Chemical Composition of Starbonnet Variety Rice Fractionated by Rough-Rice Kernel Thickness[1]

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ABSTRACT

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Two lots of Starbonnet variety long-grain rice were used to study the variation of kernel composition with kernel thickness. The rough rice was separated by thickness into six fractions. Portions of each fraction were shelled and milled under identical conditions. Proximate compositions, amylose contents, vitamin contents, and amino acid profiles were determined. As the kernel thickness increased, the brown and milled rice fractions had progressively lower protein, lipid, and crude fiber contents and higher starch contents. The amylose content and the amylose-amylopectin ratio both increased as thickness increased. The vitamin contents of the thin kernels tended to be higher than those of the thick kernels. Amino acid profiles of the unfractionated rice and the thin kernels showed essentially no differences. Mathematical relationships between kernel thickness and various properties were developed.

The variation of kernel thickness in harvested rice has implications for practically every phase of rice investigation, including cultural practices, breeding, drying, processing, quality, and composition. In a previous report (Wadsworth et al 1979), the relationships between the thickness of the kernels and the physical and physicochemical properties for Starbonnet variety rice were investigated.

This study investigates the chemical properties of Starbonnet variety rice kernels of varying thickness. This information, which provides a much more detailed characterization of the rice kernel than has hitherto been available, and the information on the physical and physicochemical properties will be helpful to investigators working on the improvement of equipment and procedures for rice handling and the development of new products and uses for rice.

MATERIALS AND METHODS

Rice

Two lots of Starbonnet variety long-grain rice grown in Southwest Louisiana during 1975 and 1977 were used to study the variation of chemical properties with kernel thickness. These were the same lots of rice previously used to study the physical and physicochemical properties. The procedures for drying, cleaning, fractionating, shelling, and milling have been reported in detail (Wadsworth et al 1979).

The rice lots grown in 1975 and 1977 are referred to as "A" and "B," respectively. The two lots of rough rice were each separated by thickness into six fractions with a Carter dockage tester and the five slotted screens described in Table I.

The unfractionated rice lots were dried by a commercial rice-drying facility. Before and after fractionation the rice lots were stored in closed containers at 22° C. The moisture contents of rice lots A and B as received at this laboratory were 12.9 and 11.9% (wet basis), respectively.

Analytical Methods

The Kjeldahl procedure was used to determine nitrogen content. Protein was calculated as N × 5.95 (Jones 1931). Determinations of moisture, lipid, crude fiber, thiamine HCl, riboflavin, and niacin were made with recommended procedures (AOCS 1976, AOAC 1975). The procedure of Simpson et al (1965) was used to determine starch. Amylose was determined with the simplified procedure described by Juliano (1971). Amino acids were determined according to the gas-liquid chromatographic procedure of Kaiser et al (1974). The automated procedure of Amaya et al (1977) was used for tryptophan determinations.

Data Analysis

Analysis of variance and Newman-Keul's multiple range test (Chew 1976) were applied to determine the significance of differences among the thickness fractions and between the rice lots for the various properties. Empirical relationships based on linear regression models were calculated by standard techniques.

RESULTS AND DISCUSSION

Table I shows for each fraction the percentages of rough rice retained on each screen, the mean kernel thickness, and the ranges of kernel thickness. Two-way analysis of variance of the thickness values indicated significant differences among the thickness fractions but not between the rice lots. For both lots of rice, the percentages of rough rice retained on each screen fall within the ranges reported by Matthews and Spadaro (1976) for other lots of long-grain rice fractionated by thickness with screens of similar size.

After each lot was fractionated, the moisture contents of the thickness fractions in order of decreasing thickness were 13.0, 13.1, 12.9, 12.9, 12.6, and 12.7% for lot A and 11.4, 11.3, 11.4, 11.4, 11.4, and 11.1% for lot B. No significant differences were found among the moisture contents of the thickness fractions. All the results presented in the remainder of this report are expressed on a dry-weight basis.

The starch, protein, lipid, and crude fiber contents of the brown rice from the thickness fractions are presented in Table II. The column labeled "other" was calculated by difference and consists of everything else such as ash, sugars, hemicellulose, and phytin.

TABLE I
Fractionation of Lots A and B of Starbonnet Rough Rice by Kernel Thickness

Screen No.[a]	Slot Size (mm)	Percentage Retained A	Percentage Retained B	Mean Thickness, mm A	Mean Thickness, mm B	Range of Thickness, mm A	Range of Thickness, mm B
24	1.98 × 12.70	4.0	1.8	1.94	1.92	1.88–2.06	1.88–2.01
23	1.93 × 19.05	13.7	10.0	1.88	1.86	1.83–1.93	1.80–1.93
5	1.78 × 12.70	64.8	69.7	1.80	1.79	1.68–1.88	1.70–1.85
4	1.63 × 9.53	12.1	14.1	1.65	1.65	1.50–1.75	1.52–1.70
22	1.55 × 12.70	2.3	2.4	1.48	1.47	1.32–1.57	1.35–1.57
Unders	···	3.1	1.7	1.28	1.31	0.94–1.45	1.09–1.47

[a] Screen numbers refer to slotted screens in the Carter dockage tester.

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[2] One of the facilities of the Southern Region, Science and Education Administration, U.S. Department of Agriculture.

Names of companies or commercial products are given solely for the purpose of providing specific information; their mention does not imply recommendation or endorsement by the USDA over others not mentioned.

TABLE II
Composition (%, db) of Brown and Milled Rice of Lots A and B, by Thickness Fractions and Unfractionated Lots[a]

	Brown Rice										Milled Rice									
	Starch		Protein[b]		Lipid		Crude Fiber		Other		Starch		Protein[b]		Lipid		Crude Fiber		Other	
Fraction	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Over screen No.																				
24	81.4 a	81.3 a	7.7 a	8.9 a	2.96 a	2.85 a	1.1 a	1.1 ab	6.8	5.8	88.6 a	89.0 a	6.8 a	8.0 a	0.55 a	0.34 a	0.5 a	0.2 a	3.6	2.4
23	81.3 a	81.3 a	7.8 a	8.8 a	2.92 a	2.85 a	1.3 a	1.0 a	6.7	6.0	88.8 a	89.3 a	7.0 a	8.0 a	0.53 a	0.23 a	0.5 a	0.3 a	3.2	2.1
5	80.3 b	80.3 b	8.4 b	9.2 a	3.11 a	3.24 b	1.3 a	1.0 a	6.9	6.2	88.9 a	88.0 a	7.7 b	8.3 a	0.63 a	0.57 b	0.3 a	0.2 a	2.5	2.9
4	76.2 c	77.2 c	10.4 c	11.1 b	3.61 b	3.48 c	1.6 b	1.3 ab	8.2	7.0	85.1 b	86.4 ab	9.7 c	10.2 b	0.92 b	0.51 b	0.5 a	0.3 a	3.8	2.6
22	73.0 d	72.5 d	1.0 d	12.3 c	3.93 c	3.93 d	2.1 c	1.4 b	10.0	9.9	83.4 c	84.3 bc	10.3 d	11.7 c	0.92 b	0.57 b	0.6 a	0.3 a	4.8	3.1
Unders	68.9 e	69.3 e	12.2 e	12.9 c	4.04 c	3.82 d	2.6 d	1.8 c	12.3	12.2	78.9 d	81.8 c	10.7 e	12.7 d	1.03 b	0.51 b	0.5 a	0.3 a	8.9	4.7
Unfractionated	80.0	79.8	8.7	9.3	3.21	2.96	1.3	1.2	6.8	6.7	88.3	89.3	7.8	8.3	0.72	0.29	0.6	0.3	2.6	1.8
Recombined[c]	79.5	79.4	8.7	9.5	3.19	3.25	1.4	1.1	7.2	6.5	88.0	87.5	8.0	8.7	0.67	0.52	0.4	0.2	2.9	3.0

[a] The same letter within a column indicates no significant difference between means at $P = 0.05$ (Newman-Keul's multiple range test).

[b] Protein calculated as N × 5.95.

[c] Values calculated from a materials balance on the recombined thickness fractions.

Analyses of variance indicated no significant differences between the two rice lots for brown rice starch and lipid contents. The brown rice from lot B had significantly higher protein content, and that from lot A had significantly higher crude fiber content. However, for two lots of the same variety to have significant differences in composition is not unusual. Of more importance is that significant differences were found for both lots among the brown rice thickness fractions for all of the components. The thin brown rice fractions had higher protein, lipid, crude fiber, and other contents; the thick fractions had higher starch contents.

Proximate analyses data for the milled rice thickness fractions are also given in Table II. Analyses of variance indicated that rice lot B had significantly higher protein content and lot A significantly higher lipid and fiber contents. No significant differences were found between the starch contents of the two lots. The thin fractions had significantly higher protein and lipid contents than the thick fractions, and the thick fractions had significantly higher starch contents.

Regression equations were developed with data from both rice lots to describe the relationships between the starch, protein, lipid, fiber, and other contents and the rough rice kernel thickness (Table III). All of these regressions were statistically significant at $P < 0.05$. The regression for milled rice fiber content on thickness was not significant. The coefficient of determination values for the brown rice are all higher than the corresponding values for the milled rice. This result indicates that, even though all samples were milled under similar conditions, the degree of milling variation from sample to sample increased the variances of the regressions for the milled samples.

Table IV shows the amount of starch and protein in the brown rice thickness fractions on a "per kernel" basis. These values were calculated from the proximate analysis data and the mean kernel weight for each thickness fraction. The quantities of starch and of protein per kernel both increase as kernel thickness increases. The starch content increases at a greater rate than the protein content; thus, the percentage of protein decreases.

The amylose content (Table V) of the milled rice increases as the kernel thickness increases. Also the ratio of amylose to amylopectin increases with thickness, indicating that the amylose is increasing at a rate faster than that of the amylopectin. Halick and Kelly (1959) reported that higher amylose starches would show greater Brabender amylograph setback viscosity values. Thus, the thicker kernels, which have higher amylose content, should have higher setback viscosity values. However, Wadsworth et al (1979) found

TABLE III
Regression Equations Showing Relationship Between Contents of Brown (b) and Milled (m) Rice and Rough Rice Kernel Thickness (T)

	Rice	
Content	Brown	Milled
Starch (S)	$S_b = 42.7 + 20.5T$ $r^2 = 0.985$[a]	$S_m = 62.9 + 13.9T$ $r^2 = 0.931$
Protein (P)	$P_b = 22.4 - 7.39T$ $r^2 = 0.896$	$P_m = 21.7 - 7.47T$ $r^2 = 0.851$
Lipid (L)	$L_b = 6.52 - 1.87T$ $r^2 = 0.905$	$L_m = 1.60 - 0.59T$ $r^2 = 0.341$
Fiber (F)	$F_b = 4.39 - 1.75T$ $r^2 = 0.712$	...[b]
Other (O)	$O_b = 24.2 - 9.61T$ $r^2 = 0.918$	$O_m = 13.3 - 5.73T$ $r^2 = 0.531$

[a] Coefficient of determination, ie, the fraction of the total sum of squares accounted for by the regression.

[b] Not significant.

TABLE IV
Starch and Protein Content (mg per kernel) for Each Thickness Fraction of Brown Rice Lots A and B

	Starch		Protein	
Fraction	A	B	A	B
Over Screen No.				
24	18.7	18.1	1.77	1.98
23	17.6	17.2	1.69	1.86
5	15.6	15.1	1.63	1.73
4	11.5	11.6	1.56	1.66
22	8.5	8.6	1.28	1.46
Unders	5.9	6.5	1.05	1.20

TABLE V
Amylose Contents[a] (%, db) of Thickness Fractions and Unfractionated Lots of Milled Rice, Lots A and B

	Amylose		Amylose-Amylopectin Ratio	
Fraction	A	B	A	B
Over screen No.				
24	26.5 a	27.4 a	0.427	0.445
23	26.1 ab	27.9 a	0.416	0.454
5	25.7 b	27.5 a	0.407	0.455
4	23.6 c	25.2 b	0.384	0.412
22	20.9 d	23.8 c	0.334	0.393
Unders	19.8 e	22.4 d	0.335	0.377
Unfractionated	25.6	26.6	0.408	0.424
Recombined[b]	25.2	27.0	0.401	0.446

[a] The same letter within a column indicates no significant difference between means at $P = 0.05$ (Newman-Keul's multiple range test).

[b] Values calculated from a material balance on the recombined thickness fractions.

TABLE VI
Vitamin Contents (μg/g, db) of Unfractionated Lots and of Combined Thin Fractions of Brown Rice Lots A and B

	Thiamine HCl		Riboflavin		Chemical Niacin	
	A	B	A	B	A	B
Unfractionated	5.54	5.50	0.206	0.538	89.1	56.3
Fractions						
Thin[a]	6.16	6.14	0.217	0.748	104.4	67.2
Thick[b]	5.41	5.38	0.204	0.493	85.9	54.1
Least significant difference (0.05)	0.83		0.170		3.64	

[a] All of the rice that passed through the No. 5 screen; kernel thickness less than 1.65 mm.

[b] All of the rice that would not pass through the No. 5 screen. These values calculated by difference.

that the thin fractions gave higher setback viscosity values than the thick fractions did. This apparent discrepancy has not been resolved. It might be related to differences in starch concentration (Bhattacharya and Sowbhagya 1978) or to the differences in protein content of the thickness fractions (Kester 1961).

Data on vitamin content for the brown rice are presented in Table VI. The data for the thin fractions refer to the three thinner fractions combined—ie, all of the rice that passed through the No. 5 screen. The thick fractions are all of the rice that would not pass through the No. 5 screen. The vitamin-content values for the thick fractions are calculated from the values for the thin fractions and the unfractionated rice. The differences between the thiamine contents were not statistically significant for either the rice lots or the thickness fractions. For riboflavin, significant differences were found between the rice lots, and the value for the thin fraction from lot B was significantly higher than that for the unfractionated rice. For niacin, significant differences were found between the rice lots and between the thickness fractions, with the thin fractions having significantly higher values. In general, the vitamin-content determinations for the thin fractions were higher than for the unfractionated rice, even when the differences were not large enough to be statistically significant.

In Table VII amino acids are expressed as milligrams per gram of protein recovered. Values were not adjusted for partial destruction of certain amino acids during hydrolysis. (Percent recoveries of protein were 95.2 and 87.3% for the unfractionated and thin fractions of lot A and 88.3 and 82.6% for the unfractionated and thin fractions of lot B, respectively.)

Table VII gives the amino acid profiles for the brown rice protein from the unfractionated lots and from the three thinner fractions combined. Amino acid profiles for the unfractionated rice and for the thin fractions show essentially no differences. Isoleucine was the only amino acid significantly higher in the thin fractions for both lots of rice. Several differences were apparent between the rice lots. Valine, isoleucine, cystine, and tryptophan were significantly higher in lot B, and glutamic acid was significantly higher in lot A.

Several investigators have reported the changes in the amino acid contents of rice during grain development (Cagampang et al 1976, Juliano 1966, Palmiano et al 1968). They generally agree that, of the essential amino acids, lysine and threonine decrease as the grain matures. No significant differences were found between the lysine and threonine contents of the thin fractions and those of the unfractionated rice.

Table VIII shows the amino acid scores for the essential amino acids for the unfractionated rice and for the three thinner fractions combined. The amino acid scores are based on a provisional amino acid scoring pattern for an "ideal protein" for children, established by the FAO/WHO expert committee on energy and protein requirements (FAO/WHO 1973). The limiting essential amino acid for both fractions is lysine. An inverse relationship of protein content and lysine content has been noted for rice (Nalivko et al 1975, Roxas et al 1975). Thus, the quality of the protein from high-protein rices is generally not as good as that from rice having a normal protein content. However, the thin kernels from these two lots of Starbonnet rice have a protein content equivalent to some of the high-protein rices, without a corresponding decrease in protein quality.

TABLE VII
Amino Acid Profiles (mg/g of protein) of Unfractionated Lots and of Combined Thin Fractions[a] of Brown Rice Lots A and B

	Unfractionated		Thin Fractions		Least Significant Difference
Amino Acid	A	B	A	B	($P = 0.05$)
Alanine	59	58	58	59	1.0
Valine	56	62	60	63	1.4
Glycine	47	49	44	50	2.2
Isoleucine	37	42	40	44	1.4
Leucine	77	79	83	81	2.4
Proline	45	45	46	46	1.0
Threonine	35	35	36	37	2.2
Serine	52	49	54	50	4.2
Methionine	23	21	22	21	3.0
Phenylalanine	61	53	54	52	6.0
Aspartic acid	94	95	90	95	2.2
Glutamic acid	177	168	183	163	5.7
Tyrosine	42	38	41	41	2.4
Lysine	44	39	41	41	1.7
Histidine	38	33	36	32	7.2
Arginine	86	86	78	83	5.7
Cystine	17	25	17	20	1.4
Tryptophan	15	25	18	23	2.0

[a] All of the rice that passed through the No. 5 screen; kernel thickness less than 1.65 mm.

TABLE VIII
Amino Acid Scores for the Essential Amino Acids[a] of Rice Lots A and B

Essential	Unfractionated		Thin Fractions[b]	
Amino Acid	A	B	A	B
Isoleucine	93	105	100	110
Leucine	110	113	119	116
Lysine	80	71	75	75
Methionine + cystine	114	131	111	117
Phenylalanine + tyrosine	172	153	158	155
Threonine	88	88	90	93
Trytophan	150	250	180	230
Valine	112	124	120	126

[a] Amino acid scores based on a provisional amino acid scoring pattern for an "ideal protein" for children, established by the FAO/WHO expert committee on energy and protein requirements (FAO/WHO 1973). An amino acid score of 100 is an ideal value.

[b] The three thinner fractions combined (kernel thickness less than 1.65 mm).

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