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Chemical, Physical, and Nutritional Properties of High-Protein Flours and Residual Kernel from the Overmilling of Uncoated Milled Rice.I. Milling Procedure and Protein, Fat, Ash, Amylose, and Starch Content[1]

B. M. KENNEDY, M. SCHELSTRAETE, and A. R. DEL ROSARIO, Department of Nutritional Sciences, University of California, Berkeley 94720

ABSTRACT

Twelve lots of commercially milled rice of different varieties and treatment were abraded in a rice-polishing machine. The rices were put through the mill three times to give an average yield for each pass of about 2% flour passing through a 40-mesh screen, with 87% of the rice left as residual kernel. First-pass flours contained twice as much protein as did the original rice, about two-thirds as much amylose and total starch, eight times as much ash, and 17 times as much petroleum ether-extractable fat. Except for amylose and starch, concentrations of these components decreased with each successive pass. Residual kernels contained as much amylose as did the original rice, slightly more starch, and less of the other constituents. Variations due to variety and processing are discussed. This study extends the data and is in accord with results obtained from previous work on experimentally milled rices.

High-protein rice flour has been obtained by abrasive milling of the outer layers of milled rice or by air classification of the ground milled rice, as reported by several workers in recent years (1–5). The high-protein fractions could be separated by abrasion because of the higher concentration of protein in the outer portion of the endosperm—a concentration that decreased toward the center of the kernel, as demonstrated histologically by Little and Dawson (6). Unusually high contents of fat, vitamins, and minerals were also found in the outer layers of the rice kernel (3,4,7,8).

Because these rice flours were promising as a nutritional supplement and as a high-protein food for augmenting protein-deficient diets of infants in predominantly rice-eating areas, further information was needed on rice flour obtained on a semicommercial scale and from several varieties of rice.

The purpose of this project was to make a comprehensive study of 12 lots of different varieties and treatment of rice, milled by abrasion. The study included analysis of various chemical constituents of the rice and rice fractions, determination of the nutritive value of the protein by animal-feeding tests, a

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TABLE I. DESCRIPTION OF SAMPLES: COMMERCIALLY MILLED UNCOATED RICE

Variety	State of Origin	Code	Length of Kernel	Special Treatment
			1966 Crop	
Belle Patna	Texas	BP	Long	...
Bluebonnet 50	Arkansas	BB	Long	...
Calrose	California	CR	Medium	...
Saturn	Louisiana	S	Medium	...
Caloro	California	CL	Short	...
Colusa	California	CS	Short	...
			1968 Crop	
Belle Patna[a]	California	CB	Long	...
Calrose	California	CC	Medium	...
Belle Patna	Texas	TE	Long	Early seeding
Belle Patna	Texas	TL	Long	Late seeding
Pearl	California	CP	Short	Parboiled, medium
Belle Patna	Texas	TP	Long	Parboiled, light

[a]1967 crop.

characterization of the flours for potential food use, and an appraisal of the eating quality of the original and residual kernels. Data on the different rices used and on milling conditions, protein content, fat, ash, amylose, and total starch in the whole kernel, abraded flours, and residual kernel are presented here. Biological evaluation of the protein, amino acid, vitamin, and mineral composition, and characteristics of the flours and residual kernels, will be reported in succeeding papers.

MATERIALS AND METHODS

Rices

Twelve lots of uncoated, commercially milled rice, of approximately 1,000 lb. each, were studied. These included six different varieties grown in 1966—two long-, two medium-, and two short-grain—for the first year's work and six additional lots from 1967 and 1968 crops, including an early and a late seeding of Belle Patna and two parboiled rices, for subsequent study. The rices are described in Table I. Rices were packaged in plastic bags, placed in fiber drums, and stored in a refrigerator at 40°F. until milled.

Milling

The rices were milled on a small Japanese barley polishing and whitening machine equipped with a tapered, abrasive, cone-type roll.[2] The mill was set to yield about 3% flour per pass, and the rice was passed through the mill three times. While waiting for delivery of the mill, one lot of rice, Belle Patna, was milled in another machine of the same model lent to us by the Western Regional Research

[2]CeCoCo Type E. Chuo Boeki Goshi Kaisha (Central Commercial Co.), Ibaraki City, Osaka Pref., Japan.

TABLE II. FLOUR YIELDS OF RICE ABRADED IN A RICE-WHITENER MACHINE

Rice Lot and Variety	Flour as Percent of Original Rice							
	Total Flour %	Over 40-Mesh Total	Through 40-mesh Frac. 1	Frac. 2	Frac. 3	Total	As % of total flour (Avg. of 3 passes)	Residual kernel % of original rice
1966								
BP	8.1	1.9	2.2	2.2	1.9	6.2	77	89.3
BB	11.4	6.6	1.8	1.6	1.3	4.8	42	85.0
CR	13.0	5.8	2.6	2.5	2.2	7.2	56	88.2
S	15.2	7.2	2.4	2.8	2.8	8.0	53	78.9
CL	11.0	5.3	1.5	2.3	2.0	5.7	52	87.0
CS	12.0	4.9	1.4	2.7	3.0	7.1	59	86.8
1968								
CB	9.4	3.0	2.5	2.1	1.7	6.3	68	89.0
CC	9.4	3.2	2.1	2.3	1.8	6.2	66	89.0
TE	7.9	2.2	2.0	1.9	1.8	5.7	72	88.2
TL	10.3	3.6	2.6	2.3	1.7	6.6	65	88.9
CP	10.0	4.5	1.4	1.9	2.1	5.4	55	87.2
TP	7.0	2.9	1.0	1.7	1.4	4.2	59	88.7
Avg.	10.4	4.3	1.9	2.2	2.0	6.1	60	87.2
Std. Dev.	±2.3	±1.7	±0.7	±0.4	±0.5	±1.1	±10	±2.9

Laboratory (WRRL). Some difficulty was encountered in milling this long-grain variety. The mill jammed after about 150 to 200 lb. of rice had been fed in, because the long kernels lodged in the openings of the screen. When the mill was stopped after each 50 to 75 lb. and the screen cleaned with a steel brush, jamming was prevented. This procedure was thereafter used routinely.

Before any of the experimental rices were milled on the newly purchased machine, 100 lb. of nonexperimental rice was put through the mill to break in the new abrasive roll and to ascertain the setting required to yield about 3% flour per pass.

It was noted that the flour from the new mill was coarser than that obtained from the WRRL mill; for this reason particle size of the flours was determined. The coarseness appeared to be caused by chipping of the kernel surface as a result of the speed and force of operation of the new mill. Before the six lots of 1968 rices were milled, some time was spent in studying various adjustments of the machine. The settings which produced the finest flour were then used for milling the remaining lots of rice.

Two lots of Texas Belle Patna—early and late seedings—were fed into the mill too rapidly, and six passes were required to yield 8% flour. The first two passes of each lot were combined, as were the third and fourth, and the fifth and sixth, hereafter called first, second, and third passes, respectively. Percentage of broken kernels was determined on residual kernels after all six passes. The remaining lots were fed into the mill more slowly and yielded about 3% flour per pass.

Particle Size of Flours

Particle size for all first-pass flours of the 1966 rices was determined by shaking 100 g. of each flour through 20-, 40-, 60-, and 80-mesh screens (U.S. Sieve Series) on a Ro-Tap testing sieve shaker for 30 min.

For chemical determinations, about 500 g. of each flour, in 100- to 200- g. portions, was sieved for 30 min. through a 40-mesh screen on a Tyler portable sieve shaker, thus yielding two fractions: 1) over 40-mesh, and 2) through 40-mesh.

For biological testing, about 5 kg. of flour in 200-g. portions–enough to yield 2,500 g. flour through 40-mesh screen–was sieved for 15 min. in a Ro-Tap shaker.

Broken Kernels

The percentage of broken kernels was determined on a weight basis by analyzing a weighed sample of 20 to 30 g. Kernels of less than 75% estimated length were separated by hand and weighed, and the percentage of broken kernels was calculated. Each value represents the average of eight to ten replicates.

Sampling

For the analysis of the original rice (whole kernel) and residual kernel, about 1 kg. of sample was ground finely enough to pass through 60- to 80-mesh sieves. For chemical determinations of the flours, about 500 g. of sample was sieved through a 40-mesh screen as described above. Analyses for moisture, protein, ash, and fat were made on flour samples not passing through the 40-mesh screen as well as on the portions that passed through. All other determinations on flour were made only on the samples that went through the screen. All milled and sieved flours and ground original and residual kernels were packaged in plastic bags or glass jars and kept in frozen storage until required for analysis. All reported values represent the average of three to five replicates, and were calculated to a moisture-free basis.

Moisture

Five-gram samples were dried in stainless-steel dishes for 28 hr. at 65°C. under reduced pressure (about +5 in. Hg). Loss of weight was calculated as percent moisture in the rice.

Protein

The nitrogen in 2-g. samples was determined by the macro-Kjeldahl method, with selenium as the catalyst for digestion. Percentage of protein was computed by multiplying the nitrogen content by the factor 5.95.

Ash

Ten grams of ground whole kernel, 15 g. of ground residual kernel, and 2 to 4 g. of flour were used, sufficient to yield ash weights of at least 30 mg. Samples in Vycor crucibles were pre-ashed by means of an infrared heater, and were then ashed to constant weight for 18 hr. or overnight in a muffle furnace set at 600°C., starting with a cool muffle. Some difficulty was encountered in obtaining good precision on replicates of the first-pass flours over 40-mesh, particularly with the variety Caloro, the first lot milled on the new mill, because of the presence of small fragments of stone from the mill cone. When visible fragments were removed before samples were weighed, better precision was obtained.

Fat

The samples from the moisture determinations were transferred quantitatively to Whatman No. 12 fluted filter papers. Filters were gathered and stapled at the rim, transferred to Soxhlet extractors, and extracted for 16 hr. with petroleum ether (b.p. 30 to 60°C.). The extracts were centrifuged to remove starch particles, decanted, evaporated at the steam table, and dried in vacuo at 100°C. for approximately 6 hr.

Starch

Starch in the whole kernel, in flours through 40-mesh screen, and in residual kernel was determined according to the method described by Simpson et al. (9, p. 23). Samples were ground to pass through an 80-mesh screen, defatted with hot ethanol, and solubilized by boiling with $CaCl_2$-acetic acid solution. The starch solutions were deproteinized with uranyl acetate, and centrifuged. Optical rotation of the clear solutions was obtained by means of a polarimeter. Modifications of the method included: 1) Heating on a hot plate instead of in a glycerin bath when solubilizing the starch. The mixture was brought to boiling in 2 to 3 min. 2) Additional filtration through Whatman No. 1 or No. 12 filter papers for the flours (all passes) after heating the mixture with $CaCl_2$-acetic acid, in order to remove some light floating material that was not brought down even after 30 min. centrifugation.

Amylose

Amylose was determined according to the method of Williams et al. (10). Defatted samples were solubilized in the cold with sodium hydroxide, and the absorbance of the blue starch-iodine color, developed at pH 10.5, was read at 500 nm. on a Spectronic 20 colorimeter. Amylose obtained from Nutritional Biochemicals Corp. was used as a standard.

TABLE III. FINENESS OF GRIND OF FIRST-PASS FLOURS ABRADED FROM SIX VARIETIES OF MILLED RICE, 1966 CROP

Variety	Percent Flour Passing Over or Through Various Screen Meshes[a]						
	Over 20	Over 40	Over 60	Over 80	Through 80	Over 40[b]	Through 40[b]
Belle Patna	3.5	17.4	13.1	54.7[c]	11.0[c]	20.9	78.8
Bluebonnet 50	14.4	42.0	12.2	5.8	25.2	56.4	43.2
Calrose	15.1	31.7	16.3	32.0[c]	4.1	46.8	52.4
Saturn	14.9	38.0	13.9	9.8	22.7	52.9	46.5
Caloro	13.9	34.2	11.4	6.7	33.3	48.1	51.3
Colusa	14.1	33.2	10.1	7.0	35.4	47.2	52.5
Avg.[d]	14.5 ±0.5	35.8 ±4.2	12.8 ±2.4	7.3[e] ±1.7	29.2[e] ±6.2	50.3 ±4.2	49.2 ±4.1

[a]Samples of 100 g. flour were shaken through four screens, mesh designation U.S. Sieve Series, for 30 min. on a Ro-Tap testing sieve shaker.

[b]Values in column "Over 40" are the sums of the percentages over 20- and 40-mesh screens; values in column "Through 40" are the sums of the percentages through 40, 60, 80.

[c]Samples clogged sieve.

[d]Average and standard deviation excluding Belle Patna; $n = 5$.

[e]Belle Patna and Calrose excluded, $n = 4$.

RESULTS

Milling

From the 12 lots of rice, 10.4 ± 2.3%, average and standard deviation, of flour was obtained by abrasive milling, 3 to 4% from each of three passes through the mill (Table II). About 60% of this flour passed through a 40-mesh screen, equivalent to about 2% of the original rice for each pass. Losses due to evaporation and to handling amounted to about 1.5%, while samples of residual kernel removed after the first and second passes amounted to approximately 1%. Thus the total amount of material removed was about 13%. Residual kernels remaining after the third pass averaged 87%.

The largest yield of flour was obtained from Saturn. However, only about one-half of the flour passed through a 40-mesh screen. The lowest yields, 7.0 and 7.9%, from six mill passes, were obtained from the rices TP and TE, which had been fed into the mill quite rapidly. The parboiled and the short-grain rices gave the smallest yields of first-pass flour. All three flours from BP and CR clogged the screen during the sifting process. The fat contents of these flours were among the highest of the lots, but so, too, were those of the parboiled rices which presented no sifting difficulty.

Fineness of Flour

Flours from BP, milled on the CeCoCo mill from WRRL, were much finer than were those from varieties milled on the new mill (Table III). Of the first-pass flour

TABLE IV. FINENESS OF FLOURS ABRADED FROM COMMERCIALLY MILLED RICE

Rice Lot and Variety	Percent Flour Passing Over or Through 40-Mesh Screen[a]					
	First Pass		Second Pass		Third Pass	
	Over	Through	Over	Through	Over	Through
1966						
BP	24.6[b]	75.4	25.8[b]	74.2	17.9[b]	82.1
BB	56.9	43.1	59.8	40.2	56.8	43.2
CR	45.0[b]	55.0	45.4[b]	54.6	42.7[b]	57.3
S	54.8	45.2	50.2	49.8	34.6	65.4
CL	48.4	51.6	45.9	54.1	49.7	50.3
CS	48.1	51.9	39.6	60.4	37.2	62.8
1968						
CB	45.4	64.6	32.1	67.9	28.2	71.8
CC	35.8	64.2	33.6	66.4	31.6	68.4
TE	31.8	68.2	26.2	73.8	24.5	75.5
TL	40.4	59.6	32.3	67.7	30.0	70.0
CP	47.5	52.5	45.7	54.3	43.6	56.4
TP	46.6	53.4	40.7	59.3	36.4	63.6
Avg.[c]	45.5 ±7.4	55.4 ±8.0	41.0 ±9.7	59.0 ±9.7	37.8 ±9.7	62.2 ±9.7

[a]U.S. Sieve Series. A motor-driven Tyler portable sieve shaker was used with a shaking time of 30 min.

[b]Sample clogged sieve and matted on screen. Only a little flour went through the screen in the shaker. Nearly all the sample had to be brushed through with a nylon brush.

[c]Average and standard deviation. Belle Patna excluded, n = 11.

from BP, 3.5% was over the 20-mesh screen, while the average percentage for the five other varieties was 14.5. Nearly 80% of the flour from BP went through the 40-mesh screen, while only 49 ± 4% from the other five varieties went through. Yields of flour through 40-mesh increased somewhat with each successive pass (Table IV), the average of the five varieties being 52% for second-pass flour and 56% for third-pass.

Before the last six lots of rice were milled, various settings on the mill were adjusted in an attempt to produce a larger yield of flour through the 40-mesh screen. With the optimum conditions, an average of 64 ± 4% of the first-pass flour from four of the lots passed through 40-mesh (Table IV), as compared with the 49% obtained for the previous rices. The two parboiled rices gave yields of about 53%. As with the first six lots of rice, the yields of flour through 40-mesh generally increased with each successive pass.

Broken Kernels

The average percentage, with standard deviation, of broken kernels in the original rices was 4.9 ± 1.3, excluding CB which had 20% (Table V). The highest percentage of broken kernels in the residual rices, 35.4, was found in TE, while the lowest, 1.7, was found in TP, both after the sixth pass. In general, the percentage of broken kernels increased with each successive milling pass, except for the parboiled rices, for which the increase was either small or nonexistent. The BP lot showed little or no increase, except after the third pass.

Excluding the two parboiled rices, the percentage of broken kernels in the rices after the third pass averaged over twice that in the original kernel. The greatest increase, about 3.5 times, was observed in Caloro.

Moisture

Moisture in the whole kernel averaged about 12% for the 1966 rices and 9% for the 1968 rices. Moisture content of all of the flours was 2 to 3% lower, with values of about 9.5% for the flours over 40-mesh and 9.0% for those through 40-mesh for the 1966 rices, and 7.5% for flours from the 1968 rices.

TABLE V. BROKEN KERNELS IN ORIGINAL RICE AND IN RESIDUAL KERNELS

Rice Lot and Variety	Original Rice %	Residual Kernels After Pass, %					
		1	2	3	4	5	6
1966							
BP	6.2	4.2	5.6	11.3	...	...	...
BB	7.4	11.2	14.5	16.4	...	...	...
CR	4.6	11.0	9.2	10.8	...	...	...
S	3.9	4.0	6.3	9.6	...	...	...
CL	4.7	8.9	9.4	16.5	...	...	...
CS	4.3	9.1	13.2	10.8	...	...	...
1968							
CB	20.0	21.6	23.4	24.8	...	...	...
CC	2.9	4.2	4.9	5.5	...	...	...
TE	8.0	11.1	16.5	17.9	31.1	33.9	35.4
TL	4.2	7.5	7.8	8.1	...	...	...
CP	4.9	3.7	5.7	6.0	...	...	...
TP	2.6	2.5	3.6	2.4	3.2	2.2	1.7

TABLE VI. PROTEIN CONTENT OF FRACTIONS OF OVERMILLED RICE

Rice Lot and Variety	Whole Kernel	Protein (N X 5.95), Percent Dry Basis Flour Over or Through 40-Mesh Screen: First Pass Over	First Pass Through	Second Pass Over	Second Pass Through	Third Pass Over	Third Pass Through	Residual Kernel After Third Pass
1966								
BP	9.7	14.1	19.2	13.4	20.0	12.9	19.5	8.7
BB	8.1	11.2	15.2	10.2	14.7	9.3	13.6	7.4
CR	6.9	10.2	13.0	9.2	12.2	9.1	11.4	6.3
S	7.0	10.5	13.7	9.5	12.3	8.9	11.6	6.2
CL	6.4	10.2	11.6	8.9	10.9	8.0	10.1	6.1
CS	6.5	9.7	10.9	9.0	10.2	7.9	9.9	5.9
Avg.	7.4	11.0	13.9	10.0	13.4	9.4	12.7	6.7
Std. Dev.	±1.3	±1.6	±3.0	±1.7	±3.6	±1.8	±3.6	±1.1
$n = 6$								
1968								
CB	7.6		14.8		13.6		13.0	7.2
CC	6.0		10.9		10.8		9.9	5.9
TE	8.1		16.4		16.2		15.1	7.5
TL	10.2		18.2		18.1		17.7	9.4
CP	6.9		14.7		13.2		11.7	6.6
TP	7.2		15.6		15.1		14.8	6.8
Avg.	7.5		14.5		14.0		13.2	7.0
Std. Dev.	±1.3		±2.7		±3.0		±3.1	±1.1
$n = 12$								

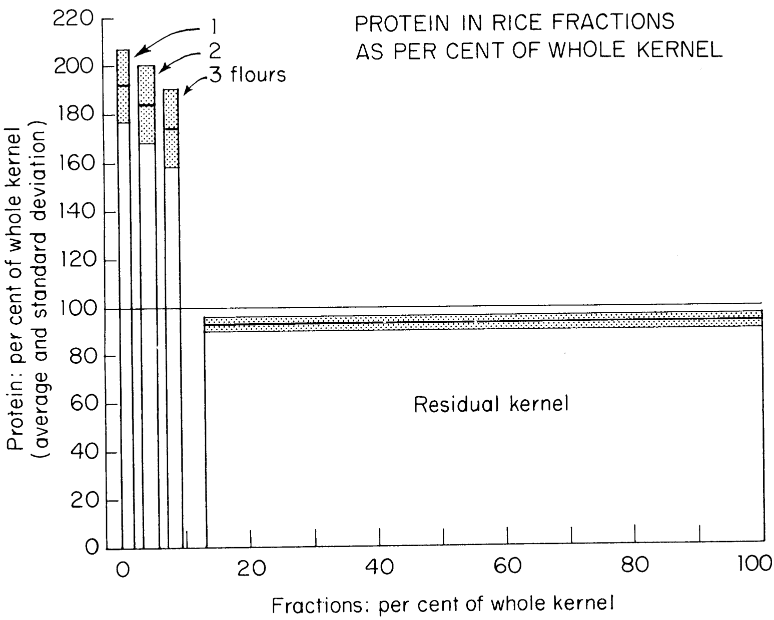

Fig. 1. Percent protein in flours and residual kernel of 12 lots of rice compared with percent protein in the original rices.

TABLE VII. FAT CONTENT OF FRACTIONS OF OVERMILLED RICE

Rice Lot and Variety	Whole Kernel	Petroleum Ether-Extractable Material, Percent Dry Basis Flour Through or Over 40-Mesh Screen: First Pass Over	First Pass Through	Second Pass Over	Second Pass Through	Third Pass Over	Third Pass Through	Residual Kernel After Third Pass
1966								
BP	0.92	3.0	10.6	2.6	7.8	1.7	6.3	0.23
BB	0.58	2.1	8.2	1.0	4.3	0.4	2.1	0.06
CR	0.70	3.7	10.6	1.2	5.2	1.2	2.4	0.10
S	0.86	3.2	8.0	1.4	4.6	0.7	3.0	0.17
CL	0.45	2.1	5.0	0.9	3.0	0.5	1.9	0.12
CS	0.41	1.5	4.1	0.5	2.3	0.2	1.6	0.18
Avg.	0.65	2.6	7.8	1.3	4.5	0.8	2.9	0.14
Std. Dev.	±0.21	±0.8	±2.7	±0.7	±2.0	±0.6	±1.8	±0.07
$n = 6$								
1968								
CB	0.26		6.1		3.1		1.7	0.08
CC	0.34		5.1		2.8		1.6	0.12
TE	0.20		5.2		2.3		1.7	0.06
TL	0.31		4.4		2.5		1.4	0.03
CP	0.50		11.6		6.0		3.0	0.12
TP	0.33		11.3		8.5		4.1	0.11
Avg.	0.49		7.5		4.4		2.6	0.12
Std. Dev.	±0.23		±2.9		±2.1		±1.4	±0.06
$n = 12$								

Std. Dev.

Protein

The protein content of the original kernel of 12 lots of rice averaged 7.5 ± 1.3%, ranging from 6.0 to 10.2% (Table VI). Protein in the first-pass flours through 40-mesh averaged 14.5%, ranging from 10.9 to 19.2%, nearly twice that of the corresponding whole kernel. In general, decreases in protein content occurred with each successive pass, first-pass flours averaging 1.92 times that of the corresponding original kernel; the second-pass, 1.84 times; and the third, 1.74. The largest increases, 118 and 113%, were from the first-pass flours of the parboiled rices, while the smallest increase, 52%, was from the third-pass flour of CS. An exception was BP, for which the protein contents of the three flours were much the same, 19.2 to 20.0%. The average ratios of protein in the various fractions to that of the original whole kernel are shown in Fig. 1.

In the six rices of the 1966 crop, the protein contents of the flours over 40-mesh were higher than those of the corresponding whole kernel, average increases of 48, 35, and 26% for the first-, second-, and third-pass flours, respectively, but were lower when compared with the corresponding flours through 40-mesh. Protein in the residual kernel of the 12 lots averaged 7.0 ± 1.1% which amounts to 93 ± 3% of that of the original kernel.

Fat

Fat (petroleum-ether extract) for the 12 lots of rice averaged 0.49% in the whole kernel and 7.5% in the first-pass flours, 17 times as much as in the whole kernel (Table VII). Percentage fat in the flours decreased with each successive pass and, as with protein, values for flours over 40-mesh were intermediate between those of the whole kernel and the flours through 40-mesh. Residual kernels had 0.12% fat, one-fourth that of the original rice. Because of the analytical difficulty in determining fat at very low levels, 0.2% or less, these values are not so reliable as those for other fractions.

Ash

The average ash content of the original kernel was 0.58% for the 12 rices and that of the residual kernel, 0.35% (Table VIII). Ash content of the flours, both through and over a 40-mesh screen, also decreased with each successive pass with values for flours over 40-mesh between those of the original kernel and flours through 40-mesh. There was more than a 40-fold difference between the highest and lowest values, 10.56% for the first-pass flour of BP through 40-mesh and 0.24% for the residual kernel of TE. Residual kernels contained about 60% of the ash in the whole kernel—as little as 36% for BP and as much as 75 to 80% for the short-grain and parboiled rices.

Starch

The average starch content of the residual kernel, 93.2%, was slightly higher than in the corresponding original rice, 91.9%, and was similar in all six varieties analyzed (Table IX). Starch content of the first-pass flours was about two-thirds that of the original rice, ranging from 54 to 64%. Starch in the flours increased with each successive pass.

Amylose

Amylose content of the original rice was higher in the long-grain rices, 31%,

TABLE VIII. ASH CONTENT OF FRACTIONS OF OVERMILLED RICE

Rice Lot and Variety	Whole Kernel	Ash, Percent Dry Basis, Flour Over or Through 40-Mesh Screen: First Pass Over	First Pass Through	Second Pass Over	Second Pass Through	Third Pass Over	Third Pass Through	Residual Kernel After Third Pass
1966								
BP	0.85	3.2	10.6	2.1	6.4	1.5	5.0	0.31
BB	0.54	1.2	4.8	0.9	3.1	0.6	1.7	0.27
CR	0.64	1.8	6.6	0.9	3.1	0.7	1.8	0.28
S	0.56	1.6	4.6	0.9	2.6	0.6	1.7	0.26
CL	0.49	1.7	3.5	0.9	2.1	0.5	1.3	0.37
CS	0.50	1.3	3.1	0.7	1.8	0.5	1.3	0.39
Avg.	0.60	1.8	5.5	1.0	3.2	0.7	2.1	0.31
Std. Dev. $n = 6$	±0.14	±0.7	±2.7	±0.5	±1.6	±0.4	±1.4	±0.05
1968								
CB	0.49		4.1		2.3		1.3	0.30
CC	0.43		3.0		1.8		1.2	0.31
TE	0.40		3.8		1.8		1.1	0.24
TL	0.49		3.7		2.3		1.4	0.26
CP	0.79		6.4		3.7		2.3	0.64
TP	0.72		5.2		3.7		2.3	0.57
Avg.	0.58		5.0		2.9		1.9	0.35
Std. Dev. $n = 12$	±0.14		±2.1		±1.3		±1.1	±0.13

than in the medium- and short-grains, 18 to 24% (Table IX). Amylose percentages in the residual kernel were similar, i.e., ±2% of the original rice, except for BB, which was slightly higher.

Among the various fractions, only small differences were found in amylose as percent of the total starch, except for BP and CR. In BP the percentage decreased in the flours—values of 25 to 28%, as compared with 34% for the original whole rice. In CR, amylose as percent of the starch decreased in the first-pass flour only—15% as compared with 22% for the whole kernel. The variety BB with the highest amylose contents, both as percent of the rice and as percent of the starch, had values which were about twice as large as those of S with the lowest values.

DISCUSSION

With the exception of starch, the concentration of nutrients was highest in the first-pass flour, and decreased as the center of the kernel was approached (Figs. 1 and 2). This finding is in agreement with previous data on the composition of rice flours milled by abrasion (1-5,7,8). The flours contained about twice as much protein as that in the whole kernel, with only small decreases in concentration,

TABLE IX. AMYLOSE AND TOTAL STARCH CONTENTS OF FRACTIONS OF OVERMILLED RICE

		Flour Through 40-Mesh Screen			
Variety	Whole Kernel	First Pass	Second Pass	Third Pass	Residual Kernel After Third Pass
		Amylose, percent of rice, dry basis			
BP	31	14	18	21	29
BB	31	22	25	29	35
CR	21	9	15	17	21
S	18	11	15	14	18
CL	24	17	19	22	25
CS	21	15	16	19	19
Avg. & Std. Dev.	24 ± 5	15 ± 5	18 ± 4	20 ± 5	24 ± 7
		Starch, percent of rice, dry basis			
BP	90	54	62	78	93
BB	91	59	65	81	92
CR	93	61	72	86	94
S	91	64	80	83	93
CL	93	61	76	79	94
CS	93	63	72	84	93
Avg. & Std. Dev.	92 ± 1	60 ± 3	71 ± 7	82 ± 3	93 ± 1
		Amylose, percent of starch			
BP	34	25	28	26	31
BB	34	38	39	36	38
CR	22	15	21	20	22
S	20	17	18	17	19
CL	26	27	25	27	26
CS	23	24	23	22	20
Avg. & Std. Dev.	26 ± 6	24 ± 8	26 ± 7	25 ± 7	26 ± 7

about 10%, between the first- and third-pass flours. Normand et al. (8), using an experimental mill and a sample of Bluebonnet 50, obtained rice flours from the outer 6% of the kernel which contained nearly three times as much protein as that from the original kernel. Ash and fat values averaged, respectively, 8 and 17 times greater in the first-pass flours than in the original rices. Concentrations of these components were about three times higher in the first-pass flours than in the third-pass. Flour through 40-mesh from the three passes accounted for one-half to two-thirds of the fat present in the whole kernel, one-third of the ash, and about one-eighth of the protein. The first-pass flour alone contained one-third of the fat.

Amylose and starch contents were lowest in the first-pass flours—about two-thirds those of the original rice—increased in the flours with each successive milling pass, and were highest in the interior of the kernel. About one-fourth of the

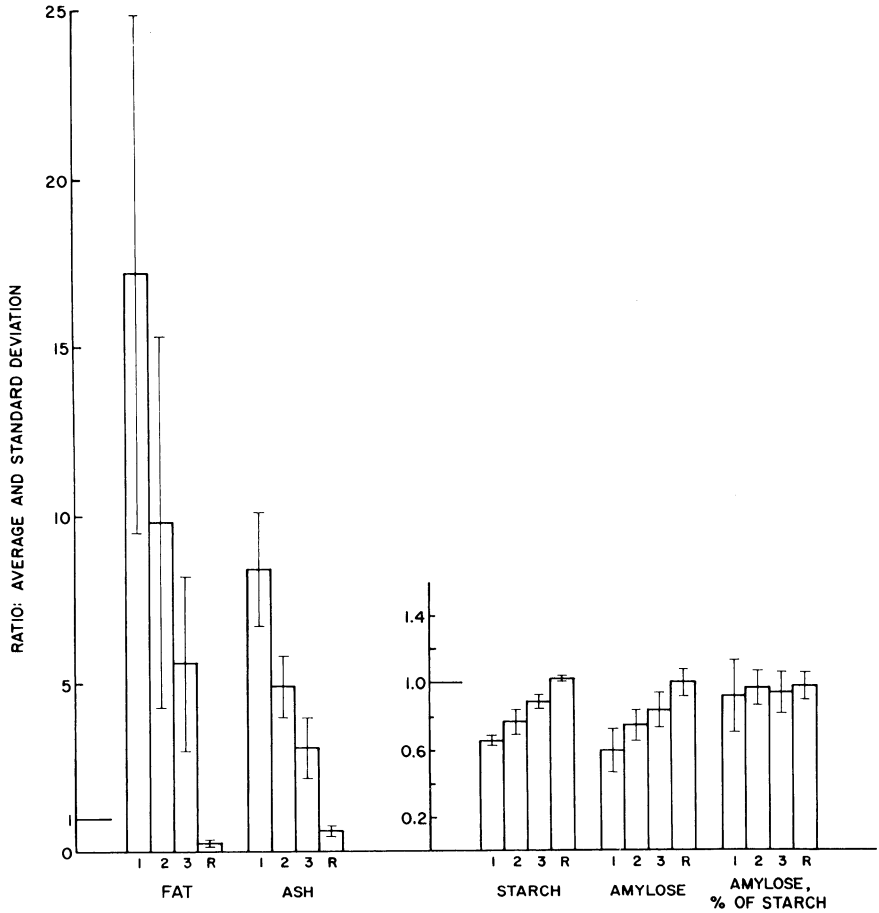

Fig. 2. Average and standard deviation of concentration of constituent in flours through 40-mesh and in residual kernel to that of the original rice. Ash and fat from 12 lots of rice; starch and amylose from six lots. 1, first-pass flour; 2, second-pass flour; 3, third-pass flour; R, residual kernel after third milling pass.

starch was amylose, and there was relatively little difference, among passes, in amylose as percent of total starch.

There was considerable difference in concentration of the components among the various lots of rice. The most uneven distribution—that is, high concentrations in the periphery of the kernel and low in the center—occurred in the long-grain rices, BP and BB, and the least in the short-grain rices, CL and CS. In comparing the first-pass flours of CS with BP, protein varied from 10.9 to 19.2%, a twofold difference; ash from 3.1 to 10.6% and fat from 4.1 to 10.6%, both about threefold differences. Of the rices studied, BP had a particularly high concentration of nutrients in the original rice and in the flours. These samples were the highest, or nearly so, in protein, fat, and ash, and lowest in starch. The flours varied little in percent protein; they did not show the decrease with successive passes as did the other rices. The greatest increases in ash in the flours, as compared with the original rice, were also found in BP; with the exception of the parboiled rices, this was also true for protein. Some variation among lots is to be expected because, in addition to varietal and environmental factors, with commercially milled rice the amount of outer portion of endosperm removed with the bran is not known.

Processing, as well as varietal, differences are apparent. The two lots of parboiled rice had high concentrations of ash in the whole kernel and the highest concentrations of fat in the first-pass flours. How much of these higher values was the result of parboiling alone is not known as we did not have samples of the unprocessed rice. Milled parboiled rice, however, is known to have a greater fat content than the comparably milled, unprocessed rice (3).

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Literature Cited

1. PRIMO, E., CASAS, A., BARBER, S., and BENEDITO de BARBER, C. Factores de calidad del arroz. IV. Distribución del nitrógeno en el endospermo. Rev. Agroquim. Tecnol. Aliment. 3: 22 (1963).
2. HOGAN, J. T., NORMAND, F. L., and DEOBALD, H. J. Method for removal of successive layers from brown and milled rice. Rice J. 67(4): 27 (1964).
3. HOGAN, J. T., DEOBALD, H. J., NORMAND, F. L., MOTTERN, H. H., LYNN, L., and HUNNELL, J. W. Production of high-protein rice flour. Rice J. 71(11): 5 (1968).
4. HOUSTON, D. F., MOHAMMAD, A., WASSERMAN, T., and KESTER, E. B. High-protein rice flours. Cereal Chem. 41: 514 (1964).
5. HOUSTON, D. F. High-protein flour can be made from all types of milled rice. Rice J. 70(9): 12 (1967).
6. LITTLE, R. R., and DAWSON, E. H. Histology and histochemistry of raw and cooked rice kernels. Food Res. 25: 611 (1690).
7. CASAS, A., BARBER, S., and CASTILLO, P. Factores de calidad del arroz. X. Distribución de grasa en el endospermo. Rev. Agroquim. Tecnol. Aliment. 3: 241 (1963).

8. NORMAND, F. L., SOIGNET, D. M., HOGAN, J. T., and DEOBALD, H. J. Content of certain nutrients and amino acid patterns in high-protein rice flour. Rice J. 69(9): 13 (1966).
9. SIMPSON, J. E., ADAIR, D. R., KOHLER, G. O., DAWSON, E. H., DEOBALD, H. J., KESTER, E. B., HOGAN, J. T., BATCHER, O. M., and HALICK, J. V. Quality evaluation studies of foreign and domestic rices. U.S. Dep. Agr., ARS Tech. Bull. 1331 (1965).
10. WILLIAMS, V. R., WU, W., TSAI, H. Y., and BATES, H. G. Varietal differences in amylose content of rice starch. J. Agr. Food Chem. 6: 47 (1958).

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