Characteristics of Muffins Containing Various Levels of Waxy Rice Flour

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Cereal Chem. 67(2):114-118

ABSTRACT

Characteristics of muffins containing 5, 15, and 25% replacement levels of waxy rice for wheat flour were evaluated using physical test methods and a trained sensory panel. The experimental muffins and the reference standard wheat product were found to differ with respect to several characteristics. However, the sensory panel evaluated all characteristics to be "moderately close" to "very close" matches with the reference muffin. No significant differences were found among test muffins and reference standard regarding tenderness, volume, and flavor characteristics. The muffin containing 5% waxy rice for wheat flour was significantly taller than the reference standard or the other muffins. Physical evaluations showed that all waxy rice products retained more moisture during baking than the reference standard muffin. Tenderness of all products decreased at a similar rate following 9 and 33 hr of room temperature storage and seven days at freezer temperature.

Waxy rice is a minor crop in the United States. It also is identified as glutinous or sweet rice, terms descriptive of its characteristics and uses. When cooked, waxy rice tends to lose its shape and becomes sticky (Webb 1985). Waxy rice contains higher levels of free sugars, specifically maltooligosaccharides, than nonwaxy types (Pascual et al 1978). Additionally, it is differentiated from other rices on the basis of granule density, gel viscosity, and high amylopectin content (Juliano 1985).

The superiority of waxy rice starch as a thickening agent for items that undergo freeze-thaw cycles has been known for several years (Hanson et al 1951, Hanson et al 1953), but due to economic factors and the availability of modified starches and other additive ingredients, the use of waxy rice flour to impart stability to products during frozen storage is not common (Bean et al 1984). Bean and co-workers suggested using waxy rice flour in baked products subjected to frozen storage conditions. They found that waffles containing 10-15% waxy rice substituted for wheat flour retained fresh product characteristics after frozen storage and reheating. Earlier, it was demonstrated that up to 25% of nonwaxy flour may be replaced with waxy rice flour without affecting the volume of yeast-leavened bread (Nishita and Bean 1979).

A recent study (Johnson 1988) revealed that products containing 25% replacement of waxy for nonwaxy rice flour in muffins using rice flour as the only cereal source were preferred by sensory panelists. The waxy rice product was reported to be sweeter than the wheat flour standard. Physical test data revealed that the waxy rice flour is equivalent to sodium alginate and xanthan gums in retaining moisture during baking; however, products containing all rice flour were significantly less tender than the standard. Exterior appearance and standard height, though not volume, were sacrificed by the addition of the waxy rice flour. The gummy texture was noted to be a disadvantage for all the rice flour products. Bean et al (1983) found that cakes prepared using long-grain rice flour had a grainy and dry crumb texture. Perez and Juliano (1988) reported that a sensory panel found fermented cakes prepared using low-amylose flour to be less acceptable because of their sticky and mushy texture than products made from high- and intermediate-amylose rices.

A limited amount of study using nonwaxy rice has been conducted concerning the effects of various flour and product preparation techniques on the characteristics of baked goods. It was reported that the appearance and mouthfeel characteristics of

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baked products are improved by hydrating and intensely mixing the rice flour before use and altering the temperature of the added water, regardless of the rice grain type used (Bean et al 1983). Rice breads with the largest volumes were made from flour produced using mills that created larger flour particles, thereby reducing damage to the starch granules (Nishita and Bean 1982). Chinese scientists found that flour made from raw rice produced more acceptable products than when the items were made from drum-dried or roasted flour (Bean and Nishita 1985).

Previous works have indicated the advantages as well as the disadvantages afforded to baked goods as a result of adding waxy rice flour to products. This project was undertaken to describe the quality characteristics of a quick bread product containing various substitution levels of waxy rice flour. Physical and sensory tests were performed using fresh products as well as those stored at room and freezer temperatures.

MATERIALS AND METHODS

Product Preparation

A standard muffin formulation (Rombauer and Becker 1964) was used to prepare the products. Ingredients (on percent flour basis) were as follows: wheat flour (Pillsbury, all-purpose) and waxy rice flour (Calmochi, 101), 100%; sucrose (Spreckles, granulated), 16.7%; baking powder (Clabber Girl, double-acting), 5.7%; salt (Crown Colony), 1.5%; eggs (Lucerne, fresh), 20.0%; oil (Wilsey, refined vegetable), 20.0%; and milk (Lucerne, fluid, whole), 100.0%. Experimental muffin formulations consisted of 5, 15, and 25% replacements of wheat with waxy rice flour. Milled waxy rice (variety Calmochi 101) was obtained from the Rice Research Foundation, Inc., Biggs, CA, and stored in moisture- and vapor-proof containers until needed. Immediately prior to the commencement of this study, the waxy rice flour was produced using a Samap commercial stone mill, type 380, at the Lundberg Family Farms, Richvale, CA. Flour particles that passed through a 100-mesh (U.S. Standard sieve) screen on a Ro-Tap testing sieve shaker after 10 min of shaking were used in this project.

The mixing procedure finalized following a pilot study involved placing the wet ingredients in the 3-qt bowl of a KitchenAid mixer (model K-5SS) and whipping at speed 4 (120 rpm) for 1 min. The sifted dry ingredients were added and blended using the flat paddle at speed 1 (76 rpm) for 4 sec before scraping the bowl and paddle. Batter samples (50 g) were weighed into each muffin cup of an aluminum pan (Ekco, 7.2 × 3.27 cm) that had been sprayed with a nonstick pan coating substance. Products were baked in a preheated oven (General Electric, model J355002 WH) for 22 min at 204°C (400°F).

Following a 5-min setting period, the muffins were removed from the pans and allowed to cool on wire racks for 1 hr before being packaged in moisture- and vapor-proof wrap material for use in various physical and sensory tests. Products to be evaluated 9 and 33 hr after baking were stored at room temperature, whereas those evaluated one week after baking were stored at −10°C. The frozen samples were thawed, covered, at room temperature for 9 hr prior to testing. Order of preparation of the variables, placement in oven, and selection of muffins for various tests were performed according to a predetermined plan using a random number table (Snedecor and Cochran 1980). Three replications were conducted.

Sensory Evaluation

Sensory analyses were conducted by a panel of nine selected judges from 20–40 years old. Prior to the data collection period, all judges participated in training sessions, during which the panelists were familiarized with test techniques and procedures. The group discussed the evaluative terminology and the characteristics of the products to be evaluated. Sensory tests were conducted in white booths in a room with controlled environmental conditions.

Immediately prior to each evaluation session, panelists were presented with a reference standard product and three experimental muffins representing the three levels of waxy rice replacement for wheat flour. Nine quality characteristics were evaluated for each muffin by sensory comparison with the 100% wheat flour reference standard product. These characteristics included height, appearance of exterior surface, exterior color, grain, interior color, moistness, tenderness, flavor, and mouthfeel. The score card used by the panelists included a nine-point bipolar scale derived from a modification of the Multiple Comparison Procedure (Mahoney et al 1957). A score of one indicated that the quality was absent from the test muffin, whereas a score of nine denoted that the quality was absent from the standard. A score of five represented a complete match of the characteristic between the reference standard and the test muffin. Point values deviating upward or downward from five represented the following descriptions: very close, moderately close, slightly close, and quality absent.

The experimental design was a randomized complete block. Additionally, the order of presentation, selection of products for each panelist, and the code number of samples were prearranged (Snedecor and Cochran 1980).

Physical Evaluations

Several physical tests were performed 9 and 33 hr after baking and after seven days of frozen storage. Determinations made on the fresh samples only included volume, weight loss during baking, and standing height. Volume was determined using the rapeseed displacement method. Weights after baking were obtained to allow the computation of water loss during baking. Ruler measurements determined the standing height of each item. Penetrometer (Ser. no. 13, AE; Precision Scientific) values using 65-mm, 14-g cone and texture press (model S-2H; Food Technology Corp.) readings were obtained for all products 9 and 33 hr and seven days post-baking to infer tenderness. Colorimeter (Gardner XL-23) values were recorded for all test muffins from previously frozen products at the conclusion of the project. All testing was done in duplicate.

Statistical Analysis

Three-way analysis of variance was performed on the sensory data. Independent variables included storage time, treatment, and replication. Dependent variables were the measured quality characteristics. Two- and three-way analyses of variance were performed on the physical evaluation data. Independent variables included treatment and replication, and in some instances, length of storage. Dependent variables were the measured quality characteristics of the products. Where appropriate, the Student-Newman-Keul's multiple comparisons test was performed.

TABLE I
Effect[a] of Waxy Rice Flour Substitution on Sensory Characteristics of Muffins

	Substitution					
	5%		15%		25%	
Characteristic[b]	Mean	SEM	Mean	SEM	Mean	SEM
Height	5.1 a	0.11	4.6 b	0.16	4.4 c	0.12
Exterior surface	4.5 a	0.16	4.3 b	0.14	4.0 c	0.11
Exterior color	4.4 a	0.16	4.2 a	0.17	4.0 b	0.19
Grain	4.9 a	0.24	4.6 b	0.23	4.6 b	0.20
Moistness	4.7 a	0.14	5.1 b	0.19	5.3 c	0.12
Mouthfeel	4.6 a	0.12	4.3 b	0.13	4.0 c	0.13
Interior color	4.7	0.12	4.8	0.20	4.7	0.15
Tenderness	4.7	0.17	4.6	0.19	4.6	0.17
Flavor	5.1	0.16	4.9	0.20	4.8	0.21

[a]Each mean is the average of values obtained from three replications, two samples/replication, for 9 and 33 hr at room temperature and seven days of storage at freezer temperature. Means within rows followed by different letters are significantly different ($P < 0.01$) from each other. 5 = complete match with standard.

[b]Mean square error: height = 1.129; exterior surface = 0.334; exterior color = 0.779; grain = 0.378; moistness = 1.241; mouthful = 0.645; interior color = 0.232; tenderness = 1.633; flavor = 1.035; df = 16.

RESULTS AND DISCUSSION

Analysis of variance of the sensory and physical evaluation test data revealed that the independent variable treatment was the major source of significant variation in this study. More than one-half of the characteristics evaluated by the sensory panel and measured by physical evaluation means showed significant differences as a result of this variable. The two remaining independent variables, storage time and replication, showed significant variations to a minor extent. Tenderness, determined by texture press and penetrometer scores, showed significant ($P > 0.05$) variation as a result of storage time, and only moistness, evaluated by the sensory panel, showed significant ($P > 0.05$) variation as a result of replication. It must be noted that while panel members found significant differences for several evaluated characteristics, the lowest rating was 4.0, indicative of a "very close" match to the reference standard.

Sensory panelists found that six of the measured quality characteristics (Table I) showed significant differences ($P > 0.05$) as a result of treatment. Interior color, tenderness, and flavor were unaffected by level of waxy rice for wheat flour substitution.

Physical evaluation tests (Tables II and III) indicated significant differences ($P > 0.01$) resulted from treatment for interior and exterior color, weight loss during baking, and standard height of the products.

Volume, Height, and External Appearance

Volume of the muffins was not influenced by treatment. Both visual comparisons of test muffins to the reference standard by the panel (Table I) and the standing height measurements (Table II) revealed that the 5% substitution product was significantly ($P > 0.01$) taller than the other products. Panelists rated both the 15 and 25% substitution level products to be significantly ($P > 0.01$) lower; however, standing height measurements indicated that only the 25% substitution product was significantly ($P > 0.01$) lower than the reference standard.

An explanation for the significant difference in volume and height characteristics may be inferred from the panelists' evaluation and written descriptions of the external characteristics of the muffins. They found significant differences ($P > 0.01$) in the external appearance of the muffins as a result of treatment. Table I shows that the panel judged the external surface of the products to be less similar to the standard as the level of waxy rice flour substitution increased. Panel members commented that the top surface of the products became broader and flatter as the level of the waxy rice flour substitution increased. It is apparent that the broader shape of the muffins compensated for the decreased height, allowing no significant differences to be noted in the volume of the products. These findings are like those of previous research (Johnson 1988).

Moistness, Mouthfeel, and Flavor

Based on both sensory panel and physical test data (Tables I and II), the products containing waxy rice flour were significantly ($P > 0.01$) more moist than the reference standard muffin. The 25% replacement product retained significantly ($P > 0.01$) more moisture during baking than the other products and was evaluated by the panel as being significantly ($P > 0.01$) more moist; however, panelists found this level to be excessive, because several members described this item as being "wet" or "mushy." These results support findings published by Perez and Juliano (1988).

Table I shows that significant differences ($P > 0.01$) were found in the panel's response to the mouthfeel characteristics of the muffins. As the level of waxy rice flour substitution in the products increased, the rating scores decreased. Additionally, panelists' written comments describing the mouthfeel reflected this trend. They reported the 5% substitution product to have "grainy" and "chewy" characteristics. These findings are in agreement with work previously reported (Nishita and Bean 1979, Bean et al 1983, and Johnson 1988).

The sensory panel did not find a statistically significant difference in flavor between the test muffins and the reference standard or among the test muffins. However, written comments from some panel members indicating that the 25% replacement product was

TABLE II
Effect[a] of Waxy Rice Flour on Physical Characteristics of Muffins

Percent Substitution[b]	Texture Press[c] (lb/gm)		Penetrometer[c] (0.1 mm)		Standing Height[d] (mm)		Weight Loss[d] (g)		Volume[d] (ml)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
0	1.0 a	0.07	135.7 a	5.16	39.8 b	0.18	9.3 c	0.09	52.7 a	2.18
5	1.1 a	0.07	128.0 a	3.82	41.2 a	0.09	7.7 a	0.18	52.6 a	1.54
15	1.1 a	0.06	133.9 a	6.46	39.7 b	0.45	7.6 a	0.19	51.1 a	2.00
25	1.1 a	0.06	134.5 a	5.24	36.8 c	0.36	7.4 b	0.29	50.1 a	1.65

[a]Means within columns followed by different letters are significantly different ($P < 0.01$) from each other.
[b]Mean square error: texture press = 0.0343, 36 df; penetrometer = 188.972, 36 df; standing height = 0.375, 12 df; weight loss = 0.003, 12 df; volume = 17.625, 12 df.
[c]Each mean is the average of values obtained from three replications, two samples/replication, for 9 and 33 hr of storage at room temperature and seven days of storage at freezer temperature.
[d]Each mean is the average of values obtained from three replications, two samples/replication, for 9 hours storage at room temperature.

TABLE III
Effect[a] of Waxy Rice Flour on Color Measurements[b] of Muffins

Percent Substitution[c]	Exterior						Interior					
	L		*a*		*b*		*L*		*a*		*b*	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
0	58.96 a	0.585	2.38 a	0.166	22.87 a	0.254	69.36 a	0.257	−1.33 a	0.025	17.45 a	1.000
5	60.59 a	0.547	2.05 a	0.094	22.17 a	0.330	69.11 a	0.143	−1.28 a	0.045	17.59 a	0.069
15	60.24 a	0.259	1.65 b	0.094	22.03 a	0.291	68.76 a	0.236	−1.29 a	0.024	17.42 a	0.051
25	60.75 a	0.367	1.52 b	0.153	22.73 a	0.270	67.57 b	0.264	−1.10 a	0.034	17.35 a	0.094

[a]Each mean is the average of values obtained from three replications, two samples/replication, for 9 and 33 hr of storage at room temperature and seven days of storage at freezing temperature. Means within columns followed by different letters are significantly different ($P < 0.01$) from each other.
[b]*L* (100 = white, 0 = black), *a* (− = green, + = red), *b* (− = blue, + = yellow).
[c]Mean square error for exterior: $L = 5.371$, $a = 3.231$, $b = 0.868$; interior: $L = 0.694$, $a = 0.019$, $b = 0.124$; df = 12.

sweeter than others may be explained by findings previously reported by Pascual et al (1978).

Grain and Tenderness

Results of texture press and penetrometer (Table II) data reveal that no significant differences were found between the standard and the test muffins, or among the test muffins as a result of level of rice flour substitution. This finding is supported by sensory panel data indicating that unlike the nonwaxy source, waxy rice flour does not contribute to a decrease in product tenderness. Johnson (1988) found that muffins composed entirely of nonwaxy and waxy rice flours were significantly less tender than the wheat flour standard. The sensory panel noted significant differences in the grain of the products. The 5% substitution level product was rated as being closer to the reference standard. The panel did not note a significant difference in the grain of the products containing 15 and 25% replacement levels.

Interior and Exterior Color

Significant differences in color were found only for redness of exterior surfaces and lightness of the interior of the products. Products having higher levels of waxy rice flour had significantly ($P > 0.01$) less redness than the standard and 5% replacement products. Panelists noted (Table I) that these products were significantly different ($P > 0.01$) than the standard but did not describe the difference. Colorimeter values (Table III) revealed that only the 25% flour substitution product had a significantly darker ($P > 0.01$) interior than the other samples. Panelists did not express concern about the color of any samples. However, sensory panel data revealed a significant ($P > 0.05$) interaction between storage time and treatment with respect to interior color.

Tenderness

Measurements of tenderness (texture press and penetrometer) indicated that storage time had a significant ($P > 0.01$) effect on the tenderness characteristic. The analysis shown in Table IV revealed that a similar level of tenderness existed between the products stored for 9 hr at room temperature and seven days in frozen storage regardless of waxy rice flour substitution level. In all instances the products stored for 33 hr at room temperature were significantly ($P > 0.01$) less tender than the other products.

Based on data obtained from this study and a previous one (Johnson 1988), it can be concluded that waxy rice flour aids in the retention of moisture during baking and does not contribute to maintenance of tenderness during room temperature storage when the products are not reheated prior to evaluation. Retrogradation can be reversed to some extent by heat energy in the presence of moisture or other lubricating substances (Whistler and Daniel 1985). Therefore, it can be speculated that the greater retention of moisture in the waxy rice products might contribute to a reversal of retrogradation if the products were heated prior to testing.

TABLE IV
Effect[a] of Waxy Rice Flour Substitution Levels on Tenderness of Stored Muffins

Tests for Tenderness/ Replacement Level[b]	Storage Time[c]		
	9 hr	33 hr	7 Days
Texture press, lb/g			
0%	0.8 a	1.5 b	0.9 a
5%	0.9 a	1.5 b	1.0 a
15%	1.0 a	1.4 b	1.0 a
25%	0.9 a	1.3 b	1.0 a
Mean	0.9 a	1.3 b	1.0 a
Penetrometer, 0.1 mm			
0%	154 a	113 b	141 a
5%	137 a	112 b	136 a
15%	149 a	114 b	135 a
25%	150 a	113 b	141 a
Mean	147 a	113 b	138 a

[a]Each mean is the average of values obtained from three replications, two samples/replication. Means within rows followed by different letters are significantly different ($P < 0.01$) from each other.
[b]Percent waxy rice substituted for wheat flour.
[c]Room temperature storage for 9- and 33-hr samples; freezer storage for seven-day samples.

CONCLUSIONS

Data from this investigation revealed that muffins produced using 5, 15, and 25% replacement levels of waxy rice flour for wheat flour generally had characteristics different from those of the 100% wheat flour reference standard. Sensory panelists found significant differences between the products containing rice flour and the reference standard for six of the nine evaluated characteristics; however, all products were rated at least a "moderately close" match to the reference standard. In three instances (height of the 5% and moistness of the 15 and 25% replacement products) the treatment products were rated significantly higher than the reference standard.

Standing height measurements also revealed the 5% replacement product to be significantly higher and the 15 and 25% replacement products to be significantly lower than the reference standard, although no differences in volume were noted. Muffins containing waxy rice flour were found to retain significantly more moisture than the reference standard. Products containing waxy rice flour may require a longer baking time than wheat-based products to compensate for the greater moisture retention and to improve sensory scores. Significant differences in tenderness as a result of level of waxy rice flour substitution were not observed. However, on the basis of the moisture retention during baking data and previous work, it is speculated that if the products had been reheated prior to testing the waxy rice containing products would have been more tender.

The external appearance of the products became broader and smoother as the level of substitution of waxy rice flour increased. Mouthfeel differed from the reference standard as the substitution level increased. The only color influences noted from addition of waxy rice flour were the redness characteristic of the exterior and the lightness of the interior.

ACKNOWLEDGMENTS

Partial funding for this project was provided by the Kraft Corporation and the American Home Economics Association. Some materials were provided by Lundberg Family Farms and the California Cooperative Rice Research Station. Technical assistance of J. Buhlert, P. Milbury, and C. Livingston is gratefully acknowledged.

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[Received April 21, 1989. Revision received August 1, 1989. Accepted August 16, 1989.]