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Effect of Starch Properties on the Extent of Breakage of Non-Glutinous Dried Rice Cake

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This study was conducted to determine the reason why dried rice cakes for non-glutinous rice crackers (*Senbei*) often break in the production process. Breakage after drying at 40°C for 12 h was found to be due to milling and storage conditions of the rice flour. Gel permeation chromatography revealed that the molecular weight of starch decreased as the extent of breakage increased. Damage to rice flour starch differed according to the milling methods. When press roller milled rice flour was stored at 5–25°C, the activity of α-amylase increased as the temperature became higher. The total water-soluble carbohydrate content of dried rice cake may be a good criterion to judge the extent of breakage. Reduction of the molecular sizes of starch, due to milling and action of α-amylase, is considered to cause the breakage of dried rice cake.

Keywords: non-glutinous rice cracker, breakage of dried rice cake, α-amylase, degradation of starch

To prepare non-glutinous rice crackers (*Senbei*), non-glutinous polished rice grains are washed, soaked, milled with a press roller, steam-kneaded, cooled in water, extended, primarily dried, tempered, secondarily dried and baked. Breakage of the dried rice cake in the tempering process is often a big problem. However, the causes of breakage have been difficult to determine, because the manufacturing process is complicated.

Only a few reports are available concerning the stable production of rice crackers. Miyao *et al.* (1991) reported the presence of heat-stable bacteria in rice cake to be a significant factor in the expansion of glutinous rice crackers. Ohno & Kariya (1994) reported that tempering is not necessary for continuous drying at 40°C and RH 80%.

In this report, the relationship between the properties of rice starch and breakage of non-glutinous dried rice cake was studied in order to establish a method of avoiding breakage.

Materials and Methods

Materials Polished rice grains were obtained from the market. Rice flours were prepared with an abrasive type polishing machine. Flours produced in the rice-polishing process of sake brewing were purchased from a sake brewery.

Preparation of dried rice cake Polished rice was washed five times by hand and soaked overnight. After draining, the soaked rice was pulverized with a press roller. Water was added to the rice flour to a moisture content of 38% and steamed with a steam-kneader for 7 min to make dough (*Dango*). The dough was cooled in water for 5 min and extended to about 2.2 mm thick after kneading twice. The dough was then cut into 6.2 cm diameter circles and dried for 12 h at 40°C in a ventilation dryer to make dried rice cake.

Measurement of extent of breakage of dried rice cake The percent of breakage after drying for 12 h at 40°C was used to express the extent of breakage of dried rice cake.

Degree of shrinkage of dried rice cake The volume of the sheets after cutting was calculated by measuring the diameter and thickness of 10 sheets before and after drying. The ratio of the volumes before and after drying was used to express the degree of shrinkage.

Percentage of damaged starch in rice flour The percentage of damaged starch in rice flour was measured as follows (Arisaka & Yoshii, 1991). A 500-mg sample was suspended in 50 ml of 0.25 M HCl solution and mixed for 2 h at 55°C. The solution was poured into a centrifuge tube and centrifuged for 20 min at 1,580×g. The amount of carbohydrate in the supernatant was determined by the phenol-sulfuric acid method and expressed as glucose (Fukui, 1990).

Bacterial counts The total bacterial populations of the rice flour were estimated on duplicate count agar plates (PCA, Nissui, Tokyo). Colonies were counted after incubating for 2 days at 30°C.

α-Amylase activity of rice flour A crude enzyme preparation from the rice flour was obtained by extracting with 5 volumes (v/w) of 0.1 M acetate buffer (pH 5.2) for 1 h at room temperature followed by filtration. α-Amylase activity was assayed as follows. A tablet of Amylase test A (Shionogi, Osaka) was suspended in 4.5 ml of 0.1 M acetate buffer (pH 5.2) and used as an enzyme reaction substrate solution. The crude enzyme extract (3 ml) was incubated with 1 ml of the substrate solution for 30 min at 50°C. After incubation, the enzyme reaction was stopped by adding 1 ml of 0.5 M NaOH solution, and the liberated blue color was measured by the absorbance at 620 nm after filtration. The enzyme activity was expressed by the absorbance.

Total water soluble carbohydrate content of dried rice cake Two grams of pulverized dried rice cake (passed through a 100-mesh screen sieve) was suspended in 50 ml of

water and shaken for 2 h at room temperature. The mixture was centrifuged at 1,580×*g* for 20 min. Fifty milliliters of water was added to the precipitate and the mixture was centrifuged again. The supernatants were pooled and filled to 100 ml. The total carbohydrate in the supernatant was measured by the pheno-sulfuric acid method and expressed as glucose.

Sephacryl S-1000 gel-permeation chromatography of starch from dried rice cake Procedures of gel-permeation chromatography were essentially similar to the methods described by Konishi *et al.* (1985). Pulverized dried rice cake (0.1 g) was suspended in 10 ml of dimethyl sulfoxide. After standing overnight, the solution was heated in an autoclave for 10 min at 121°C and centrifuged at 1,580×*g* for 20 min. One milliliter of the supernatant was loaded on a Sephacryl S-1000 (Pharmacia, 2×65 cm) column equilibrated with 0.02 M NaOH-0.2% NaCl and eluted with the same solvent at a flow rate of 5 ml/h. Fractions (3 ml each) were collected and the total carbohydrate content of each fraction was measured. The recovery yield of starch was about 90%.

Amylography of rice flour Rice flours were passed through a 100 mesh-screen sieve in order to avoid the effect of particle size. Using a Brabender Viskograph, amylography was carried out with 10^{-2} M $CuSO_4$ solution at 8% concentration on a dry matter basis. The measurement conditions were as follows. Torque of the head cartridge 700 cm•g; Heating or cooling rate 1.5°C/min; Heating 30–96°C; Holding time at 96°C 10 min; Cooling 96°C–30°C; Rotational speed 75 rpm.

Results and Discussion

Extent of breakage Dried rice cake was made using various rice flours which were milled by different methods or stored under different conditions after press roller milling to determine the effects of rice flour properties upon breakage. Press roller milled (RM, moisture content was 30.1%), abrasion-milled rice flour (AM, moisture content was 13.7%) and pulverized dried rice cake (DM, passed through a 28-mesh screen sieve, moisture content was 9.6%) were used as rice flours which were different in preparation methods. Press roller milled rice flour was stored hermetically for 24 h at 5°C (R5) or 25°C (R25) and used as rice flour under different storage conditions.

Table 1 shows the extent of breakage. Moisture content of dried rice cake after drying for 12 h at 40°C was about 12% and the difference in moisture content was small. The extent of breakage of the control (prepared using RM), DRA (using R5), DRB (using R25), DRC (using DM) and DRD(using AM) was 1.5, 3.7, 30.8, 14.8 and 100%, respectively. For preparing rice crackers, the dried rice cake is ordinarily tempered at a moisture content of about 20% after primary drying. When drying was stopped at a moisture content of 20%, no breakage was observed. However, after standing for a week, the control, DRA, DRB, DRC and DRD showed 2.3, 31.0, 79.4, 23.6 and 100% breakage, respectively.

Table 1. Extent of breakage or shrinkage of dried rice cake.

Dried rice cake	After drying for 12 h at 40°C		Extent of breakage after a week at moisture content of 20%
	Extent of breakage (%)	Percent of Shrinkage of volume (%)	
Control	1.5	36.8	2.3
DRA	3.7	39.8	31.0
DRB	30.8	41.1	79.4
DRC	14.8	39.4	23.6
DRD	100	—	100

Control: Dried rice cake was made from press roller milled rice flour, DRA: Dried rice cake was made from press roller milled rice flour left for 24 h at 5°C, DRB: Dried rice cake was made from press roller milled rice flour left for 24 h at 25°C, DRC: Dried rice cake was remade from pulverized dried rice cake, DRD: Dried rice cake was made from rice flour prepared by an abrasive type milling machine.

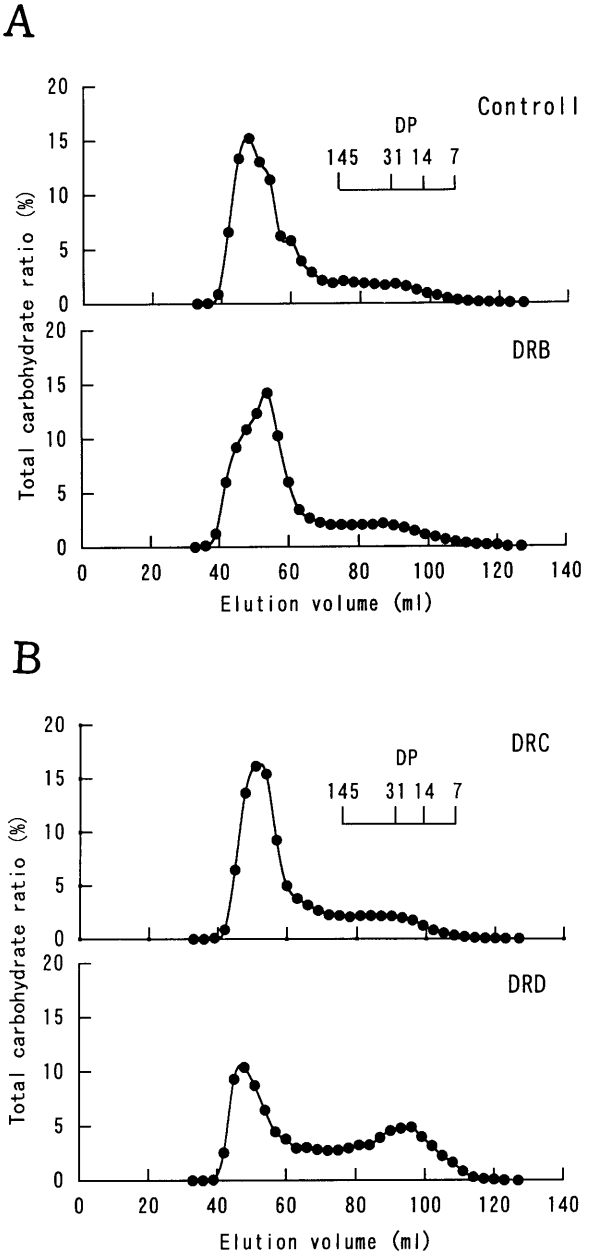

Fig. 1. A: Sephacryl S-1000 column chromatography of starch from pulverized dried rice cake. Sample names are the same as shown in Table 1. Dried rice cake was pulverized and 100 mg of the flour was suspended overnight in 10 ml of dimethyl sulfoxide, and then autoclaved for 10 min. After centrifugation (1,580×*g*, 20 min), 1 ml of sample was loaded on a Sephacryl S-1000 column (2 cm×65 cm). B: Sephacryl S-1000 column chromatography of starch from pulverized dried rice cake. Sample names are same as the shown in Table 1.

In a comparison of these two drying methods, the latter showed a high extent of breakage in every case. The extent of breakage was estimated immediately after drying in the former method, while it was estimated after a week in the latter. Thus, the period after drying is considered to cause the differences in the extent of breakage. However, the extent of breakage may be estimated by drying for 12 h at 40°C, because the same order for the extent of breakage was obtained.

Data for shrinkage due to drying are shown in Table 1. The degrees of the control, DRA, DRB, DRC were 36.8, 39.8, 41.1 and 39.4%, respectively. That of DRD could not be determined because all the rice cake samples crumbled. The degree of shrinkage showed a tendency to increase with the extent of breakage, indicating that they might be determined by the flours used and the shrinkage during drying.

Gel permeation chromatography of starch from dried rice cake on Sephacryl S-1000 The molecular weight distribution of starch from dried rice cake was examined using a Sephacryl S-1000 column. The results are shown in Fig. 1. DRA is not included because its chromatographic pattern is essentially the same as that of the control. The first peak represents a high molecular weight starch, and this high molecular weight fraction represented most of the sample in every case. The profiles of DRB and DRD, showing extensive breakage, were different from that of the control. The elution peak shifted to a lower molecular weight fraction and the amounts of the lower fraction increased; this increase was remarkable for DRD. This increase in the low molecular weight fraction for DRD was considered to be due to the starch degradation caused by an emery wheel in the rice milling process (Arisaka *et al.*, 1992). The water solubility of sorghum starch increases on pressure cooking or extrusion, and the starch molecular weight decreases on extrusion or popping as revealed by gel permeation chromatography (Glennie, 1987). The starch degradation and the increase in the low molecular weight fraction for DRC would thus appear to be due to the repeated steam-kneading and kneading.

Properties of rice flours The percentages of damaged starch, bacterial counts and α-amylase activities of rice flours are shown in Table 2. The percentages of damaged starch of RM, R5, and R25 were 1.4%, but that for AM was 37.1%. DM could not be measured because the starch was gelatinized in the steam-kneading process. The especially high value for AM was considered to be due to the damaged starch in the abrasion-milled rice flour by an emery wheel in the rice milling process (Arisaka *et al.*, 1992).

The bacterial counts of RM, R5, R25, DM and AM were 10^5, 10^5, 10^8, 10^2 and 10^3 cells/g, respectively. α-Amylase activities of R5 and R25 were higher than that of RM, but those of DM and AM were lower. When RM was left at 25°C, the α-amylase activity of the rice flour increased with the bacterial counts (Fig. 2), and hence the α-amylase activity was considered to be due to bacteria in the rice flour.

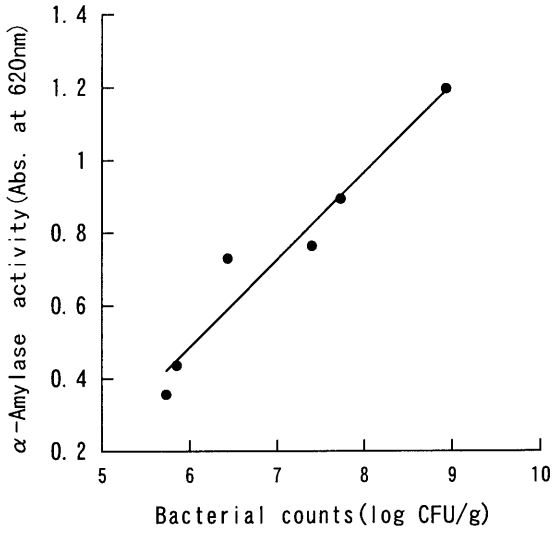

Fig. 2. Relationship between bacterial counts and α-amylase activity of rice flour.

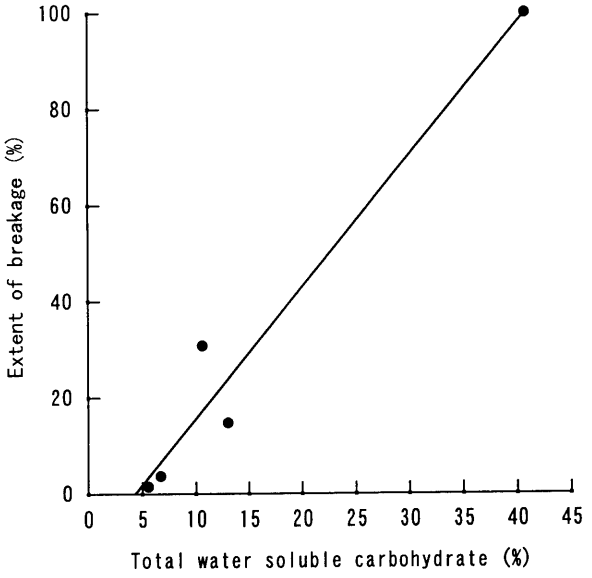

Fig. 3. Relationship between total water-soluble carbohydrate content and extent of breakage of dried rice cake. Extent of breakage was calculated after drying for 12 h at 40°C. Two gram of pulverized dried rice cake was suspended in 50 ml of water and shaken for 2 h. After centrifugation, the precipitate was washed again. Total carbohydrate content of the supernatant was measured by the phenol-sulfuric acid method and expressed as glucose.

Table 2. Damaged starch, bacterial counts and α-amylase activity of rice flour.

	Damaged starch (%)	Bacterial counts (/g)	α-amylase[a] activity
RM	1.4	3.1×10^5	0.518
R5	1.4	9.0×10^5	0.698
R25	1.4	7.4×10^8	1.003
DM	–	<300	0.068
AM	37.1	1.3×10^3	0.112

RM: Press roller milled rice flour (moisture content: 30.1%), R5: Press roller milled rice flour left for 24 h at 5°C, R25: Press roller milled rice flour left for 24 h at 25°C, DM: Pulverized dried rice cake (moisture content: 9.6%), AM: Rice flour prepared by an abrasive milling machine. [a]α-Amylase activity was measured using Blue starch and expressed as absorbance at 620 nm.

Table 3. Amylography characteristics of rice flour.

	Peak	Minimum	Final (at 30°C)
RM	750 BU	370 BU	795 BU
R5	770	370	775
R25	725	350	755
AM	85	30	70

Sample names are the same as in Table 2. Amylography was carried out with 10^{-2} M $CuSO_4$ at 8% concentration on a dry matter basis.

The extent of breakage showed a tendency to increase with the percentage of damaged starch and α-amylase activity. The relation between total water-soluble carbohydrate and breakage is shown in Fig. 3. The extent of breakage increased with the total water-soluble carbohydrate, and hence the breakage was concluded to be due to the change in physical properties of the starch.

Thus, the pasting characteristics of the rice flours were examined using an amylograph. Amylography was carried out with 10^{-2} M $CuSO_4$ solution to inhibit α-amylase activity (Shoji & Kurasawa, 1988), because this enzyme activity was shown to be present in each rice flour. DM could not be measured, because the starch had already gelatinized in the steam-kneading process. This result is shown in Table 3. As Arisaka *et al.* (1992) reported, AM showed a much lower viscosity than RM. Although R25 showed a slightly lower viscosity, the differences in viscosity between RM and R25 were slight, because the reproducibility of amylography was within $\pm$10 BU (Maeda, 1986). Based on the results of amylography, it is presumed that the properties of rice flour starch will not change during storage.

Bajwa and Bains (1990) reported that α-amylase supplement significantly increased the reducing sugar content of bread crumbs; therefore, the starch degradation in DRB is considered to be caused by α-amylase in rice flour during steam-kneading based on the results of amylography and the action of α-amylases to cleave internal α-1,4,-bonds of starch into products which possess a new reducing group (Martin, 1988).

In this study, it was revealed that the decrease in starch molecular weight is the main factor in the breakage. The extent of breakage of the control (made using RM) was the lowest and that of DRA (made using R5) followed. Therefore, a rice flour storage temperature of 5°C is better than that of 25°C for preventing the breakage. Furthermore, starch degradation causes a decrease in the volume of dried rice cake during drying and an increase in water-soluble total carbohydrate content.

References

Arisaka, M. and Yoshii, Y. (1991). Measuring damaged starch in rice flour by acid method. *Rep. Food Res. Inst. Niigata Pref.*, **26**, 11–12.

Arisaka, M., Nakamura, K. and Yoshii, Y. (1992). Properties of rice flour prepared by different milling methods. *Denpunkagaku*, **39**, 155–163 (in Japanese).

Bajwa, U. and Bains, G.S. (1990). Supplementation of glycerolysed oils and alpha-amylases in bread making. *Int. J. Food Sci. Technol.*, **27**, 153–155.

Fukui, S. (1990). Phenol-sulfuric acid method. In "Kangentou no Teiryouhou," ed. by I. Uritani, T. Komano, K. Shimura, M. Nakamura and M. Funazu. Gakkai Shuppan Center, Tokyo, pp. 50–52.

Glennie, C.W. (1987). Physicochemical properties of sorghum starch thermally treated by different methods. *Starch*, **39**, 273–276.

Konishi, Y., Nojima, H., Okuno, K., Asaoka, M. and Fuwa, H. (1985). Characterization of starch granules from waxy, nonwaxy and hybrid seeds of *Amarantausa hypochondriacus L. Agric. Biol. Chem.*, **49**, 1965–1985.

Maeda, I. (1986). Amylograph. In "Denpun Kanren Tousitu Jikkenhou," ed. by I. Uritani, K. Shimura, M. Nakamura and M. Funazu. Gakkai Shuppan Center, Tokyo, pp. 175–176.

Martin, S. (1988). Amylases. In "The Biochemistry of Plants," ed. by P.K. Stumpf and E.E. Conn. Academic Press, San Diego, pp. 258–259.

Miyao, S., Numata, K. and Sato, T. (1991). Effects of microorganisms on the making of Japanese rice cracker (*Arare*). *Bull. Tokyo Metrop. Food Technol. Res. Cent.*, **1**, 1–8.

Ohno, H. and Kariya, M. (1994). Study on improvement *Arare-kiji* making process. *Rep. Gifu Prefect. Ind. Res. Tech. Cent.*, **26**, 67–70.

Shoji, I. and Kurasawa, H. (1988). Studies on science of cooking of rice and starch. *Nippon Kasei Gakkaishi*, **39**, 237–241 (in Japanese).