Chemical Composition of Different Fractions of 12 Mexican Varieties of Rice Obtained During Milling

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ABSTRACT

The proximate chemical analysis and mineral and vitamin content of 12 Mexican varieties of rice were determined after milling. In all varieties, measurements were made on the brown rice, the polished rice, the hull, and the bran. For brown grain rice, the average and standard deviation of the data as percentages were the following: 9.2 ± 1.3 protein, 1.4 ± 0.2 ash, 2.6 ± 0.3 fat, 1.9 ± 0.6 fiber, and 84.9 ± 1.6 starch. The hull and bran contained averages of 2.4 and 13.7% protein, respectively. Elimination of the hull significantly diminished the amounts of calcium, iron, and riboflavin. Polishing the rice significantly reduced the thiamin, riboflavin, potassium, and iron content and lowered the content of zinc and calcium to a lesser extent. Differences were found between varieties of brown and white rice in vitamin, mineral, fiber, and fat contents.

Rice is an important world cereal source of energy and protein. Its primary disadvantage among cereals is its relatively low protein content (5–8%) (Lorenz 1978, Mosse and Baudet 1983, Tabekhia and Toma 1981). However, varieties of rice with high protein content have been obtained through genetic improvements, fertilization, and environmental manipulation (Nishizawa et al 1977, Saunders and Betschart 1979).

Whole rice is milled before marketing. The milling process produces four fractions: brown rice, hull, white rice, and bran. Each one of these fractions can vary in chemical content according to the variety of rice and the type of milling performed (Palipane and Swarnasiri 1985, Roberts 1979).

The purpose of the present study was to determine the chemical composition of different fractions of 12 varieties of Mexican rice.

MATERIALS AND METHODS

The varieties of Mexican rice studied were provided by the Instituto Nacional de Investigaciones Agrícolas, Programa de Arroz, Zona Sur, Zacatepec Morelos, México. The 12 varieties were the following: Morelos A-70, Morelos A-83, CICA 4, CICA 6, Navolato A-71, Juchitán A-74, Bamoa A-75, Campeche A-80, Sinaloa A-80, Cárdenas A-80, Champotón A-80, and Culiacán A-82.

Samples of each variety of rice were dehulled with a McGill dehusker and were milled to bran removal in a McGill-type miller no. 2 friction-type mill. For each variety, the brown rice, hull, white rice, and bran were subjected to proximate chemical analysis, and the determination of mineral content was done according to the techniques described in the AOAC (1970). The analyses of sodium, potassium, calcium, iron, and zinc were made using an atomic absorption spectrophotometer (Perkin Elmer, model 5000). Ashes of the various samples were dissolved in nitric acid for these mineral analyses. Concentrated nitric acid was used for the brown and white rice samples and 20% nitric acid was used for the hull and bran samples.

Thiamin and riboflavin measurements were made using a Technicon Autoanalyzer II, following the AOAC (1980) techniques as described in the instrument manual (Technicon Instruments Corp., Industrial Method nos. 479-77A for thiamin and 140-71A for riboflavin). The mineral and vitamin contents of bran were measured using a pooled sample from all of the varieties of rice used in the study, since the amount of bran of each rice variety was quite small. All measurements were performed in duplicate. Statistical analysis of the data was performed by means of Student's paired t test (Steel and Torrie 1960).

RESULTS AND DISCUSSION

The yield obtained in the milling process was very similar for all of the varieties of rice studied. The values obtained and their standard deviations are shown in Table I as a percentage of whole rice (paddy). Although these results are similar to those described by Bechtel and Pomeranz (1978) and by Saunders and Betschart (1979), yields may be manipulated intentionally during milling to increase or decrease the bran content of rice. Obviously, this will affect the chemical composition of the white rice and the bran (Pedersen and Eggum 1983, Roberts 1979).

Table II shows the proximate chemical composition of the brown and white rices for the varieties studied. The process of polishing brown rice eliminated 13% protein, 50% ash, 69% fat, and 66% fiber. These losses were calculated, taking into consideration the percentage of each fraction (brown 100%, white rice 91%, and bran 9%) and its relative chemical composition. In general, the chemical compositions of brown and white rices in this study were similar to those of rice varieties studied by other scientists (Bean et al 1983, Chang et al 1986, Chinnaswamy and Bhattacharaya 1983, Eggum et al 1981). For the 12 varieties of brown rice, the protein varied from 6.8 to 11.9%; for white rice the range was 6.9 to 11.6% protein. Significant differences in protein were found between brown and white rices ($P \leq 0.01$), in accordance with the findings of other authors (Ellis et al 1986) who reported between 14 and 18% protein loss during the polishing process. Most of the Mexican varieties of rice contained more than 8% protein in both brown and white fractions, with Morelos A-70 and Juchitán A-74 being the only exceptions. The Navolato A-71 variety had an exceptionally high protein content, 11.9 and 11.6% in brown and white rice, respectively. These findings, as well as the diminution of fat observed in the white rices compared with the brown rices, mainly resulted from the elimination of germ during polishing.

The chemical compositions of hull and bran for the rice varieties studied are given in Table III. Bran protein content ranged from

TABLE I
Yield Obtained in the Milling Process of 12 Mexican Varieties of Rice

Fractions	Yield (%) From Whole Rice	Yield (%) From Brown Rice
Hull	24.2 ± 1.4	...
Brown rice	75.8 ± 1.3	100
White rice	68.9 ± 1.4	91
Bran	6.9 ± 0.8	9

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12.0 to 14.7%. The high fat (22.7 ± 2.8%), fiber (12.7 ± 2.1%), and ash (10.0 ± 1.8%) content in bran reconfirmed the difference in the contents of these nutrients between brown and white rices. These values are similar to those reported by other researchers for 6–10% bran yield (Fujino 1978, James and Sloan 1984, Palipane and Swarnisiri 1985).

The hull in all varieties contained more fiber and ash and less protein and fat than the bran. The highest protein content was found in the hull of the CICA 6 variety. This variety contained 4.1% protein, whereas the other varieties averaged 2% protein. On the basis of the results for nutrient contents, bran could be considered a very balanced food, which is why it is used in feeding animals (Campabadal et al 1976).

Tables IV and V present the mineral and vitamin contents of the brown and white rice fractions. The first thing that can be observed is the variability in mineral and thiamin content, which is more pronounced in white than in brown rice.

Secondly, iron, zinc, potassium, calcium, thiamin, and ribo-

TABLE II
Chemical Composition of Brown and White Rices Obtained from Mexican Varieties of Rice (g/100 g of sample)[a]

	Protein (N × 5.95)		Ash		Crude Fat		Crude Fiber		Carbohydrate	
Variety	Brown	White	Brown	White	Brown	White	Brown	White	Brown	White
Champotón A-80	9.9 ± 0.02	9.0 ± 0.07	1.5 ± 0.01	0.6 ± 0.06	2.5 ± 0.14	0.7 ± 0.11	1.5 ± 0.01	0.7 ± 0.00	84.5 ± 0.04	89.0 ± 0.06
Morelos A-70	6.8 ± 0.11	6.9 ± 0.37	1.6 ± 0.06	1.0 ± 0.03	2.5 ± 0.15	1.5 ± 0.06	1.4 ± 0.28	0.4 ± 0.01	87.6 ± 0.15	90.2 ± 0.12
Morelos A-83	9.5 ± 0.02	8.4 ± 0.16	1.4 ± 0.03	1.0 ± 0.05	3.2 ± 0.38	1.1 ± 0.06	2.9 ± 0.01	0.5 ± 0.07	83.0 ± 0.11	89.0 ± 0.08
Sinaloa A-80	9.3 ± 0.08	8.8 ± 0.44	1.2 ± 0.04	0.5 ± 0.05	2.5 ± 0.20	0.6 ± 0.00	2.2 ± 0.07	0.4 ± 0.04	84.8 ± 0.10	89.7 ± 0.13
Bamoa A-75	9.3 ± 0.09	8.5 ± 0.06	1.2 ± 0.03	0.4 ± 0.01	2.7 ± 0.00	0.5 ± 0.01	2.6 ± 0.03	0.6 ± 0.06	84.2 ± 0.04	90.0 ± 0.03
CICA 4	8.5 ± 0.03	8.4 ± 0.23	1.7 ± 0.05	0.7 ± 0.01	3.1 ± 0.41	1.2 ± 0.09	1.4 ± 0.06	0.5 ± 0.07	85.3 ± 0.14	89.2 ± 0.10
CICA 6	9.7 ± 0.08	8.9 ± 0.08	1.2 ± 0.07	0.5 ± 0.04	2.3 ± 0.11	1.0 ± 0.18	1.5 ± 0.02	0.4 ± 0.01	85.3 ± 0.07	89.2 ± 0.08
Cárdenas A-80	9.9 ± 0.03	9.5 ± 0.17	1.7 ± 0.13	1.0 ± 0.01	2.4 ± 0.01	1.0 ± 0.13	2.0 ± 0.08	0.5 ± 0.06	84.0 ± 0.04	88.0 ± 0.09
Campeche A-80	8.8 ± 0.08	9.0 ± 0.01	1.3 ± 0.04	0.5 ± 0.01	2.3 ± 0.12	0.7 ± 0.23	1.2 ± 0.07	0.5 ± 0.01	86.4 ± 0.08	89.2 ± 0.06
Navolato A-71	11.9 ± 0.20	11.6 ± 0.15	1.0 ± 0.07	0.4 ± 0.01	2.5 ±0.13	1.0 ± 0.09	2.7 ± 0.04	0.6 ± 0.01	81.9 ± 0.11	86.4 ± 0.06
Culiacán A-82	9.6 ± 0.01	9.1 ± 0.03	1.2 ± 0.06	0.4 ± 0.01	2.5 ± 0.03	1.0 ± 0.14	1.7 ± 0.03	0.6 ± 0.03	85.0 ± 0.03	88.9 ± 0.05
Juchitán A-74	7.4 ± 0.31	7.1 ± 0.33	1.4 ± 0.04	0.9 ± 0.08	2.2 ± 0.36	1.1 ± 0.01	1.7 ± 0.16	1.3 ± 0.16	87.3 ± 0.22	89.7 ± 0.14
Average	9.2		1.4	0.7	2.6	1.0	1.9	0.6	84.9	89.0
SD	1.3		0.2	0.2	0.3	0.3	0.6	0.2	1.6	1.0

[a] Dry basis, brown = 8.4 ± 0.6 mc, white = 7.0 ± 0.7 mc.

TABLE III
Chemical Composition of Brands and Hull from Mexican Varieties of Rice (g/100 g of sample)[a]

	Protein (N × 5.95)		Ash		Crude Fat		Crude Fiber		Carbohydrate	
Variety	Bran	Hull	Bran	Hull	Bran	Hull	Bran	Hull	Bran	Hull
Champotón A-80	13.5 ± 0.20	2.0 ± 0.03	12.4 ± 0.03	25.7 ± 0.37	24.3 ± 0.22	0.4 ± 0.01	14.0 ± 0.11	38.3 ± 1.42	35.8 ± 0.14	33.6 ± 0.46
Morelos A-70	12.0 ± 0.08	1.9 ± 0.21	11.0 ± 0.06	22.8 ± 0.03	21.9 ± 0.01	0.6 ± 0.07	10.0 ± 0.30	45.2 ± 1.10	45.1 ± 0.11	29.5 ± 0.35
Morelos A-83	13.2 ± 0.01	2.1 ± 0.07	11.0 ± 0.02	25.3 ± 0.01	27.6 ± 0.33	0.7 ± 0.03	10.3 ± 0.00	44.1 ± 2.52	37.9 ± 0.09	27.8 ± 0.66
Sinaloa A-80	14.2 ± 0.20	2.3 ± 0.08	9.4 ± 0.39	21.5 ± 0.07	23.4 ± 0.21	1.1 ± 0.03	13.0 ± 0.01	42.9 ± 0.76	40.0 ± 0.20	32.3 ± 0.23
Bamoa A-75	14.7 ± 0.01	2.1 ± 0.03	9.3 ± 0.04	21.2 ± 0.11	23.6 ± 0.35	0.7 ± 0.06	13.4 ± 0.20	40.7 ± 0.80	39.0 ± 0.15	35.3 ± 0.25
CICA 4	14.7 ± 0.16	2.5 ± 0.00	9.6 ± 0.10	19.9 ± 0.42	19.7 ± 0.15	0.7 ± 0.11	11.3 ± 0.54	42.2 ± 4.49	44.7 ± 0.24	34.7 ± 1.25
CICA 6	13.8 ± 0.01	4.1 ± 0.20	8.2 ± 0.16	19.0 ± 0.32	22.1 ± 0.02	1.2 ± 0.04	10.6 ± 0.24	39.0 ± 1.97	45.3 ± 0.11	36.7 ± 0.63
Cárdenas A-80	13.0 ± 0.05	2.1 ± 0.01	13.8 ± 0.04	24.8 ± 0.01	21.9 ± 0.01	0.6 ± 0.06	15.2 ± 0.01	43.2 ± 2.22	36.1 ± 0.03	29.3 ± 0.57
Campeche A-80	13.7 ± 0.03	2.9 ± 0.08	10.2 ± 0.32	20.0 ± 0.26	20.3 ± 0.54	0.5 ± 0.08	13.3 ± 0.40	44.5 ± 3.04	42.5 ± 0.32	32.1 ± 0.86
Navolato A-71	14.3 ± 0.25	2.0 ± 0.06	8.4 ± 0.03	23.7 ± 0.24	24.8 ± 0.81	0.5 ± 0.06	15.2 ± 0.46	44.1 ± 0.35	37.3 ± 0.39	29.7 ± 0.18
Culiacán A-82	13.4 ± 0.12	2.3 ± 0.11	9.1 ± 0.04	21.2 ± 0.11	25.4 ± 0.05	0.8 ± 0.00	15.2 ± 0.79	44.4 ± 4.52	36.9 ± 0.25	31.3 ± 1.18
Juchitán A-74	13.5 ± 0.93	2.4 ± 0.41	7.7 ± 0.19	20.9 ± 0.02	17.4 ± 0.08	0.6 ± 0.03	10.2 ± 0.81	43.2 ± 5.23	51.2 ± 0.50	32.9 ± 1.42
Average	13.7	2.4	10.0	22.2	22.7	0.7	12.7	42.5	40.9	32.0
SD	0.8	0.6	1.8	2.2	2.8	0.2	2.1	2.2	4.8	2.7

[a] Dry basis, bran = 5.8 ± 0.5 mc, hull = 6.4 ± 0.8 mc.

TABLE IV
Mineral Contents in Mexican Varieties of Brown and White Rices (mg/100 g of sample)

	Fe		Zn		Na		K		Ca	
Variety	Brown	White	Brown	White	Brown	White	Brown	White	Brown	White
Champotón A-80	0.8 ± 0.04	0.5 ± 0.02	2.7 ± 0.02	1.8 ± 0.01	8.0 ± 0.37	6.6 ± 0.31	228 ± 3.6	123 ± 3.8	9.2 ± 0.28	9.2 ± 0.12
Morelos A-70	1.4 ± 0.03	0.6 ± 0.04	3.1 ± 0.04	1.2 ± 0.02	11.7 ± 1.30	13.8 ± 0.19	218 ± 3.8	87 ± 2.6	13.4 ± 0.25	7.5 ± 0.09
Morelos A-83	1.1 ± 0.04	0.4 ± 0.04	1.7 ± 0.02	1.2 ± 0.01	13.5 ± 0.34	6.6 ± 0.21	211 ± 5.1	74 ± 2.4	18.8 ± 0.27	7.9 ± 0.09
Sinaloa A-80	1.1 ± 0.02	0.9 ± 0.02	1.8 ± 0.04	1.3 ± 0.02	16.4 ± 0.46	5.8 ± 0.25	222 ± 4.0	91 ± 1.8	13.6 ± 0.24	7.0 ± 0.08
Bamoa A-75	1.3 ± 0.05	0.4 ± 0.02	1.9 ± 0.02	0.8 ± 0.07	8.5 ± 0.93	15.9 ± 0.63	220 ± 4.2	48 ± 1.7	13.8 ± 0.22	11.7 ± 0.09
CICA 4	2.5 ± 0.03	0.8 ± 0.02	2.5 ± 0.04	1.8 ± 0.02	7.6 ± 0.47	9.6 ± 0.24	368 ± 5.6	134 ± 4.0	12.0 ± 0.19	10.3 ± 0.13
CICA 6	1.4 ± 0.00	0.7 ± 0.03	2.1 ± 0.03	1.6 ± 0.05	11.2 ± 1.51	12.2 ± 0.23	181 ± 1.3	107 ± 2.6	13.3 ± 0.13	7.0 ± 0.09
Cárdenas A-80	0.9 ± 0.04	0.6 ± 0.02	1.6 ± 0.03	1.0 ± 0.01	6.3 ± 0.86	6.5 ± 0.22	291 ± 4.9	113 ± 1.8	11.8 ± 0.16	4.5 ± 0.06
Campeche A-80	1.4 ± 0.02	0.5 ± 0.02	2.0 ± 0.03	1.5 ± 0.03	10.5 ± 0.52	8.3 ± 0.19	184 ± 4.3	127 ± 2.3	15.6 ± 0.20	14.1 ± 0.17
Navolato A-71	1.0 ± 0.00	0.6 ± 0.02	2.7 ± 0.03	2.1 ± 0.02	7.4 ± 0.52	8.9 ± 0.50	272 ± 4.2	76 ± 4.1	10.9 ± 0.21	13.4 ± 0.11
Culiacán A-82	2.3 ± 0.03	0.4 ± 0.03	2.8 ± 0.03	1.2 ± 0.01	8.1 ± 1.88	2.9 ± 0.24	186 ± 3.4	60 ± 1.8	13.3 ± 0.22	5.1 ± 0.07
Juchitán A-74	1.2 ± 0.04	0.3 ± 0.02	2.7 ± 0.04	1.8 ± 0.01	8.1 ± 0.52	7.8 ± 0.72	257 ± 4.9	103 ± 1.3	11.6 ± 0.23	5.7 ± 0.06
Average	1.4	0.6	2.3	1.5	9.8	8.7	236	95	13.1	8.8
SD	0.5	0.2	0.5	0.4	3.0	3.7	54	27	2.4	3.1

TABLE V
Vitamin Contents in Mexican Varieties of Brown and White Rices
(mg/100 g of Sample)

Variety	Thiamin		Riboflavin	
	Brown	White	Brown	White
Champotón A-80	0.67 ± 0.055	0.22 ± 0.002	0.06 ± 0.002	0.02 ± 0.0009
Morelos A-70	···	···	0.05 ± 0.003	0.02 ± 0.0010
Morelos A-83	0.48 ± 0.083	0.09 ± 0.010	0.05 ± 0.007	0.01 ± 0.0007
Sinaloa A-80	0.46 ± 0.018	0.09 ± 0.006	0.05 ± 0.007	0.01 ± 0.0001
Bamoa A-75	0.50 ± 0.052	0.08 ± 0.004	0.05 ± 0.000	0.01 ± 0.0007
CICA 4	1.80 ± 0.070	0.17 ± 0.012	0.04 ± 0.003	0.02 ± 0.0010
CICA 6	1.54 ± 0.334	0.12 ± 0.024	0.04 ± 0.003	0.02 ± 0.0002
Cárdenas A-80	0.71 ± 0.052	0.16 ± 0.021	0.04 ± 0.001	0.01 ± 0.0003
Campeche A-80	1.31 ± 0.039	0.15 ± 0.007	0.05 ± 0.001	0.02 ± 0.0001
Navolato A-71	1.16 ± 0.294	0.08 ± 0.013	0.06 ± 0.005	0.01 ± 0.0006
Culiacán A-82	0.61 ± 0.004	0.12 ± 0.002	0.06 ± 0.002	0.02 ± 0.0007
Juchitán A-74	1.74 ± 0.397	0.08 ± 0.002	0.04 ± 0.000	0.02 ± 0.0010
Average	1.00	0.12	0.05	0.016
SD	0.52	0.05	0.01	0.005

TABLE VI
Mineral and Vitamin Contents in Bran and Hull of Mexican Varieties of Rice[a]
(mg/100 g of sample)

Variety	Fe	Zn	Na	K	Ca	Thiamine	Riboflavin
Bran[b]	7.8 ± 0.05	9.4 ± 0.02	21.0 ± 2.90	1,149 ± 16.0	40.6 ± 0.57	4.16 ± 0.339	0.27 ± 0.002
Champotón A-80	1.6 ± 0.02	1.3 ± 0.02	10.1 ± 0.74	225 ± 4.4	57.7 ± 0.64	0.13 ± 0.006	0.07 ± 0.001
Morelos A-70	5.0 ± 0.01	0.9 ± 0.02	12.7 ± 0.93	178 ± 2.8	74.7 ± 1.16	···	0.08 ± 0.004
Morelos A-83	2.3 ± 0.02	1.4 ± 0.01	6.0 ± 1.14	241 ± 4.6	58.8 ± 0.62	0.05 ± 0.010	0.07 ± 0.008
Sinaloa A-80	2.4 ± 0.03	0.8 ± 0.02	13.5 ± 0.80	298 ± 5.2	43.4 ± 0.47	0.13 ± 0.013	0.08 ± 0.008
Bamoa A-75	3.2 ± 0.02	1.5 ± 0.02	7.7 ± 0.52	272 ± 7.1	46.6 ± 0.30	0.09 ± 0.006	0.07 ± 0.002
CICA 4	2.2 ± 0.01	1.7 ± 0.02	6.6 ± 0.46	221 ± 4.9	31.8 ± 0.41	0.13 ± 0.023	0.08 ± 0.003
CICA 6	2.0 ± 0.03	1.6 ± 0.03	13.0 ± 0.54	242 ± 3.5	42.8 ± 0.47	0.35 ± 0.016	0.08 ± 0.002
Cárdenas A-80	1.4 ± 0.04	1.1 ± 0.02	7.0 ± 0.60	209 ± 2.5	68.2 ± 0.71	0.18 ± 0.016	0.06 ± 0.001
Campeche A-80	3.0 ± 0.03	1.1 ± 0.01	7.5 ± 0.57	194 ± 3.2	48.4 ± 0.39	0.21 ± 0.036	0.07 ± 0.002
Navolato A-71	2.4 ± 0.04	2.1 ± 0.01	6.2 ± 0.46	169 ± 2.6	78.6 ± 0.65	0.07 ± 0.016	0.07 ± 0.003
Culiacán A-82	2.5 ± 0.03	4.4 ± 0.05	11.0 ± 0.62	265 ± 6.3	43.8 ± 0.55	0.05 ± 0.006	0.08 ± 0.005
Juchitán A-74	2.4 ± 0.03	2.7 ± 0.03	9.9 ± 0.67	210 ± 2.9	38.8 ± 0.37	0.11 ± 0.005	0.08 ± 0.001
Hull average	2.5	1.7	9.3	227	52.8	0.14	0.07
SD	0.9	1.0	2.8	39	14.8	0.09	0.01

[a]Of the total Fe in whole rice, 35% is in the bran and 38% in the hull; for total Zn, 31% is in the bran and 19% in the hull; 15% of Na is in the bran and 23% in the hull; 40% of K is in the bran and 27% in the hull; 13% of Ca is in the bran and 59% in the hull; 71% of thiamin is in the bran and 8% in the hull; 40% of riboflavin is in the bran and 35% in the hull.
[b]Mixture of all varieties.

flavin are present in higher concentrations in brown rice. However, this is not the trend for sodium. Possibly sodium is more highly concentrated in the endosperm of the grain and, therefore, the loss of this element is not as significant during removal of the bran. The high variability in mineral content among rice varieties found in this study is also documented throughout the literature. For example, the calcium, iron, and zinc values obtained in the present work were similar to those found by Pedersen and Eggum (1983), but lower than those obtained by Roberts (1979), and higher than the data reported by Wolnick et al (1985). Potassium was present in the highest concentrations, which agrees with the results reported by Saunders and Betschart (1979) and Roberts (1979).

Chinnaswamy and Battacharaya (1983) reported that sodium had the widest range of values (from a trace to 48.8 mg per 100 g of sample). Thiamin suffered the greatest loss during polishing process. For instance, the brown rice of CICA 4, which had the most thiamin (1.8 mg), diminished to 0.17 mg in white rice, a 90% loss. Similar results were found for the Juchitán A-74, CICA 6, and Campeche A-80 varieties. The average thiamin content for all varieties studied was 1.00 ± 0.52 mg. These results are higher than the data reported for other varieties (Roberts 1979, Saunders and Betschart 1979, Toma and Tabekhia 1979). Although riboflavin is present in lower concentrations than thiamin in brown rice, it also suffered significant losses during the polishing process.

The vitamin and mineral contents of the mixture of bran from all 12 varieties and in the hull of each variety is given in Table VI.

As expected, the bran had higher mineral and vitamin contents than the hull. Thiamin in bran (4.16 mg/100 g of sample) represents 71% of the total present in whole rice. Calcium and iron were present in very high concentrations in the hull, especially in the Morelos A-70 variety, which is very rich in both elements. For this reason, the simple removal of the hull caused a 60% loss of calcium and a 40% loss of iron in this variety. Polishing further reduced the calcium and iron contents to a 73 and 76% loss, respectively, from whole grain levels.

The hull contained low levels of both riboflavin and thiamin in all 12 varieties of rice, even though 35% of the riboflavin present in whole rice was in the hull. All of these data support the superiority of parboiling rice to produce white rice. According to Bechtel and Pomeranz (1978) and Saunders and Betschart (1979), the parboiling process for polishing rice produces white rice with a higher percentage of minerals and vitamins than white rice produced by milling alone. During parboiling, some of the mineral and vitamin contents of the bran and hull are transferred to the endosperm of the rice grain.

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