Food Sci. Technol. Int. Tokyo, **3** (1), 6–9, 1997

Characterization of Factors Affecting Properties of Rice Cake and Its Structure

Toshiyuki WATANABE,[1] Yutaka HASHIMOTO,[1] Toshio JOH[2] and Toshiro HAYAKAWA[2]

[1]*Kameda Seika Co., Ltd., Kameda-machi, Niigata 950-01, Japan*
[2]*Department of Applied Biological Chemistry, Faculty of Agriculture, Niigata University, 2, Igarashi, Niigata, Niigata 950-21, Japan*

Received August 25, 1995

In the manufacturing process, the relationship between the expansibility of glutinous rice crackers and the properties of gelatinized and retrograded rice flour gel (rice cake) has not been fully clarified. We analyzed glutinous paddy rice from various angles using proximate analysis, amylography, measurement of degree of dispersion and differential scanning calorimetry. The tendencies, depending on cultivars, as measured were related. In particular, it was suggested that the amount and strength of intermolecular hydrogen bonds in rice was related to the expansion volume of rice cake because the enthalpy and peak temperature of DSC is closely related to its volume. Accordingly, it was suggested that DSC might be usable as a common standard for characterization of the factors affecting the properties of rice cake and its structure from the viewpoint of rice cracker expansibility.

Keywords: rice cake, rice cracker, amylography, degree of dispersion, DSC

Rice crackers (arare, okaki, senbei) are traditional Japanese pastry which have been familiar to us for a long time. The unique texture of rice crackers varies with expansion conditions. On the basis of experience, it is known that in the manufacturing process the expansibility of rice crackers is affected by many factors which are the physical properties of the rice and rice cakes (i.e., gelatinization, retrogradation and drying the rice cakes before roasting). A number of studies have been performed on rice, etc., from various viewpoints (Chikubu *et al.*, 1985; Kainuma, 1986; Fuwa, 1987; Shibuya, 1990; Kuge, 1992; Miyoshi *et al.*, 1992; Hizukuri, 1993a, b; Ohya & Kawabata, 1993; Onda *et al.*, 1994; Otsubo, 1995). However, the relationship between the qualities (in particular, expansibility) of glutinous rice crackers and the properties of rice cakes has not been fully clarified. In the present paper, therefore, attempts have been made to characterize the factors affecting the properties of rice cake and its structure from the viewpoint of rice cracker expansibility using many analytical procedures.

Materials and Methods

Preparation of sample The glutinous paddy rice used was cultivar; "Koganemochi" (abbreviated K, hereafter) produced in Niigata, "Hiyokumochi" (abbreviated H, hereafter) produced in Saga and "Tannemochi" (abbreviated T, hereafter) produced in Hokkaido, Japan, in 1990. Moreover, "Koganemochi" produced in Niigata, "Hakuchomochi" produced in Hokkaido and "Hiyokumochi" produced in Kumamoto, Japan, in 1993 and "Wataboshi" produced in Niigata, "Hatsukazari" produced in Niigata and "Hiyokumochi" produced in Kumamoto, Japan, in 1995 were used. The rice was polished to a degree of 90%.

Rice flour: The polished rice was dried at about 30°C at atmospheric pressure and allowed to stand in a desiccator overnight to reduce the water content to about 10%. It was then pre-milled with a Willey grinder. After screening through a 100 mesh sieve, the mesh-on fraction was milled with a sample mill (an air-stream grinder). The 100 mesh-passed fraction thus obtained was employed as a sample.

Rice starch: Rice starch samples were prepared in accordance with Denpun Kanren Toshitsu Jikken-ho (Taniguchi, 1986).

Rice cake and refrigerated rice cake: The polished rice was washed for 10 min, soaked in water for 12 h, drained for 30 min, steamed for 25 min and then kneaded for 10 min with the use of an electrical kneading machine to give the prepared rice cake. This rice cake was then refrigerated at 5°C for 24 h to produce the refrigerated rice cake. Each sample was rapidly frozen in liquid nitrogen and ground with a coffee mill. It was then dehydrated with ethanol overnight and dried at 40°C overnight. After screening through a 100 mesh sieve, the passed fraction was employed as a sample.

Measurement method Proximate analysis: The rice produced in 1990 was used for the analysis. Protein, fat, ash and carbohydrate contents were determined by each conventional method.

Amylography: The rice produced in 1990, 1993 and 1995 was used for the measurement. Rice flour and rice starch were used. Using a BrabenderViskograph at a rotation speed of 75 rpm, 500 g of a sample suspension (concentration: 8% by weight) was heated from 30°C to 96°C at a rate of 1.5°C/min and maintained at 96°C for 10 min. It was then cooled to 45°C at a rate of 1.5°C/min and subjected to measurement. In the case of polished rice flour, the amylase activity was suppressed by adding disodium 0.04 M ethylenediaminetetraacetate.

Measurement of degree of dispersion: The rice produced in 1990 was used for the measurement. Using the modified method of Arisaka *et al.* (1991), prepared rice cakes and refrigerated rice cakes were examined. After weighing 0.5 g of a sample, the sample (concentration: 1% by weight) was dispersed in a 0.04% sodium lauryl sulfate solution at a dispersion temperature of 30°C for 2.5 h using a shaker. The sample was shaken at an amplitude of 40 mm and 16,500 times, then centrifuged at 3000 rpm for 20 min. The starch content in the supernatant was determined by the phenol-sulfuric acid method (Sakano, 1986). The degree of dispersion was the percentage of dispersed matter weight (total sugar) relative to sample weight (dry matter). The measurement was repeated 10 times, and the result was indicated as an average.

Differential scanning calorimetry: The rice produced in 1990, 1993 and 1995 was used for the measurement. Rice flour, rice starch and refrigerated rice cake were used. For DSC, a heat flow differential scanning calorimeter DSC-50 (Shimadzu Ltd., Kyoto) was used, and a sealed aluminum container (resistant to 3 atm) was employed in the measurement. Prior to the measurement, the container was heated together with water to react the container with water. About 10 mg (wet matter) of a sample was weighed into a cell, and water was added thereto to adjust the water content to 70%. After sealing and maintaining at room temperature for 30 min, the cell was placed in the DSC apparatus. In the case of rice flour and rice starch, heating was performed at a rate of 5°C/min with the use of a reference (α-alumina). In the case of a refrigerated rice cake, heating was performed at a rate of 7°C/min with the use of a reference (α-alumina). For each sample, the measurement was repeated 5 times and the average was calculated.

Measurement of expansion volume: The rice produced in 1993 and 1995 was used for the measurement. Refrigerated rice cake kneaded for 20 min and refrigerated at 5°C for 72 h was employed as a sample. The cylindrical samples were drawn from a block of the refrigerated rice cakes by a cork punch. The diameter and length of the samples were about 8 mm and 30 mm, respectively. The weight of the samples was about 1.5 g. These samples were placed in a hard test tube with an inside diameter of 8.2 mm and expanded in a drying oven under 135°C atmosphere for 10 min. The sample temperature rose at a rate of about 15°C/min. The expansion volume [i.e., volume after roasting/sample weight (wet matter) before roasting] was indicated as an average of 6 samples. The expansibility of rice crackers was estimated by this simple method. It was confirmed by making rice crackers on an experimental basis in which the expansibility of the rice cracker depended on that of the rice cake.

Results and Discussion

Proximate analysis of rice components Table 1 shows the results obtained by the analysis. It is reported that,in the case of non-glutinous rice, protein and lipids affect the gelatinization swelling and relate to the taste (Inazu, 1982; Kuge, 1992; Yamada *et al.*, 1994). In particular, it is known that lipids closely relate to the aging of the rice.

Measurement of degree of dispersion In this measurement, the degree of gelatinization and retrogradation usually measured by an enzymatic method were estimated based on the dispersion properties of a gelatinized and retrograded rice flour gel in a solvent. Rice flour gel with a firm structure is hardly dispersible and digested by the enzyme, while one with a brittle structure is highly dispersible and easily digested by the enzyme. Table 2 shows the result obtained by this measurement method. In the case of rice cake, the degree of dispersion is in the order of K<T<H. It is therefore considered that K has a firm structure, while T and H have brittle ones. In the case of the refrigerated rice cake, the degree of dispersion is in the order of K<H<T. Thus it is considered that, after rearrangement due to refrigeration, K has the firmest structure while T and H have brittle ones, similar to the case of the gelatinized rice flour gels.

Amylography In Table 3, data for each measurement

Table 1. Proximate composition of rices.

Cultivars	Protein[a] (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Koganemochi	6.9	1.6	0.4	91.1
Hiyokumochi	7.8	1.2	0.5	90.5
Tannemochi	8.7	1.8	0.5	89.0

[a] N×5.95.
The data show the content in dry matter.

Table 2. Degree of dispersion of rice cake and refrigerated rice cake.

Cultivars	Degree of dispersion (%)	
	Rice cake	Refrigerated rice cake
Koganemochi	77	14
Hiyokumochi	88	29
Tannemochi	81	49

Table 3. Amylography and DSC characteristics of rice flour, starch and refrigerated rice cake.

	Amylography		DSC	
	Peak temp. (°C)	Peak (BU)	Peak temp. (°C)	ΔH (J/g)
(Rice flour)				
Koganemochi	72.8	970	70.9±0.0	9.8±0.0
Hiyokumochi	67.5	760	66.4±0.0	8.3±0.0
Tannemochi	66.0	790	64.0±0.0	8.7±0.0
(Rice starch)				
Koganemochi	69.8	1050	68.6±0.0	18.4±0.0
Hiyokumochi	66.0	1080	63.9±0.0	16.5±0.4
Tannemochi	63.8	1360	61.2±0.3	16.0±0.1
(Refrigerated rice cake)				
Koganemochi	—	—	44.1±0.3	4.9±0.0
Hiyokumochi	—	—	43.0±0.6	3.8±0.2
Tannemochi	—	—	43.4±0.6	1.7±0.0

DSC values are mean±standard deviation of five trials.

Table 4. Relationship between expansion volume of refrigerated rice cake and DSC, amylography characteristics of rice flour.

Cultivars	Expanison volume*1 (ml/g)	DSC		Amylography	
		ΔH*2 (J/g)	T_p*3 (°C)	Peak*4 (BU)	T_p*5 (°C)
Wataboshi (1995)	3.29±0.15	11.5±0.1	70.4	670	74.3
Hatsukazari (1995)	3.26±0.18	11.0±0.2	70.1	650	73.5
Hiyokumochi (1995)	2.89±0.08	10.5±0.1	63.9	600	69.6
Koganemochi (1993)	2.78±0.10	11.0±0.2	74.1	950	78.0
Hakuchomochi (1993)	2.51±0.16	7.8±0.2	61.5	780	68.3
Hiyokumochi (1993)	2.34±0.03	9.1±0.2	63.3	700	69.9

Correlation coefficients between *1 and *2,*3,*4,*5.
*1 and *2 are mean±standard deviation of five and six trials.
*2 0.818, *3 0.613, *4 0.338, *5 0.489.

are given. It should be assumed that the maximum viscosity-attaining temperature and the maximum viscosity correspond to the ease of gelatinization and the strength of the gelatinized rice flour gel. In the case of rice flour, the maximum viscosity-attaining temperature is in the order of K>H>T, which should suggest that K is structurally firm and T is brittle from the viewpoint of the ease of gelatinization. In the case of rice starch, the maximum viscosity-attaining temperature shows the same tendency as those of rice flour. It is therefore considered that this characteristic value shows the properties of starch *per se*. In the case of rice flour, the maximum viscosity is in the order of K>T>H. However, this property is in the order of K>H>T when each rice has not been long-stored but is fresh (these values are not shown in this report). This may show that H becomes less aged than T because H has a lower lipid content than T. It is therefore considered that K has a firm structure, while T and H have brittle ones. In the case of rice starch, the maximum viscosity shows the reverse tendency, i.e., K<H<T, which may be caused by the properties of starch *per se*, excluding protein, lipids, etc. The tendency of K<H<T agrees with that of viscoelasticity in the previous paper (Watanabe *et al.*, Submitted for publication). Based on these results, it is assumed that the properties of rice flour are greatly affected by the properties of starch *per se* but the maximum viscosity is affected by coexisting components other than starch. Moreover, the coexisting components other than starch may cause the inequality of H and T to be reversed in "2. the degree of dispersion of a gelatinized rice flour gel."

Differential scanning calorimetry In Table 3, the average data for each measurement are given. In the differential scanning calorimetry of rice starch, the peak temperature (T_p) and enthalpy (ΔH) are said to correspond to the amount and strength of intermolecular hydrogen bonds in starch, respectively (Yamada, 1989). In this measurement, T_p is in the order of K>H>T almost in common with that of rice flour, starch and refrigerated rice cake. Similarly, ΔH's are in the order of K>H>T in the case of starch and refrigerated rice cake. However, in the case of rice flour, ΔH is in the order of K>T>H, which may be caused by T becoming more aged than H. These results indicate that the amount and strength of intermolecular hydrogen bonds in rice originate in the starch and affect the state of hydrogen bonds in the gelatinized rice flour gel and retrograded rice flour gels. Moreover, the strength and amount of the hydrogen bonds relate to the tendencies depending on the cultivars as measured in "2. and 3." Thus it may seem that they are factors affecting the properties (structure) of gelatinized and retrograded rice flour gels. It may also seem that they are factors affecting the viscoelastic properties and pseudo-network structure of rice cake because this tendency K<H<T agrees with the tendency of viscoelasticity in the previous paper (Watanabe *et al.*, 1997).

Expansion volume and DSC, amylography Table 4 shows the relationship between the expansion volume of refrigerated rice cake and characteristic values of DSC or amylography of rice flour. The relationship between the expansion volume and ΔH or T_p is expressed in the following formulas.

$$Y_1=0.583+0.223X_1 \quad (r_1=0.818) \qquad Y_2=-0.337+0.047X_2 \quad (r_2=0.613)$$

Y_1, Y_2: expansion volume
X_1: ΔH
X_2: T_p
r_1, r_2: correlation coefficient

Better correlations were estimated for DSC characteristics than for amylography characteristics based on the above.

These results indicate that the amount (ΔH) and strength (T_p) of hydrogen bonds in rice closely relate to the expansion volume. Accordingly, it is suggested that DSC may be usable as a common standard for characterization of the factors affecting the properties of rice cake and its structure from the viewpoint of rice cracker expansibility.

References

Arisaka, M., Yoshii, Y. and Yachida, T. (1991). Estimation of gelatinization, retrogradation and destruction of mochi (glutinous rice cakes) for arare by degree of dispersion. *Nippon Shokuhin Kogyo Gakkaishi*; **36**, 55-61 (in Japanese).
Chikubu, S., Watanabe, S., Sugimoto, T., Manabe, N., Sakai, F. and Taniguchi, Y. (1985). Establishment of palatability estimation formula of rice by multiple regression analysis. *Denpun Kagaku*, **32**, 51-60 (in Japanese).
Fuwa, H. (1987). Recent progress of starch science. *Chorikagaku*, **20**, 2-8 (in Japanese).
Hizukuri, S. (1993a). Properties of rice starch. *Denpun Kagaku*, **40**, 183-190 (in Japanese).
Hizukuri, S. (1993b). Towards an understanding of the fine structure of starch molecules. *Denpun Kagaku*, **40**, 133-147 (in Japanese).
Inazu, O., Sasaki, T. and Arai, T. (1982). Taste and its physicochemical properties. In "Taste of Rice," ed. by S. Osanai. Hokunoukai, Sapporo-shi, p. 27 (in Japanese).
Kainuma, K. (1986). Structure of starch. *New Food Ind.*, **28**, 49-59 (in Japanese).
Kuge, T. (1992). On the physicochemical properties of starch. *Denpun Kagaku*, **39**, 51-56 (in Japanese).
Miyoshi, E., Kumeno, K., Ookubo, M., Takahashi, M. and Naka-

hama, N. (1992). A comparative study on the retrogradation process of starch gels using X-ray and rheological measurement. *Denpun Kagaku*, **39**, 253–260 (in Japanese).

Ohya, C. and Kawabata, A. (1993). The structure and gelatinization properties of rice starch prepared from different varieties. *Nippon Shokuhin Kogyo Gakkaishi*, **40**, 225–235 (in Japanese).

Onda, T., Abe, H., Matsunaga, A., Komiyama, Y. and Kawano, S. (1994). Analysis of gelatinization of starch by near infrared spectroscopy. *Nippon Shokuhin Kogyo Gakkaishi*, **41**, 886–890 (in Japanese).

Otsubo, K. (1995). Varieties and taste characteristics of rice. Presented at 42nd Convention on Nippon Shokuhin Kagaku Kogaku, Nagoya, March 28–30, pp. 44–47 (in Japanese).

Sakano, Y. (1986). Chemically and physically analytical method. In "Method for Experiments of Saccharides Relating to Starch," ed. by M. Nakamura & K. Kainuma. Gakkai Shuppan Center, p. 45 (in Japanese).

Shibuya, N. (1990). Chemical structure of cell walls of rice grain and grain quality. *Nippon Shokuhin Kogyo Gakkaishi*, **37**, 740–748 (in Japanese).

Taniguchi, H. (1986). General methods for preparation of starch grain. In "Method for Experiments of Saccharides Relating to Starch," ed. by M. Nakamura and K. Kainuma. Gakkai Shuppan Center, pp. 15–20 (in Japanese).

Yamada, T. (1989). Structure and retrogradation of starch. In "Interaction of Food Ingredient," ed. by M. Namiki & S. Matsushita. Koudansha Scientific, p. 76 (in Japaneae).

Yamada, T., Ito, T., Teranishi, K. and Hisamatsu, M. (1994). Characteristics of rice cooked with monoglyceride. *Nippon Shokuhin Kogyo Gakkaishi*, **41**, 251–258 (in Japanese).

Watanabe, T., Hashimoto, Y., Joh, T. and Hayakawa, T. Characterization of viscoelastic properties of rice cake. *Food Sci. Technol. Int. Tokyo*, **3**, 1–5.