Rice Flour Treatment for Cake-Baking Applications[1]

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ABSTRACT

Treatment with water just before use can enhance the funtionality of rice flour in baked products. Hydration with intense mixing and/or holding time improves eating quality, volume, and appearance of layer cakes made from 100% rice flour. Development of reducing sugars during long hydration may account for color improvement, but it is assumed that changes in protein and/or other components are involved in functional improvements. Flours from U.S. short- and medium-grain rices gave superior cake textural characteristics compared to those from U.S. long-grain rice. Baked products from rice flour may be used by those on allergy-restricted diets that do not permit consumption of wheat products.

Rice (*Oryza sativa*) is second only to wheat in tonnage produced. Some rice production and processing can be found on every continent. In areas in which rice is the principal food consumed, products made from rice are many, varied, and often novel. In the United States, the range of products is more limited, with most choices associated with processing differences for white or brown whole-kernel rice. Broken rice is used mainly as a brewing adjunct or is processed as a cereal or thickening agent. Flour from rice is used primarily as a dusting flour or in baby food. In its various forms, rice has considerable use for those allergic to wheat or other grains. It is usually the first cereal added back to an elimination diet designed to determine specific cereal allergies. Wheat gluten-intolerant patients depend on rice as an important source of carbohydrate.

Previous research at this laboratory yielded a yeast-leavened 100% rice flour bread (Nishita et al 1976) that is now used successfully in commercial and home applications, particularly for the gluten-intolerant. Later studies have defined physicochemical and milling characteristics of flours suitable for baking breads from 100% rice or with rice as a composite flour adjunct (Nishita and Bean 1979, 1982). This paper describes a formula for a rice layer cake and a treatment of rice flour which markedly improves its functionality in the cake system.

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[4] Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that also may be suitable.

MATERIALS AND METHODS

Two lots of rice flour ground from aged California short/medium-grain rice were obtained from C. E. Grosjean Rice Milling Co., San Francisco, CA. A long-grain rice flour was obtained from Riviana Foods, Inc., Houston, TX. All flours were held at −23°C until needed. Pertinent physicochemical characteristics are shown in Table I. No functional property differences important in cake baking were observed between the two lots of short/medium-grain rice flours. They were used interchangeably in flour treatments.

Gelatinization temperatures were determined in the amylograph according to Nishita and Bean (1979), as modified from the method of Halick and Kelly (1959). A 50% sucrose solution (w/w) containing 246 g of sucrose and 246 g of water to yield 400 ml of solution was prepared for a 20% rice flour slurry. Rice flour (12% m.b.) was added to water or sucrose solution while agitating with a magnetic stirrer.

Amylose content was determined at 620 nm by the method of Juliano (1971). Reducing sugars, measured as glucose, were determined by the method of Bernfeld (1955).

Layer Cake. The basic method was a formula modification of the Wooster lean cake formula (Kissell 1959). Quantities for one 6-in. cake are shown in Table II for a conventional-mix (dry flour) control cake. The pan was greased lightly, and the bottom was lined with parchment paper. The flour, sugar, and baking powder were sifted together and transferred to a 3-qt Hobart C-100 mixing bowl. The oil and water were added and the ingredients mixed with a flat beater at low speed for 1 min. The bowl was scraped down, and the contents mixed at high speed for 4 min. The bowl was scraped down again, and the mixture mixed at high speed for 4 min. Three hundred grams of the batter was baked at 177°C (350°F) for 32 min. The cake was cooled in the pan overnight and was dusted lightly with sugar before its volume was determined by rapeseed displacement.

Procedure for Treated Flour. To achieve an improved flour, the above procedure was modified so that the flour would be hydrated with formula water before the remaining dry ingredients and oil were added. Sufficient flour and water for one or more cakes were mixed with a flat beater in a Hobart C-100, 3- or 10-qt mixing bowl as follows: low speed for 1 min; scrape down; high speed for time periods determined for each experiment. If a multiple batch was mixed, an aliquot (306 g) was removed for each cake to which remaining ingredients were added, mixed, and baked as described. The bowl containing the remaining flour-water dough was covered tightly with a piece of aluminum foil and placed into storage if appropriate.

Variables studied in relation to the flour-hydration stage included mixing time and speed, temperature of water added, and temperature and time of holding flour-water mixture. In an additional experiment, one or more ingredients (sugar, baking powder, oil) were incorporated into the flour-water mixture during the hydration stage, and the results were examined.

Cake volumes were measured the next day by a rapeseed-displacement method. Cakes were judged for eating-quality changes at the lab bench by experienced bakers. Consideration was given chiefly to gummy and pasty characteristics. All cake treatments were baked at least twice.

TABLE I
Some Physicochemical Characteristics of U.S. Rice Flours

	Short/Medium A	Short/Medium B	Long C
Water, %	12.59	13.43	11.53
Nitrogen,[a] %	1.19	1.14	1.54
Protein (% N × 5.95)[a]	7.08	6.78	9.16
Fat,[a] %	1.11	1.02	1.31
Fiber,[a] %	0.39	0.31	0.40
Ash,[a] %	0.56	0.67	0.55
Amylose,[a] %	19.9	18.9	22.6
Gelatinization temperature, °C			
In water	62.0	62.0	72.0
In 50% sucrose	80.0	80.0	92.0

[a] Moisture-free basis.

TABLE II
Basic Rice Layer-Cake Formula

Ingredient	Composition (flour basis, %)	Quantity (g)
Rice flour (14% m.b.)	100.0	170.0
Sugar, fine-granulated sucrose	80.0	136.0
Baking powder, SAPP double acting[a]	5–7.0	8.5–11.9
Oil, refined vegetable, no emulsifier	15.0	25.5
Water	80.0	136.0

[a] Baking powder level can be adjusted for altitude (Yamazaki 1970).

RESULTS AND DISCUSSION

Initial layer-cake trials used the Wooster lean formula (Kissell 1959) for wheat flour cakes as a point of departure. This formula contains no milk or eggs, in order to have a critical test for wheat flour quality. Because development of a rice cake for allergy uses was one of the goals of our project, omission of milk and eggs was a first consideration.

To achieve maximum layer-cake quality characteristics (ie, contour, texture, and volume), optimum water absorption was lower for rice flour than for wheat flour. With the lean formula, wheat flour absorptions are usually above 100% with chlorinated and unchlorinated flours, whereas the rice flour cake was optimized at 80% absorption (Table II). The well-documented differences between wheat and rice flours in protein properties, starch-granule sizes, and gelatinization behavior probably account in a major part for the difference in absorption requirements. Rice protein does not form a hydrated gluten structure as wheat does. Rice starch granules are uniformly small (4–7 μm). Wheat starch has approximately 4% small (4–7 μm) granules, but most granules are 25–50 μm. Cooked rice pastes do not form gels as firm as those of wheat pastes.

When water is decreased substantially in a cake formulation, a more concentrated sugar solution results. This is the significant liquid medium for starch gelatinization and swelling in a layer-cake system and must be optimized for each formula (Bean and Yamazaki 1978, Bean et al 1978). In this rice cake formula, 80% sugar and 80% water provided a 50% sucrose solution in the batter. Complete batters having this composition gave cakes with optimum volumes and contours, suggesting that starch gelatinization and granule swelling had most likely occurred concurrent with maximum batter expansion. Amylograph studies indicated that a 50% sucrose solution delayed rice-starch gelatinization and swelling until a temperature range just above 80°C, as measured by initial viscosity increase in a 20% slurry (Table I). Results (discussed later) with long-grain rice flour indicated the importance of an amylograph initial gelatinization temperature near 80°C in this formula.

Vegetable oil was preferred over shortening because it gave a finer rice cake that was not crumbly. The texture can also be improved with addition of eggs or milk. Low levels of several gums, surfactants, or soy protein isolates diminished the gummy or pasty texture. It is of interest that chlorination did not improve cake-baking properties of the rice flour. Because a simple hydration treatment improved the cake texture, its potential for rice flour modifications in the absence of other structural ingredients was studied.

Flour Treatment

In preliminary studies on yeast-leavened rice breads, we observed a noticeable improvement in bread texture when wet-milled rice flour was used instead of dry-milled flour. The wet-milling process necessitated removal of water in excess of that needed in the product formulation, or alternatively, complete redrying and remilling to a flour. The method presented here provides a similar improvement and uses the amount of dry-milled rice flour and water needed for preparation of the final baked product.

Treatment of rice flour for improvement is based on hydration of the flour over time. Three factors are significant and interdependent in the treatment: intensity of mixing; hydration time and temperature of hydration; and temperature of the water.

Figure 1 shows some changes that occur in layer cakes with the hydration treatment. The first cake was made in a conventional manner with the dry ingredients (flour, sugar, and baking powder) blended together before oil and water were added. The middle cake was made from flour hydrated with water, mixed for 1 min at low speed and 4 min at high speed in a Hobart C-100 mixer, after which the other ingredients (sugar, baking powder, and oil) were added, and the batter then mixed as for the conventional cake and baked. The last cake was obtained when the same hydrated mixture was held 6 hr at room temperature before the remaining ingredients were added. The hydration step improved volume and reduced pastiness compared to the conventional dry-mix procedure. The holding time of 6 hr promoted marked improvement in crust color and volume, and eating quality was no longer gummy or pasty. These cakes had a pleasant, acceptable texture.

Improvement in crust color with hydration time was most likely due to an increase in reducing sugars (measured as glucose), from 0.41% in the untreated flour to 1.25 and 2.15% in flour hydrated 18 hr at 4 and 22°C, respectively. Glucose (2%) was added to the formula to obtain the same golden brown crust color comparable to that obtained by hydration treatment, but simple glucose additions could not improve volume or eating quality of cakes made with unhydrated flour.

Intensity of Mixing

The effect of mixing speed during the hydration stage on cake quality is demonstrated in Table III. With no holding period, the remaining cake ingredients (sugar, baking powder, and oil) were added immediately after hydration, and the batter mixed and baked as described for the basic method. Cake volume increased slightly over that of the dry control when hydration was accomplished by mixing 1 or 2 min at low speed, sufficient only to blend the flour and water. When high-speed mixing was used in the hydration step, additional improvement in volume occurred up to 492 cc at 1 plus 4 min of mixing. Lack of improvement with minimum mixing of 1 min was overcome when the hydrated flour was allowed to stand at room temperature for 24 hr. Cake volume increased to 522 vs 462 cc with no holding time.

Of importance also is the improvement in eating quality with hydration. "Satisfactory" (Table III) denotes a significant decrease in the pasty characteristic when intense mixing was used in the flour hydration step. The 24-hr holding period gave the most improvement and also produced a brown crust color in the resulting cake, similar to that shown in Fig. 1.

Holding Conditions

Table IV shows cake volume changes due to the interdependence of time and temperature of holding the hydrated rice flour. Seven percent baking powder was used in this set, so all volumes are higher. Eating quality improvements were independent of actual cake volumes, but occurred concurrent with volume increases within an experiment. Treated flours were mixed in batches sufficient for six cakes at each holding temperature. Mixing conditions were 1 min on low, then 4 min at high speed with 80% water at room temperature. After removal of zero-time aliquots, batches were held for times (2 hr to five weeks) appropriate to the experimental temperatures (+77 to −25°C) before the remaining ingredients for cake baking were added. All hydrated samples were brought to room temperature before mixing cake batters. With all samples, the temperature of the storage chamber markedly affected the rate of improvement. At higher temperatures (22–77°C), cake volumes increased at shorter holding times. At lower temperatures (−25 and +4°C), cake volumes increased only slightly with storage compared to hydration alone with no holding time. Cake volumes that are italicized indicate improved eating quality. Improvement occurred after 2 hr at 60 and 77°C, while 6–12 hr holding time was necessary at lower holding temperatures, and 5 weeks were required at freezer temperatures. These results indicate that several

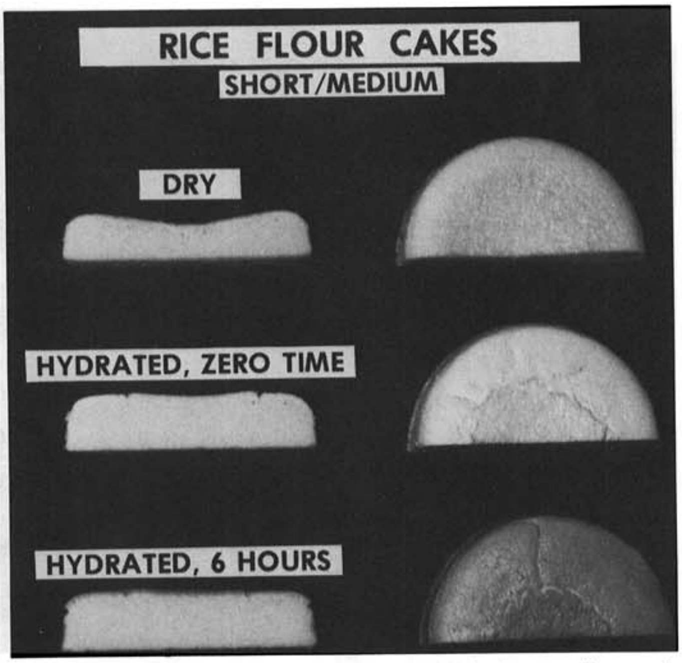

Fig. 1. Layer cakes made from rice flour from U.S. short/medium-grain rices showing effect of hydration (center cake) and of holding hydrated flour (bottom cake).

TABLE III
Effect of Hydration Mixing Speed on Rice Cakes[a]

Hydration Time (hr)	Mixing Time (min) at Speed: Low	Mixing Time (min) at Speed: High	Cake Volume (cc)[b]	Eating Quality
None	None	None	435	Unsatisfactory
0	1	0	462	Unsatisfactory
0	2	0	472	Questionable
0	1	2	477	Satisfactory
0	1	4	492	Satisfactory
0	1	8	488	Satisfactory
24	1	0	522	Satisfactory +

[a] Five percent baking powder used.
[b] Pooled standard deviation = ±19.7.

TABLE IV
Interdependence of Time and Temperature of Holding Hydrated Rice Flour[a]

Flour	Hydration Time	−25	4	22	35	60	77
		Rice Layer-Cake Volume (cc)[b,c] at Storage Temperature, °C					
Untreated control	None	479	480	480	482	492	480
Treated	0 hr	544	542	542	555	548	532
	2 hr	···	558	562	590	*588*	*588*
	4 hr	···	560	572	592	*600*	···
	6 hr	···	568	*570*	*595*	···	···
	12 hr	···	*565*	···	···	···	···
	2 weeks	565	···	···	···	···	···
	5 weeks	*568*	···	···	···	···	···

[a] Seven percent baking powder used.
[b] Italicized values indicate improved eating quality.
[c] Pooled standard deviation = ±10.2.

hours of hydration at temperatures between 22 and 35° C are most efficient for enhancing rice flour quality for this baking application. Limited tests using higher water temperatures up to boiling indicated that a water temperature of 60° C in conjunction with some holding time was feasible.

Table V summarizes cake volume effects of ingredient additions

TABLE V
Effect of Ingredients on Hydration Improvements[a]

	Cake Volume (cc)[b]	Rice Flour Hydrated With			
	555	Water	Oil		
Hydrated control	550	Water			
	508	Water	Oil	Sugar	
	515	Water	Oil		Baking powder
	502	Water		Sugar	
	495	Water			Baking powder
	472	Water		Sugar	Baking powder
Dry control	475	Water	Oil	Sugar	Baking powder

[a]Seven percent baking powder used.
[b]Pooled standard deviation = ±6.0.

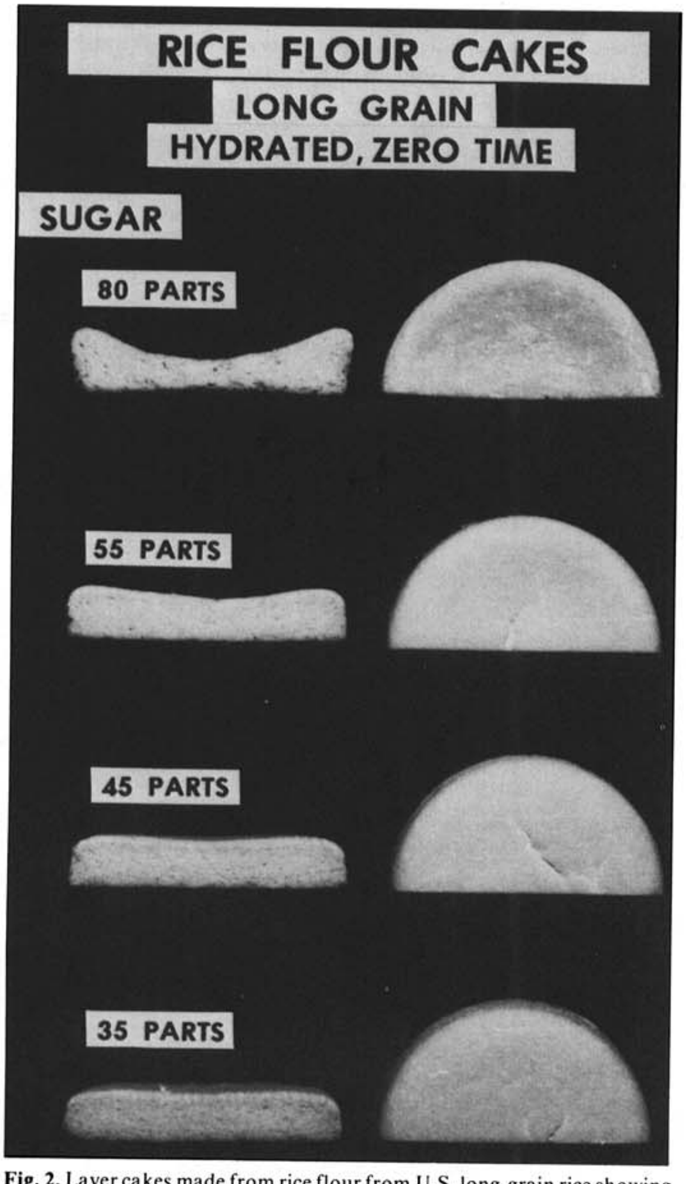

Fig. 2. Layer cakes made from rice flour from U.S. long-grain rice showing need to adjust sugar level to lower gelatinization and swelling temperature range of rice starch.

to the water during the initial hydration stage. Single ingredients or combinations were incorporated with the flour and water at room temperature (with no holding time), using 1 min low speed and 4 min high speed. Remaining ingredients were then incorporated to complete the cake batter stage, using 1 min low speed and 4 min high speed.

Only the addition of oil with water in the hydration stage gave volume improvements greater than water alone. Least improvement occurred when baking powder was included in hydration with or without sugar. Although negative results with baking powder are expected from a probable loss of leavening with the extra mixing, lower results with sugar are more speculative. They may be due to competition from the sugar for the water, resulting in incomplete hydration of the rice flour. Studies on sugar's effect in cake-baking systems have followed starch gelatinization behavior, but few have addressed sugar's role in the behavior of other flour components in batters or during baking.

Long- vs Short/Medium-Grain Rice Flour

Flours from U.S. short- and medium-grain rices, having low amylose contents and low gelatinization temperatures, are preferred over those from U.S. long-grain rices for baking applications. Cake results (Fig. 2), substituting flour from a U.S. long-grain rice, highlight part of the problem. The first cake was made from the same formula that was optimized for the medium-grain rice and used 80% sugar and 80% water. The collapsed center is typical of cake formulas with too much sugar in relation to water. This batter had expanded excessively during baking to a very high volume before collapsing. This sugar to water ratio provided a 50% sugar solution in the batter and delayed starch gelatinization and swelling of the long-grain rice until 92° C (Table I). This was too late in the baking process to set the cake structure to coincide with maximum leavening activity. In water, the long-grain rice flour has an amylograph gelatinization temperature that is about 10° C higher than that for the medium-grain, and this difference continues to exist but at higher temperatures in concentrated sugar solutions (Table I). Because the long-grain rice could not accommodate more water, the sugar level was decreased to lower the sugar solution concentration. This, in turn, lowered the gelatinization and swelling temperature range of the starch. The third cake, using 45 parts of sugar to 80 parts of water (giving a 36% sugar solution) was considered optimum for the long-grain rice. The 36% sugar solution (data not shown) allowed gelatinization and swelling of the long-grain rice starch to occur in a temperature range just above 80° C, similar to that for the medium-grain rice in a 50% sugar solution.

Results of hydration studies of the long-grain rice flour (data not shown) using this lower sugar level (45%, flour basis) produced similar volume increases and color development, as was noted for the medium-grain rice flours in Fig. 1.

Long-Grain Rice Texture Problems

Whereas formula adjustments and hydration can improve long-grain rice flour properties, similarities with medium-grain flour cakes are limited to appearance factors. Cakes from U.S. long-grain rice flour were considerably less sweet, which may not be a fault, but eating quality was unacceptable. Cakes were dry and grainy, typical of other baked products made with U.S. long-grain rice flour (Nishita and Bean 1979). This confirms the importance of selecting proper rice types for baking applications. The dry, grainy crumb texture contributed by long-grain rice reflects the dry and flaky cooked rice characteristics preferred in whole-kernel long-grain white rice.

CONCLUSIONS

Hydration studies provided unexpected modifications of rice flour. Although changes in cake performance could be documented, they could not be explained. It might be theorized that changes in both protein and starch are involved in structural improvements in these cakes. Intense mixing of flour and water may free some starch granules from the larger endosperm chunks and thus increase their functionality. Hydration at high treatment temperatures can cause incipient gelatinization of starch, a treatment that was found to improve eating quality of layer cakes made with unchlorinated wheat flour (Hanamoto and Bean 1979, 1981).

Rice proteins occur in the endosperm, chiefly as intact spherical protein bodies ranging in size up to 2 μm. Mitsuda et al (1967, 1969) and Tanaka et al (1980) have isolated two types of protein bodies from rice, and Bechtel and Pomeranz (1978) have identified a third type. They are not easily disrupted in water and retain their shapes in the fractionation and separation steps necessary for their isolation. This behavior is in sharp contrast to the fibril formation we can see under the microscope when wheat flour is wetted (Bernardin and Kasarda 1973).

Mitsuda et al (1967) found that rice protein bodies were easily broken down or aggregated during vigorous homogenization or high-speed centrifugation. Feillet[5] and co-workers in France noted that a small amount of "gel" protein is formed from rice flour that has been kneaded as a dough. No "gel" protein is obtained from rice that has not been kneaded. The significance of this relates to the importance of "gel" proteins in wheats for superior bread-making functionality (Jeanjean and Feillet 1978). Thus, if kneading rice flour doughs might bring about formation of "gel" proteins, then perhaps a potential wheatlike structure might be formed in rice flour during mixing and hydration with water. In early studies, an improvement was observed in the strength of the crumb grain of yeast-leavened rice bread made with wet-milled or with hydrated flour prepared as described in this report.

Lipids might be involved in rice flour changes. They are found intimately associated with isolated protein bodies (Mitsuda et al 1967, Tanaka et al 1978). Considerable work has been reported on the effects of lipid on eating quality of cooked rice (Barber 1972), and parallel effects may influence baked products from rice flour.

Use of rice and other nonwheat flours is increasing in a variety of foods, including those for the allergic person. A new look at their functional properties in baked systems that do not include wheat could provide useful information not only for baked products but for novel, engineered foods as well.

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