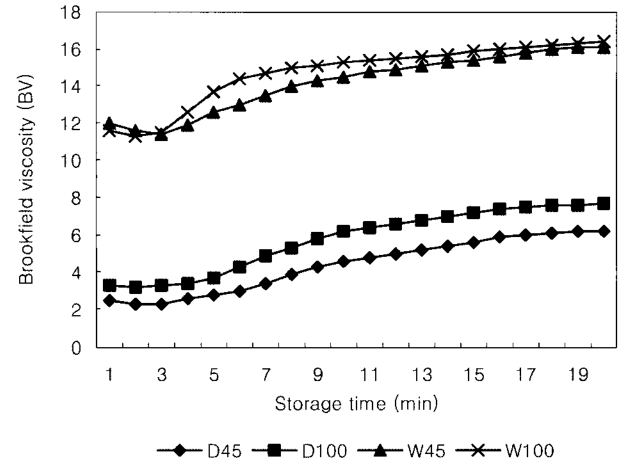

Fig. 3. Changes of apparent viscosity of rice flour pastes using Brookfield viscometer. D and W means dry- and wet-milled rice flours with different particle sizes (passed through 45 and 100 mesh screen, respectively).

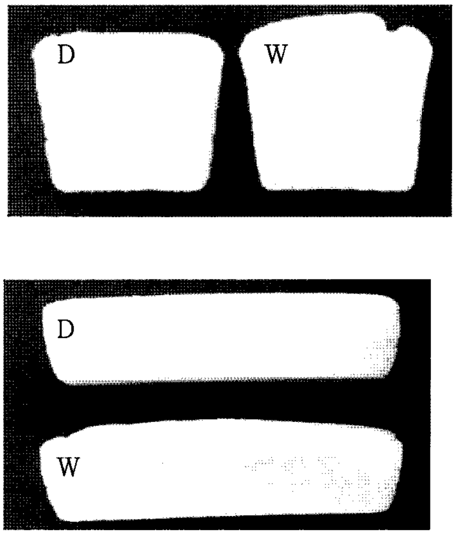

Fig. 4. Whole and cross section of gluten-free rice bread prepared from dry-milled (D) and wet-milled (W) rice flours passed through 100 mesh screen.

Paste viscosity by Brookfield viscometer Changes in the viscosity of DRF and WRF pastes with different particle sizes are shown in Fig. 3. After heating the flour suspension in a boiling water bath with stirring, the viscosity of the hot pastes was determined to increase slightly during the storage. The paste of WRF maintained consistently higher viscosity than that of DRF. Fine particle rice flour (<150 μm) paste had a higher viscosity than did coarse particle rice flour (<355 μm) paste, regardless of dry and wet milling. Chun *et al.* (28) reported dry milled rice flour (<125 μm) showed pseudoplastic behavior with 0.36 of flow behavior index (n) and 0.48 Pa·sec of apparent viscosity. Not only milling method but also particle sizes of rice flour affected hot paste viscosity. WRF had higher water binding capacity, swelling power, hot paste viscosity, initial pasting temperature, and lower setback viscosity than DRF. WRF with smaller particles might be desirable when non-waxy rice flours are used for cooking and storage. To develop rice flour products for the purpose of increasing the consumption of rice, rice flour might be prepared from wet milling of rice with smaller particles. But for transportation and storage, WRF might be also dried at lower temperature.

Preparation of gluten-free rice bread To obtain the proper conditions for rice flour to make gluten-free rice bread, DRF and WRF with different particle sizes were baked. The batters prepared from DRF and WRF passed through a 100 mesh screen were able to make bread and the shape of rice bread is shown in Fig. 4.

Rice bread without adding wheat flour or gluten, called gluten-free bread, has required different methods and technology for breadmaking. Gluten-free doughs are more fluid than wheat doughs and closer in viscosity to cake batters (12) due to the lack of a gluten network. These batter type doughs have to be handled similarly to cake batters rather than typical wheat doughs. Batter consistency was standardized by varying water levels to achieve the same force during extrusion (29). Using sorghum and corn starch mixture for making gluten-free bread, increasing water levels increased loaf volume, while increasing xanthan gum level and skim milk powder decreased the volume and loaf height, respectively (12). When two rice breads were compared, rice bread made from WRF was higher volume and more moistness, softness and homogeneous structure than that from DRF, and the latter was not cooked well.

We considered that the higher level of small particles resulted from starch granules in WRF helped gelatinize easily, and increase the viscosity of batter and paste which led to increase volume and network in rice bread.

References

1. Chiang PY, Yeh AI. Effect of soaking on wet-milling of rice. J. Cereal Sci. 35: 85-94 (2002)
2. Chen JJ, Lu S, Lii CY. Effect of milling on the physicochemical characteristics of waxy rice in Taiwan. Cereal Chem. 76: 796-799 (1999)
3. Saito S. Rice starch and rice powder as materials for food industry. Denpun Kagaku 27: 295-313 (1980)
4. Yeh AI, Hsiu WH, Shen TS. Moisture diffusion and gelatinization in extruded rice noodles. pp. 189-199. In: Food Extrusion Science and Technology. Kokini JL, Ho CT, Karwe MV (eds). Marcel Dekker Inc., New York, NY, USA (1992)
5. Nishita KD, Bean MM. Grinding methods: their impact on rice flour properties. Cereal Chem. 59: 46-49 (1982)
6. Choi CR, Kim JO, Lee SK, Shin MS. Properties of fractions from waxy rice flour classified with particle size. Food Sci. Biotechnol. 10: 54-58 (2001)
7. Bean MM, Elliston-Hoops EA, Nishita KO. Rice flour treatment for cake-baking applications. Cereal Chem. 60: 445-449 (1983)
8. Lee YT, Kim SS. Effect of elevated steeping temperature on the starch properties of stored milled rice. Food Sci. Biotechnol. 13: 332-336 (2004)
9. Kang MY, Han JY. Comparison of some characteristics relevant to rice bread made from eight varieties of endosperm mutants between dry and wet milling process. Korean J. Food Sci. Technol. 32: 75-81 (2000)
10. Sivaramakrishnan HP, Senge B, Chattopadhyay PK. Rheological properties of rice dough for making rice bread. J. Food Eng. 62: 37-

45 (2004)

11. Lee MH, Lee YT. Properties of gluten-free rice breads using different rice flours prepared by dry-, wet-, and semi-wet milling. Food Eng. 10: 180-185 (2006)
12. Schober TJ, Messerschmidt M, Bean SR, Park SH, Arendt EK. Gluten-free bread from sorghum: Quality differences among hybrids. Cereal Chem. 82: 394-404 (2005)
13. Gallagher E, Gormley TR, Arendt EK. Recent advances in the formulation of gluten-free cereal-based products. Trends Food Sci. Tech. 15: 143-152 (2004)
14. AACC. Approved Methods of the AACC. 10th ed. Methods 44-15A, 46-11A, 08-01, and 30-10. American Association of Cereal Chemists, St. Paul, MN, USA (2000)
15. Song JY, An YH, Kim JS, Choi J, Kim YC, Shin M. Swelling and pasting properties of non-waxy rice flour/food gum systems. Food Sci. Biotechnol. 15: 207-213 (2006)
16. Montgomery EM, Senti FR. Separation of amylose from amylopectin of starch by an extraction-sedimentation procedure. J. Polym. Sci. 28: 1-9 (1958)
17. Williams PC, Kuzina FD, Hlynka I. A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem. 47: 411-420 (1970)
18. Medcalf DF, Gilles KA. Wheat starches. I. Comparison of physicochemical properties. Cereal Chem. 42: 558-568 (1965)
19. AACC. Approved Methods of the AACC. 10th ed. Method 61-02. American Association of Cereal Chemists, St. Paul, MN, USA (2000)
20. An YH, Gang DH, Shin M. Effects of transglutaminase on the physical properties of resistant starch-added wheat flour doughs and baguettes. Food Sci. Biotechnol. 14: 608-613 (2005)
21. Yoon SH, Kim SK. Physicochemical properties of rice differing in milling degrees. Food Sci. Biotechnol. 13: 57-62 (2004)
22. Kum JS, Lee SH, Lee HY, Kim KH, Kim YI. Effect of different milling methods on physicochemical properties and products. Korean J. Food Sci. Technol. 25: 546-551 (1993)
23. Juliano BO. Polysaccharides, proteins, and lipids of rice. pp. 59-85. In: Rice: Chemistry and Technology. 2nd ed. Juliano BO (ed). The American Association of Cereal Chemists, Inc., St. Paul, MN, USA (1985)
24. Lee SJ, Kim SK. Amylograph pasting properties of flour and starch of Korean rice differing in maturity. Agric. Chem. Biotechnol. 41: 421-425 (1998)
25. Kum JS, Lee SY. The effect of the varieties and particle size on the properties of rice flour. Korean J. Food Sci. Technol. 31: 1542-1548 (1999)
26. Marshall WE. Effect of degree of milling of brown rice and particle size of milled rice on starch gelatinization. Cereal Chem. 69: 632-636 (1992)
27. Hamaker BP, Griffin VK. Effect of disulfide bond containing protein on rice starch gelatinization and pasting. Cereal Chem. 70: 377-380 (1993).
28. Chun SY, Kim HI, Yoo B. Effect of gum addition on the rheological properties of rice flour dispersions. Food Sci. Biotechnol. 15: 589-594 (2006)
29. Cauvain SP. Other cereals in breadmaking. pp. 330-346. In: Technology of Breadmaking. Cauvian SP, Young LS (eds). Blakie Academic & Professional, London, UK (1998)