CHEMICAL, PHYSICAL, AND NUTRITIONAL PROPERTIES OF HIGH-PROTEIN FLOURS AND RESIDUAL KERNEL FROM THE OVERMILLING OF UNCOATED MILLED RICE. IV. THIAMINE, RIBOFLAVIN, NIACIN, AND PYRIDOXINE[1]

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ABSTRACT

Average vitamin contents with standard deviations for six varieties of whole kernel rice were, per 100 g.: thiamine, 0.13 ± 0.04 mg.; riboflavin, 40 ± 3 γ; pyridoxine, 136 ± 21 γ; niacin (10 lots of rice), 1.5 ± 0.6 mg. For two lots of parboiled rice, values were 0.15 ± 0.03 mg., 44 ± 6 γ, and 3.2 ± 0.1 mg. for thiamine, riboflavin, and niacin, respectively. Contents of first-pass flours obtained by abrasive milling were greater than those in the original kernel: five times as great for riboflavin, eight for thiamine and pyridoxine, and 14 for niacin. For the two parboiled rices, values were four times as great for riboflavin and thiamine and eight for niacin.

Concentrations of the vitamins were greatest in the periphery of the kernel and decreased toward the center, except for niacin in the parboiled rices in which case the highest concentrations were found in the second-pass flours, 17 times as much as in the whole kernels. Of the vitamins studied, riboflavin was the most evenly distributed throughout the kernel, with little difference between the parboiled and untreated rices, whereas niacin was the least evenly distributed. Thiamine was more evenly distributed throughout the parboiled rices than it was in the untreated rices. Flours from the periphery of the kernel, comprising 6 to 7% of the total endosperm, contained from one-fourth to one-half of the vitamins present in the whole endosperm.

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Although considerable information exists on the content of vitamins in the bran, germ, and endosperm of cereal grains, e.g. in wheat (1) and in rice (2), only sparse data are available on the distribution of vitamins within the endosperm itself.

Hinton (3,4), Houston et al. (5), and Normand et al. (6) reported values for thiamine, riboflavin, and/or niacin in various parts of the endosperm in one or two varieties of rice. The highest concentrations of all the vitamins were in the outer portions of the endosperm, decreasing toward the center of the kernel.

As part of a study on the overmilling of commercial rice (7), 12 lots of different varieties and treatments were analyzed for certain of the B-complex vitamins. The flours were obtained by abrasion in a rice-polishing machine, the first-pass flour consisting of the outermost portion of the endosperm. Data on thiamine, riboflavin, niacin, and pyridoxine in different portions of the endosperm are reported here.

MATERIALS AND METHODS

Samples of six varieties of commercially milled rice and two milled parboiled rices were studied for thiamine, riboflavin, niacin, and pyridoxine content. The samples were: original (whole-kernel) rice; first-, second-, and third-pass flours

TABLE I
Thiamine Content of Fractions of Overmilled Rice
(mg. per 100 g., dry basis)

Rice Lot[a]	Whole Kernel	Flour through 40-Mesh Screen: First Pass	Second Pass	Third Pass	Residual Kernel after Third Pass
Regular					
BP	0.16	1.27	0.86	0.84	0.058
BB	0.10	0.81	0.50	0.32	0.037
CR	0.13	0.97	0.60	0.41	0.055
S	0.18	1.38	0.85	0.60	0.071
CL	0.11	0.80	0.49	0.35	0.037
CS	0.09	0.68	0.41	0.29	0.026
Avg. and std. dev.	0.13 ± 0.04	0.98 ± 0.28	0.62 ± 0.19	0.47 ± 0.21	0.074 ± 0.020
Parboiled					
CP	0.13	0.32	0.23	0.19	0.115
TP	0.17	0.86	0.50	0.34	0.134
Avg. and std. dev.	0.15 ± 0.03	0.59 ± 0.38	0.37 ± 0.19	0.26 ± 0.11	0.124 ± 0.013
Avg. and std. dev. $n = 8$	0.13 ± 0.03	0.89 ± 0.33	0.56 ± 0.21	0.42 ± 0.21	0.067 ± 0.039

[a]BP, Texas Belle Patna; BB, Arkansas Bluebonnet 50; CR, California Calrose; S, Louisiana Saturn; CL, California Caloro; CS, California Colusa; CB, California Belle Patna; CC, California Calrose; TE, Texas Belle Patna, early seeding; TL, Texas Belle Patna, late seeding; CP, California Pearl, parboiled, medium; TP, Texas Belle Patna, parboiled, light.

through a 40-mesh screen; residual kernel after the third milling pass. Pyridoxine was not determined on the two parboiled rices. Niacin was also determined on four other lots of milled rice. Rice samples and the milling process have been described previously (7).

Thiamine was determined by the thiochrome method (8, Method 86-80), and riboflavin by the simplified fluorescence method with modifications (8, Method 86-71). Niacin and pyridoxine were determined by microbiological assay (9, Methods 40-41 and 48-49). The niacin was extracted by autoclaving the sample in 1.0N sulfuric acid for 30 min. The acid produced by the *Lactobacillus plantarum* at 37° C., 72 hr. after inoculation, was titrated with 0.1N sodium hydroxide. Volumes of base necessary to titrate the samples were compared with volumes of base necessary for the standard curve. For pyridoxine, the growth of *Saccharomyces carlsbergensis* was measured as turbidity at 600 nm. in a spectrophotometer. The vitamin was extracted by autoclaving the sample with 0.1N hydrochloric acid for 5 hr., adjusting the pH to 4.5, and filtering. Vitamin B_6 is reported as the free base of pyridoxine. Each value reported represents the average of from three to six replicates.

RESULTS AND DISCUSSION

Contents of thiamine, riboflavin, niacin, and pyridoxine for the original rices and their milled fractions are shown in Tables I to IV. Concentrations of the vitamins were much greater in the first-pass flours than in the original rices, from five times as much for riboflavin to 14 times for niacin, decreasing from the periphery to the interior of the kernel. Of the rice samples analyzed, there was a 9-

TABLE II
Riboflavin Content of Fractions of Overmilled Rice
(γ per 100 g., dry basis)

Rice Lot	Whole Kernel	Flour through 40-Mesh Screen First Pass	Second Pass	Third Pass	Residual Kernel after Third Pass
Regular					
BP	45	205	163	133	31
BB	36	180	121	85	29
CR	40	262	136	89	30
S	43	215	138	101	33
CL	38	171	119	92	35
CS	38	141	96	79	31
Avg. and std. dev.	40 ± 3	196 ± 42	129 ± 23	96 ± 19	32 ± 2
Parboiled					
CP	40	186	171	55	30
TP	48	202	178	145	35
Avg. and std. dev.	44 ± 6	194 ± 11	174 ± 5	100 ± 64	32 ± 4
Avg. and std. dev. $n = 8$	41 ± 4	195 ± 36	140 ± 29	97 ± 29	32 ± 2

fold difference in riboflavin content between the highest and lowest values, 17-fold for pyridoxine, 46 for thiamine, and more than 100-fold for niacin.

Concentrations of the four vitamins in flours and residual kernels as compared with the original rices are presented graphically in Fig. 1. The greatest difference in distribution throughout the kernel was shown by niacin; first-pass flours of the untreated rices had 14 times as much niacin as was found in the original rices while the residual kernels contained only 50% that of the original. The most even distribution was shown by riboflavin; first-pass flours of the untreated rices had five times as much as in the original rices while the residual kernels contained 77% that of the whole rice.

TABLE III
Niacin Content of Fractions of Overmilled Rice
(mg. per 100 g., dry basis)

Rice Lot	Whole Kernel	Flour through 40-Mesh Screen			Residual Kernel after Third Pass
		First Pass	Second Pass	Third Pass	
Regular					
BP	1.76	23.4	14.6	12.1	0.55
BB	1.28	16.8	10.7	5.3	0.49
CR	2.59	36.8	17.4	9.5	0.73
S	1.95	25.2	15.2	7.9	0.73
CL	1.95	19.0	12.5	7.0	1.21
CS	1.88	17.6	10.4	6.2	1.22
CB	1.11	17.2	4.8	3.4	0.72
CC	1.04	19.1	5.1	4.5	0.50
TE	0.81	15.7	4.4	2.5	0.47
TL	1.03	12.8	5.2	2.6	0.66
Avg. and std. dev.	1.54 ± 0.57	20.4 ± 6.8	10.0 ± 4.9	6.1 ± 3.1	0.73 ± 0.28
Parboiled					
CP	3.21	24.7	55.3	10.8	2.23
TP	3.18	23.0	55.8	9.0	1.93
Avg. and std. dev.	3.20 ± 0.08	23.8 ± 1.2	55.6 ± 0.4	9.9 ± 1.3	2.08 ± 0.21

TABLE IV
Pyridoxine Content of Fractions of Overmilled Rice
(γ per 100 g., dry basis)

Variety	Whole Kernel	Flour through 40-Mesh Screen			Residual Kernel after Third Pass
		First Pass	Second Pass	Third Pass	
BP	125	1,224	859	680	71
BB	128	1,185	935	460	73
CR	109	1,155	721	664	81
S	138	1,004	601	466	75
CL	149	800	539	346	99
CS	169	1,109	763	538	128
Avg. and std. dev.	136 ± 21	1,080 ± 156	735 ± 150	526 ± 129	88 ± 22

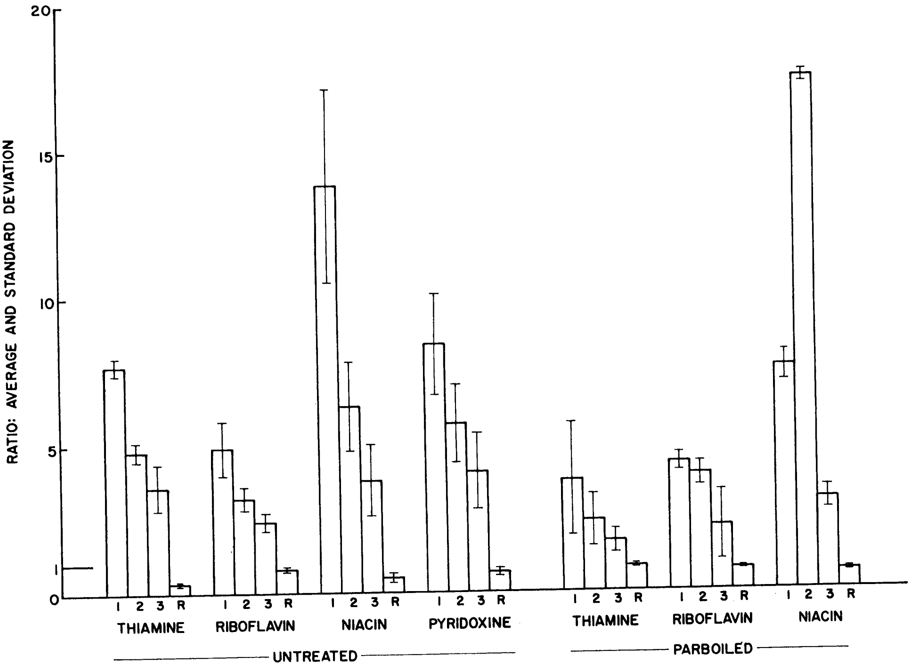

Fig. 1. Ratios with respect to the original whole-kernel rice and standard deviation of contents of thiamine, riboflavin, and niacin in flours and residual kernel in six varieties of untreated rice and in two varieties of parboiled rice, and of pyridoxine in six varieties of rice: 1, first-pass flour; 2, second-pass flour; 3, third-pass flour; R, residual kernel.

Vitamin distribution in the parboiled rices differed in some cases from that in the untreated rices (Fig. 1). For thiamine the gradient was much less. Thiamine content of the whole kernel parboiled rices was similar to that of the untreated; average thiamine content with standard deviation for the eight lots studied was 0.13 ± 0.03 mg. per 100 g. (Table I). Values for the flours of the parboiled rices were lower than for those of untreated rices which had similar quantities in the whole kernel, while values for the residual kernels were greater (84% of the original) as compared with 40% of the original for the untreated rices.

Niacin distribution also differed in the parboiled rices. The niacin content of the original and residual kernels of both parboiled samples was higher than that of the untreated rices, about twice as high for the original rice and three times as much for the residual kernels. Niacin in the flours of the untreated rices decreased with each successive pass; for the two parboiled rices, however, the second-pass flours gave the highest values, about 17 times that of the original rices.

Parboiling did not affect the distribution of riboflavin appreciably. Riboflavin values in the fractions of the parboiled rices were similar to those for corresponding fractions of the untreated rices.

Previous workers, Hinton (3,4) on rice fractions obtained by hand-dissection, Houston and co-workers (5) on fractions obtained from a lot of Calrose by abrasive milling, and Normand et al. (6) from a lot of commercially milled,

TABLE V
Comparison of Investigations on Vitamins in Rice Endosperm

		Vitamin[a]				
		Whole Endosperm	Outer Endosperm			
No. of Rice Samples	Flour from Outer Endosperm as % of Total Endosperm[a]	mg./100 g. A	mg. per 100 g. Flour[b] B	Ratio Flour/Whole Endosperm B/A	Amount in Flour as % of Whole Endosperm	Reference
			Thiamine			
1	20.5	17[d]	45[d]	2.6	54	Hinton (3)
1	6.8	0.07	0.42	5.7	39	Houston (5)
1	6.3	0.08	0.71	8.8	56	Normand (6)
6[c]	6.8 ± 1.2	0.13 ± 0.04	0.69 ± 0.22	5.4 ± 0.6	37 ± 6	This work
			Riboflavin			
1	6.8	0.037	0.20	5.4	37	Houston (5)
1	6.3	0.022	0.078	3.6	23	Normand (6)
6[c]	6.8 ± 1.2	0.040 ± 0.003	0.14 ± 0.03	3.5 ± 0.5	24 ± 5	This work
			Niacin			
2[c]	6.3 ± 0.3	0.94 ± 0.02	9.0 ± 0.5	9.6 ± 0.3	63 ± 1	Hinton (4)
1	6.3	1.26	8.1	6.4	41	Normand (6)
6[c]	6.8 ± 1.2	1.9 ± 0.4	15.0 ± 4	7.8 ± 1.6	53 ± 13	This work
			Pyridoxine			
6[c]	6.8 ± 1.2	0.14 ± 0.02	0.78 ± 0.15	5.9 ± 1.8	40 ± 13	This work

[a]Dry basis.
[b]Weighted averages of flours (1 to 3 passes).
[c]Average and standard deviation.
[d]International Units.

predominantly Bluebonnet 50, obtained by abrasion on an experimental mill, have published data on the vitamin content of the outer portions of the endosperm. These data, calculated to show the amount of the vitamin found in the outer portions as percent of the amount present in the whole endosperm, are compared with our results (Table V). In general, concentrations in the outer 6 to 7% of the endosperm were about six times as great as in the whole endosperm. Riboflavin, which is more evenly distributed throughout the kernel (as in wheat; see ref. 1, p. 96), was only about four times as concentrated. Niacin, however, which has a steeper gradient from outer to inner kernel, was concentrated eight times. In all instances one-fourth to one-half of the amount in the whole endosperm was found in the outer 6 to 7%, with riboflavin having the smallest amount and niacin the largest.

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