

Effect of Aging on the Quality of Glutinous Rice Crackers

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ABSTRACT

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The experiment was conducted to study the effects of aging on the physicochemical properties of two Thai cultivars of milled glutinous rice (RD6 and RD8). The amylose and protein content of rice samples did not change when stored from 0 to 4 months. Amylograph curves from samples of milled rice stored from 0 to 8 months were analyzed. Both cultivars gave constant gelatinization temperature during aging. The values for peak viscosity, final viscosity on cooking at 94°C, viscosity on cooling to 50°C and breakdown decreased significantly for RD6 cultivar, whereas the setback value and consistency were not changed significantly. For RD8 cultivar, no significant difference was observed for vis-

cosity on cooling to 50°C and consistency during aging up to 8 months. Peak viscosity and breakdown value were reduced during storage, whereas the final viscosity on cooking at 94°C and setback value increased with time. Raw milled rice of both RD6 and RD8 cultivars have similar water uptake rates. Stored rice tended to have a lower water uptake rate which increased proportionately with soaking time. Samples from both rice cultivars were used to make rice crackers to study the effects of aging on quality. Volume expansion of rice crackers made from RD6 and RD8 cultivars tended to decrease during storage which resulted in an increase in the hardness of the crackers.

Glutinous rice (*Oryza sativa*), also called waxy or sweet rice, is characterized chiefly by its lack of amylose in the starch (Bean et al 1984). It has been grown in the Orient for many centuries and has found extensive use in certain traditional pastries, confections, and other foods in Asia (Whistler and Paschall 1967). The kernels of all glutinous rice are sticky and adhere to one another, providing a product with a decidedly different texture when compared to amylose-containing rice (Bean et al 1984). The preparation of various rice desserts and sweets utilizes the sticky, soft nature of cooked waxy rice and its slower rate of retrogradation or hardening relative to cooked nonglutinous rice. Glutinous or waxy rice is commonly used in the preparation of baked or popped snacks because it expands readily and produces a more porous texture.

Rice cracker is one of the numerous Japanese baked snack foods made from rice. *Arare* (made from glutinous rice) and *Senbei* (made from nonglutinous rice) are the major and traditional rice crackers in Japan (Li and Luh 1980). In glutinous rice cracker processing, milled rice is washed and soaked for 16–20 hr, then drained and crushed by rollers into a fine powder. After steaming for 15–30 min, the resulting rice dough or cake is kneaded and cooled to 2–5°C for two to three days for hardening. The hard cake is cut, dried, and baked to produce various types of glutinous rice crackers. The soft texture and flavor of these products are quite different from western snacks.

In Thailand, RD6 and RD8 (two glutinous rice cultivars) are commonly used as raw materials in the production of rice crackers using processing technology transferred from Japan although many practical problems exist in the manufacture of these products. Some problems arising from processing conditions have been studied and solved by experience, but those occurring from changes in rice properties (e.g., aging effect) are still unresolved. According to manufacturers in Thailand, crackers produced from rice that has been stored for about one year have reduced volume expansion. By experience, manufacturers have solved this problem by mixing aged rice with fresh rice. This practical method, however, does not always work.

Understanding the mechanism of expansion is important in order to produce high quality rice crackers. Investigations concerning rice cracker expansion have focused on the effects of cultivar,

heating temperature, kneading method, rice cake moisture content, distribution of water absorption, and uniformity of steamed rice (Li and Luh 1980). Information concerning the effects of aging of rice on the physicochemical properties of rice crackers is limited. Therefore, the objectives of the present study were to determine the effects of aging on the physicochemical properties of two specific cultivars of Thai glutinous rice (RD6 and RD8) and the quality of the rice crackers prepared from them.

MATERIALS AND METHODS

Milled Glutinous Rice

Freshly milled Thai glutinous rice of RD6 and RD8 cultivars from the Khon Kaen Province in the northeastern part of Thailand were used in this experiment. For each cultivar, a stock of milled glutinous rice was stored at ambient temperature (28–30°C) and samples for ten replicates were taken for study at the end of each month for a period of four months.

Physicochemical Analysis of Milled Glutinous Rice

The moisture content of milled glutinous rice was determined using the AOAC Standard (Oven) Method.

The method adopted by Juliano (1971) was used to determine amylose content of rice flour samples. Flours were obtained from the milled rice using a Brabender Quadrumat Junior Mill fitted with a Brabender reel sifter, No. 64 grit gauge. A standard curve was established using standard amylose obtained from the Pathum Thani Rice Research Center, Pathum Thani province, Thailand.

The alkali digestibility test introduced by Little et al (1958) was used in this study. The method involved incubation of ten grains of milled rice in 27 mL of 1.7% KOH at room temperature for 24 hr and measurement of the degree of spreading using a 7-point scale.

Gelatinization temperature and pasting properties of each sample were determined using a C.W. Brabender Amylograph equipped with a 700 cm²g sensitivity cartridge and a cooling coil. The method of Halick and Kelly (1959) was used which entails heating the sample prepared as 10% slurry (50 g of rice flour in 450 mL of water) to 94°C during which the peak viscosity was obtained. The sample was held at 94°C for 20 min then cooled to 50°C. Gelatinization temperature was taken as the temperature when the viscosity curve starts to deviate from the zero baseline.

The protein content of the rice flour was determined by the micro-Kjeldahl method. The value for the factor used in the protein content calculation was 5.95 (Juliano 1985).

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Samples of rice (20 g) were soaked in 100 mL of distilled water at 22–24°C for different durations up to 16 hr. After the desired soaking period, the water was carefully drained. The increase in weight of the drained rice was calculated as percentage absorbed by twenty grams of rice (Bean et al 1984).

Preparation of Glutinous Rice Crackers

Milled glutinous rice was washed and soaked for 16–20 hr in water kept <20°C. After soaking, the moisture content of the drained rice was 38% wb. The drained rice was crushed by rollers into fine powder and steamed in a pressure cooker at 115°C for 20 min. The resulting dough was kneaded eight times using a screw kneader. The kneaded cake was placed in a cake vessel and allowed to harden for three days at 2–5°C. Using a cutting machine, the hard cake was cut into small pieces with approximate dimensions of 4.5 × 1.3 × 0.4 cm. These small pieces of hard cake were dried by hot air at 45°C for 3–3.5 hr to a final moisture content of 20% wb and then baked at 300°C to obtain rice crackers.

Physical Evaluation of Glutinous Rice Crackers

The physical tests conducted on the rice cracker samples were volume expansion before and after baking, and textural characterization of rice crackers after baking. For each parameter, ten replicates were conducted for each treatment.

Volume Expansion Determination

The length and width of rice crackers before and after baking were measured using a Vernier caliper while the thickness was determined using a micrometer. Volume expansion was computed from these measurements.

Textural Determination

To eliminate the effects of varying moisture contents, samples of the product were stored in a desiccator for a minimum of one

week before analysis. Texture was measured on an Instron universal testing machine (UTM model 1140) fitted with a cylindrical probe. Each sample was placed on a 1.25-cm thick aluminum plate with a 1.6-cm dia hole to allow the probe to pass through after punching through the cracker sample. The crackers were punched through completely, and the peak resistance force during the test was recorded as the apparent hardness of the crackers. The hardness was evaluated using a 4.0-mm probe with chart and crosshead speed of 100 mm/min.

Statistical Analysis

Statistical analysis was conducted using analysis of variance (ANOVA). Significant calculated mean values were compared using Duncan's multiple range test at $\alpha = 0.05$ level of significance.

RESULTS AND DISCUSSION

Effects of Aging on Physicochemical Properties of Milled Glutinous Rice

Table I shows the physicochemical properties of RD6 and RD8 milled glutinous rice at different storage durations from 0 to 4 months. It was observed that the RD8 cultivar has significantly higher amylose content (6.85%) when compared to RD6 with only 5.93%. During four months of storage, amylose content of the two rice cultivars did not change significantly. Similar results during storage were reported by some investigators (Barber 1972, Villareal et al 1976, Indudhara Swamy et al 1978, Juliano 1985), while another reported that amylose and amylopectin fractions changed (Barber 1972). Chrastil (1990) found that amylose content in starch from rice grains stored for 12 months increased slightly during storage.

Protein content of both cultivars (7.18% for RD6 and 7.15% for RD8) did not differ significantly even after storage at various durations. Similar results (no change in total nitrogen content during storage) were reported by researchers (Barber 1972, Villareal et al 1976, Juliano 1985). Even though no gross chemical composition change in rice grain during storage was observed, Chrastil (1990) revealed that interactions between protein and starch may occur resulting in an increase in disulfide bonds and average molecular weight of oryzenin (storage protein in rice grain). Furthermore, the average molecular weight of amylose may decrease but that of amylopectin could increase during storage. Oryzenin could have interacted with starch by reversible binding with amylopectin or amylose. Moreover, Juliano (1985) reported that protein oxidation can be accelerated by free fatty acids formed from lipids which can form a complex with amylose, carbonyl compounds, and hydroperoxide.

Alkali tests for the two cultivars studied yielded the same results. The value obtained (7) indicated that both RD6 and RD8 had gelatinization temperature less than 70°C. All in all, the alkali test value and the amylose and protein content for RD6 and RD8 cultivars remain unchanged during storage from 0 to 4 months.

TABLE I
Some Physicochemical Properties of RD6 and RD8 Glutinous Rice^a

Cultivar	Storage Time (months)	Moisture Content (%)	Amylose Content (%)	Protein Content (%)	Alkali Test Value
RD6	0	13.28	5.77a	7.14a	7
	1	13.17	6.03a	7.09a	7
	2	13.22	5.93a	7.27a	7
	3	13.31	5.81a	7.18a	7
	4	13.53	6.09a	7.21a	7
RD8	0	13.79	6.76b	7.25a	7
	1	13.78	6.76b	7.15a	7
	2	13.84	6.89b	7.19a	7
	3	13.84	6.89b	7.06a	7
	4	13.91	6.95b	7.12a	7

^a Each value is the average of three replicates. Mean values followed by the same letter in the same column are not significantly different both at 1% and 5% significance levels by Duncan's Multiple Range Test.

TABLE II
Amylograph Characteristics of Fresh and Stored Milled RD6 and RD8 Glutinous Rice^a

Cultivar	Storage Time (months)	Gelatinization Temperature (°C)	Viscosity (Brabender Units)					
			Peak Viscosity	Final Viscosity	Cool to 50°C	Setback	Consistency	Breakdown
RD6	0	61.12 ± 0.38a	755 ± 15a	485 ± 15a	630 ± 10a	-125 ± 5a	145 ± 5a	270 ± 0a
	2	59.80 ± 1.00a	595 ± 35b	470 ± 20a	545 ± 45a	-50 ± 8b	75 ± 6.5a	125 ± 15b
	4	60.75 ± 0.00a	510 ± 0b	440 ± 0a	570 ± 0a	60 ± 0b	130 ± 0a	70 ± 0c
	8	61.50 ± 0.50a	390 ± 30c	307 ± 22.5b	422 ± 22.5b	32 ± 7.5ab	117 ± 2.5a	82 ± 7.5c
RD8	0	61.80 ± 0.30a	620 ± 10a	260 ± 0.0a	320 ± 40a	-300 ± 5a	60 ± 4a	360 ± 10a
	2	62.50 ± 1.00a	595 ± 15ab	300 ± 0.0b	425 ± 15b	-170 ± 0b	125 ± 15a	295 ± 15b
	4	62.02 ± 0.22a	555 ± 25bc	320 ± 10.0bc	440 ± 20b	-115 ± 5bc	120 ± 10a	235 ± 15c
	8	62.50 ± 0.50a	495 ± 5c	322 ± 2.5c	430 ± 10b	-65 ± 5c	107 ± 7.5a	172 ± 2.5d

^a Mean values followed by the same letter in the same column are not significantly different at 5% level by Duncan's Multiple Range Test.

Amylograph Characteristics

The values obtained from the amylograph (in BU) were peak viscosity, final viscosity on cooking at 94°C, and viscosity on cooling to 50°C. From these three values, breakdown is calculated as the decrease in viscosity (in BU) during cooking at 94°C; setback is the viscosity when cooled to 50°C minus peak viscosity; and consistency is the viscosity when cooled to 50°C minus final cooking viscosity at 94°C. The values for these selected parameters from the amylograph curves of rice samples of both cultivars stored for different durations are summarized in Table II.

The average gelatinization temperature of RD6 and RD8 cultivars when aged from 0 to 8 months were 60.79 and 62.21°C, respectively. Statistical analysis showed that all samples from each cultivar have no significant difference in gelatinization temperature for different storage durations.

From the amylograph curves of milled rice samples stored from 0 to 8 months, the RD6 cultivar showed significant decrease in peak viscosity, final viscosity on cooking at 94°C, viscosity on cooling to 50°C and breakdown value, while setback and consistency values were not altered significantly. On the other hand, no significant difference was observed for viscosity on cooling to 50°C and consistency during aging up to eight months for RD8 cultivar. Peak viscosity and breakdown value were reduced during

storage, whereas the final viscosity on cooling at 94°C and setback value increased with time.

The change in some of the amylograph properties during aging 0 to 8 months can be attributed to some characteristics of the starch granules. As reported by Whistler and Paschall (1965), the height of peak during the heating part of the cycle is a measure of the ability of the granules to swell markedly before rupture. The trend obtained for peak viscosity of both RD6 and RD8 cultivars shows that the starch granules of stored rice were more resistant to swelling than were those of fresh rice. The decrease in breakdown value indicated that the capacity of the starch granules to rupture after cooking was reduced significantly due to aging.

The decrease in peak viscosity and breakdown value of the cultivars studied seemed to contradict the results of some previous studies (Villareal et al 1976, Perez and Juliano 1981, Bean et al 1984). Nevertheless, the final viscosity on cooking at 94°C and setback value for RD8 cultivar increased during aging which is in agreement with the reported results of these previous studies mentioned.

Varying trends in amylograph pasting viscosity had been observed in previous studies during storage of both waxy and nonwaxy rice. Some reports showed increased viscosity in stored rice (Barber 1972, Villareal et al 1976, Indudhara Swamy et al

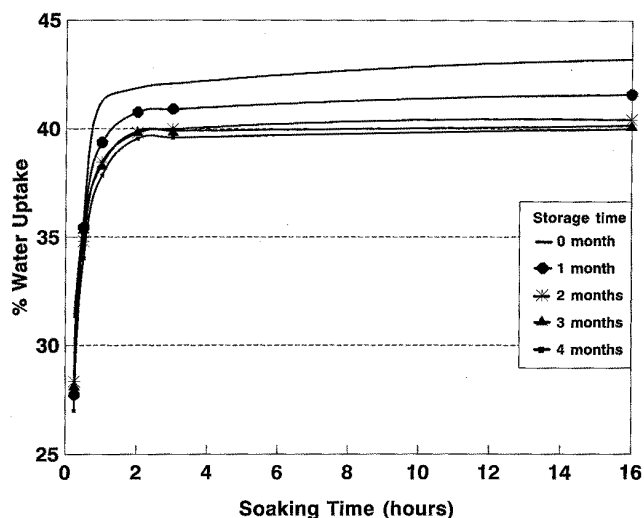


Fig. 1. Water uptake during soaking of milled glutinous rice (RD6) stored for durations from 0 to 4 months.

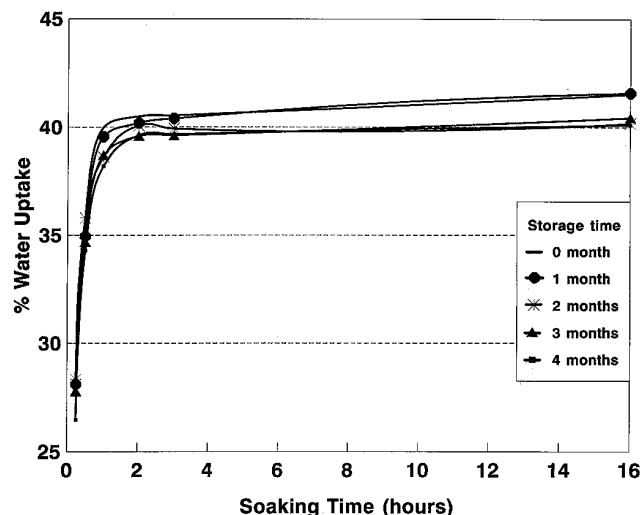


Fig. 2. Water uptake during soaking of milled glutinous rice (RD8) stored for durations from 0 to 4 months.

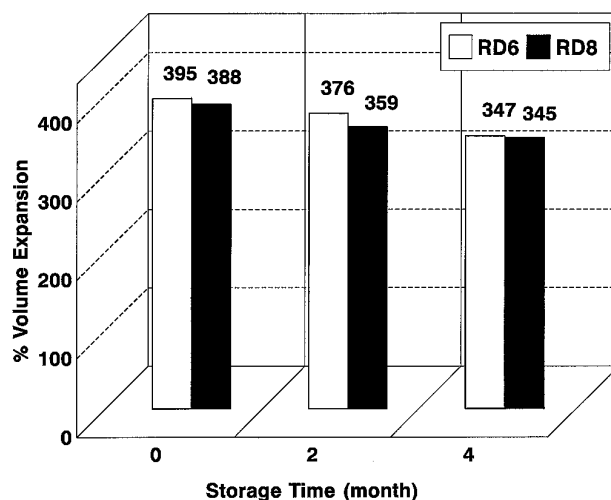


Fig. 3. Volume expansion of crackers made from RD6 and RD8 rice cultivars stored for durations from 0 to 4 months. Standard error $\pm 8\%$ at 5% significance level for 10 replicates.

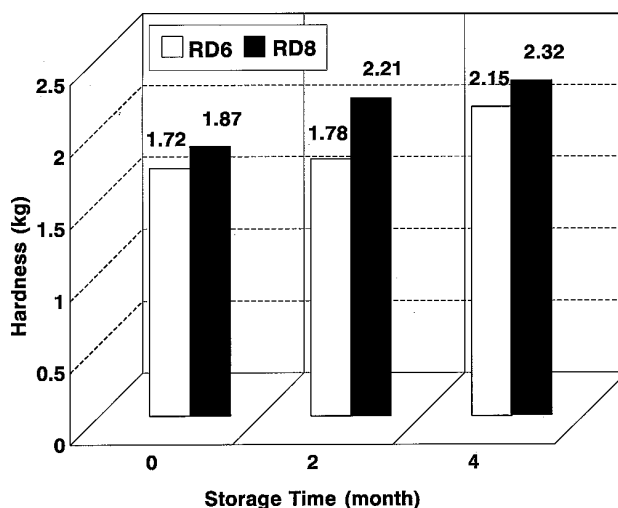


Fig. 4. Hardness of crackers made from RD6 and RD8 rice cultivars stored for durations from 0 to 4 months. Standard error ± 0.13 kg at 5% significance level for 10 replicates.

1978, Perez and Juliano 1981, Bean et al 1984, Juliano 1985), while others found no significant change such as in stored Japanese rice (Juliano 1985) and Spanish rice (Barber 1972). On the other hand, Juliano (1985) reported lower peak viscosity in starches prepared from stored Taiwan rice.

As described by Juliano (1985), the aging mechanism involves lipids, protein, and starch. Lipids form free fatty acids that can form a complex with amylose and carbonyl compounds as well as hydroperoxide. These complexes can accelerate protein oxidation and condensation plus accumulation of volatile carbonyl compounds. Protein oxidation, together with an increase in the strength of micelle binding of starch, inhibits swelling of starch granules and affects cooked rice texture. Protein oxidation also reduces the level of volatile sulfur compounds. The relatively high α -amylase activity in freshly harvested grain has been considered as the possible mechanism for the pastiness of cooked freshly harvested rice. However, α -amylase is concentrated in the bran fraction, thus the residual α -amylase activity in milled rice is low and cannot be considered as the cause of low amylograph viscosity of waxy milled rice flour.

Water Uptake of Raw Milled Glutinous Rice

In Asian societies where rice is a dietary staple, rice is commonly soaked in water for several hours before cooking. The water uptake during this hydration period serves as a useful criterion for quality evaluation of rice cultivars. Trends of water uptake of RD6 and RD8 cultivars are shown in Figs. 1 and 2, respectively.

The data obtained showed similar trends for the two cultivars. Water was absorbed rapidly in the first hour and reached steady state in about 2 hr. Freshly milled rice had the highest water uptake rate followed by rice stored for 1, 2, 3, and 4 months, respectively. Most of the water was taken up in 1 hr and as Bean et al (1984) reported, equilibration of moisture throughout the kernels took place for the remainder of the soaking period.

Stored rice takes more time to reach the same level of water uptake as fresh rice. This phenomenon, however, does not affect the quality of glutinous rice crackers due to the long period of soaking (16–20 hr) done during processing. Soaking time for these two glutinous rice cultivars (stored for 0 up to 4 months) may be reduced to durations less than the original rice cracker process and still achieve the desired effect since prolonging the soaking period beyond the point when the water uptake rate becomes almost steady-state does not significantly increase the total water uptake.

Effect of Aging on Quality of Glutinous Rice Crackers

Processing of glutinous rice crackers ends with baking at high temperature during which the dried rice cakes expand to the desired shape and size. The quality of the final product can be evaluated in terms of volume expansion and hardness of the rice crackers.

Volume Expansion of Glutinous Rice Crackers

As presented in Figure 3, these two cultivars (RD6 and RD8) showed the same trend of volume expansion even at different storage times (from 0 up to 4 months). Statistical analysis showed that the volume expansion of crackers made from the two cultivars were not significantly different. Volume expansion of crackers made from fresh rice (395%) and milled rice stored for two months (376%) for RD6 cultivar were also not different significantly. At the 95% significance level, rice stored for four months has significantly lower volume expansion (347%) compared to rice stored for two months. An almost similar trend was obtained for RD8 cultivar. Fresh rice and rice stored for two months have significantly different volume expansion (388% and 359%, respectively), but rice stored for four months (345%) gave no significant difference relative to the rice stored for two months. Volume expansion was the most important characteristic of rice snacks

and cracker products (Li and Luh 1980). However, various cereals and starches do not expand equally due to differences in the quality of its component materials. The branched structure of starches and their constituents seem to control expansion of cereals. Chinnaswamy (1993) reported that changes in the branched fraction of starches greatly affect volume expansion. During aging, changes in the starch structure and components occurred (as reported by Bean et al 1984), causing the decrease in volume of crackers made from stored rice. Volume expansion data for crackers made from rice stored at different durations could be useful in setting the process conditions for manufacturing rice crackers. To produce better quality rice crackers, appropriate processing conditions can be modified to make use of the desirable properties of fresh and aged milled rice, taking into account the difference in cost of each type.

Hardness of Glutinous Rice Crackers

The hardness of crackers was determined by probing method. As shown in Figure 4, both cultivars showed the same trend of hardness at different storage durations. Hardness tended to increase with storage time although the hardness of crackers made from fresh rice and rice stored for two months were not significantly different. Crackers made from rice stored for two and four months also gave no significant difference in hardness at the same level of significance.

Hardness of crackers seemed to correlate negatively with its volume expansion. Higher hardness values were observed for crackers with less volume expansion and vice versa, thus the effect of aging influenced both volume expansion and hardness of glutinous rice crackers.

The change in some amylograph properties of the stored rice affected both the volume expansion and hardness of rice crackers. The reduction in the peak viscosity during aging and the increased resistance of starch granules to swelling may have affected the volume expansion and hardness of the rice crackers.

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