Influence of Processing on Nutritive Value of Milled Rice

MARINUS C. KIK
Department of Agricultural Chemistry,
University of Arkansas,
Fayetteville, Ark.

A comparative study was made of the nutritive value of treated and nontreated milled rice, because the domestic use of treated milled rice is increasing. The albino rat was used as the experimental animal. This study confirms the results of previous investigations that the treatment of milled rice, by either conversion or parboiling, causes marked increases in the concentration of thiamine, riboflavin, and nicotinic acid. Such methods of processing result in considerable increases in the concentration of biotin, folic acid (total and free), pyridoxine, choline, *p*-aminobenzoic acid, pantothenic acid (total and free), inositol, calcium, phosphorus, and iron (total and available). Treated milled rice has higher nutritive value than nontreated milled rice, under conditions of parboiling processes studied.

THE PROCESS OF PARBOILING RICE consisted originally and essentially of soaking rough rice in water for several hours, draining off the water, steaming the rice, and drying it in the sun (*2*).

Some rice is parboiled commercially in Java, Italy, and the United States, where the old oriental principle is applied in modern plants on a commercial scale. The patented methods differ from the original in time of soaking, temperature of soaking water, and duration of steaming, with or without hydraulic pressure.

Modern commercial applications of parboiling include the rice conversion, the Malek, Gariboldi, and Fernandez processes. The process of rice conversion in Houston, Tex., applies a vacuum for soaking and drying. In the Malek parboiling process in Houston, Tex., the paddy is steamed under pressure. A similar process is used by the Sacramento mill in California and by another mill in Houston, Tex. The process used by Gariboldi in Pavia, Italy, employs autoclaves for soaking, steaming, and drying. A simple and efficient method is used by Fernandez in Paramaribo, Surinam, where the rice is conveyed through the apparatus, and steam at about atmospheric pressure is used for processing it (*8*, *15*).

During the process, water-soluble nutrients penetrate from the outer layers into the inner layers. This results, after milling, in a commercial finished product of higher thiamine, riboflavin, and niacin content (*11*, *14*, *15*).

The advantages of parboiling are: easier removal of the hulls, reduction of breaking during milling; retention of shape of the cooked grains, and retention of a good part of the thiamine (*3*, *22*), niacin, riboflavin, and minerals (*26*). This last advantage is partly due to the gelatinization of the starch (gelatinization temperature is 80° C.) in the endosperm during steaming and embedding of some of the bran constituents, which are thus preserved in the kernel even after milling (*23*). Less bran is removed in milling of parboiled than of nonparboiled rice. Cooking and washing losses are lower in household preparation of parboiled rice; it is far less attractive to weevils and other insects, and it keeps better.

Objections to parboiled rice are the unattractive color, taste, and odor of some products obtained in the Orient, due to fermentation during the stage of soaking and drying. This can be prevented by soaking the rough rice for a shorter time in water, heating to a temperature at which fermentation does not take place, and drying the rice by artificial means.

Improvements in the parboiling process, using modern commercial methods, have resulted in a product that is less yellow before cooking, practically white after cooking and more attractive in odor and taste.

The literature concerning parboiling has been reviewed (*13*, *21*). The most recent studies have been concerned with a new use for parboiled rice (*20*), riboflavin, niacin (*18*), and iron content (*19*) of Avorio rice (a parboiled rice, produced by Gariboldi mills in Milan and Pavia, Italy), and the effects of various treatments of rice on thiamine and niacin content (*6*).

This paper reports studies on the con-

Table I. Composition of Rations[a]

	Ration, Grams			
	1	2	3	4
Nonconverted rice	870	...	...	...
Converted rice	...	844	...	...
Nonparboiled rice	...	...	870	...
Parboiled rice	...	...	...	853
Cellu flour	20	20	20	20
Sure's salts No. 1 (*24*)	40	40	40	40
Vegetable shortening	40	40	40	40
Cod liver oil	20	20	20	20
Wheat germ oil	10	10	10	10
Cerelose	0	26	...	17

[a] Supplemented daily with a vitamin B complex mixture: 25 γ thiamine, 25 γ riboflavin, 25 γ pyridoxine, 25 γ nicotinic acid, 6 mg. choline, 150 γ calcium pantothenate, 3 mg. *p*-aminobenzoic acid, and 1 mg. inositol.

tent of members of the vitamin B complex, amino acids, and minerals, and the biological value of the proteins of samples of commercial rice processed according to the rice conversion method and the Malek process.

Experimental Procedure and Results

Commercial samples of converted and parboiled rice were used for the determination of vitamins, minerals, amino acids, and biological value of the proteins. Thiamine was determined by the thiochrome method, an adaptation of the Hennessy and Cerecedo procedure (*9*), and riboflavin by a fluorometric method (*5*). Nicotinic acid, biotin, folic acid, pyridoxine, inositol, choline, and *p*-aminobenzoic acid were determined by microbiological assay, using the methods described by Barton-Wright (*4*). The new procedure of Toepfer and others (*25*) was employed for the determination of free and total pantothenic acid. Amino acids were determined in protein extracts, by hydrolyzing 2-gram samples for 16 hours at 15-pound pressure with 50 ml. of 3*N* hydrochloric acid in 125-ml. Erlenmeyer flasks which were covered with small beakers. The testing was performed according to detailed technique described by Barton-Wright (*4*) and by Horn and associates (*10*). *Lactobacillus arabinosus* 17–5 was employed to determine nicotinic acid, pantothenic acid, biotin, and the amino acids, leucine, valine, isoleucine, and tryptophan. The enzymatic method was used for tryptophan. *Streptococcus faecalis* R was used for the determination of folic acid, arginine, and threonine. Lysine, glycine, methionine, glutamic acid, aspartic acid, tyrosine, proline, cystine, phenylalanine and serine were tested with *Leuconostoc mesenteroides* P-60. *Neurospora crassa* 37401a was used for the determination of inositol, *Neurospora sitophila* 299 for the assay of pyridoxine, *Neurospora crassa* 34486 for determination of choline, and *Neurospora crassa* 1633 for the determination of *p*-aminobenzoic acid. Dehydrated media prepared by a commercial laboratory (Difco Laboratories, Inc., Detroit, Mich.) were employed for the determination of methionine, lysine, leucine, isoleucine, phenylalanine, arginine, cystine, tyrosine, tryptophan, pyridoxine, biotin, folic acid, and pantothenic acid.

Calcium, phosphorus, and total iron were determined according to official methods (*1*). The method of Elvehjem (*7*) was used for the determination of available iron. The technique of Mitchell (*16*, *17*) was employed for the determination of the biological value of the proteins.

Growth, biological value, and true digestibility were determined in studies of growth and metabolism using albino rats as experimental animals fed rice rations containing 5.23 and 5.90% protein. All rations were supplemented with adequate amounts of salts and vitamins and the animals were fed ad libitum for 70 days in the growth experiments. Twelve animals, six males and six females, were fed each ration in the growth studies, and in the metabolism studies 24 animals were employed with converted rice and 12 with parboiled rice.

The composition of the rations is given in Table I. The protein was at the 5.23% level, in the converted rice ration, and at the 5.90% level in the parboiled rice ration.

The results of growth experiments are given in Table II and of the metabolism experiments in Table III.

From the gains in body weight per gram of protein intake the protein efficiency ratios were calculated; the results in Table II are expressed as average growth per animal during a 10-week experimental period.

Table II indicates that when converted rice was fed instead of nonconverted rice, the animals showed a 41.4% increase in body weight and a 23.1% increase in protein efficiency ratio (ration 2). An increase of 34.1% in growth and 14.5% in protein efficiency was found in animals fed ration 4 containing 5.90% protein derived from parboiled rice. These differences (except the 14.5%) were significant for $P = 0.05$.

Table II. Relative Efficiency of Proteins in Treated and Nontreated Milled Rice

(Experimental period, 10 weeks. 12 males and 12 females on rations 1 and 2. 6 males and 6 females on rations 3 and 4)

Ration	Type of Ration	Gains in Body Weight, G.	Gains in Body Weight, Increase, %	Protein Intake, G.	Protein in Rations, %	Protein Efficiency Ratio[a], G.	Protein Efficiency Ratio[a], Increase, %
1	Nonconverted rice	41.0	...	29.6	5.23	1.38 ± 0.06[b]	...
2	Converted rice	58.0	41.4[c]	34.1	5.23	1.70 ± 0.06	23.1[c]
3	Nonparboiled rice	44.0	...	28.8	5.90	1.51 ± 0.07	...
4	Parboiled rice	59.0	34.1[c]	31.9	5.90	1.73 ± 0.13	14.5

[a] Gains in body weight per grams of protein intake.
[b] Standard deviation of mean.
[c] Significant for $P = 0.05$.

Table III shows the biological values and true digestibilities of the proteins of treated and nontreated rice as determined by the nitrogen-retention method of Mitchell (*16*, *17*). The net utilization values are obtained by multiplying true coefficient of digestibility by biological value and dividing by 100. The resulting values are somewhat higher for the proteins of treated rice than for those of nontreated rice.

The results of these experiments indicate that the treatment of rice before milling tends to give higher nutritive values of the end products used for human consumption. It confirmed the results of a preliminary study (*12*), which indicated that rice proteins are not damaged by heat used in the processing.

The nutritive value of rice is not known to vary from one sample to another; therefore, differences in protein value shown in this paper are due to differences in the condition of the protein. The excess of vitamins used in the feeding tests rules out any possibility that differences in nutritive value are due to a difference in the vitamin content of the treated as against the untreated rice.

Amino Acid Content. The results of the amino acid determinations expressed percentagewise, calculated on the air-dried samples, and also expressed as the percentage in the crude proteins (N × 5.95) are given in Table IV. The content of the amino acids (essential) and (nonessential) in treated milled rice is

Table III. Biological Value of Treated and Nontreated Milled Rice Determined by Nitrogen-Retention Method

(Ad libitum feeding. 24 animals on rations 1 and 2; 12 animals on rations 3 and 4. Protein in rations 1 and 2, 5.23% in rations 3 and 4, 5.90%. Average results per animal)

Ration	Type of Ration	Biological Value[a]	True Digestibility[b]	Net Utilization[c]
1	Nonconverted rice	81.8 ± 1.6[d]	96.0 ± 0.50[d]	78.5
2	Converted rice	87.2 ± 2.3	93.1 ± 0.40	81.1
3	Nonparboiled rice	72.8 ± 1.3	95.6 ± 0.43	69.6
4	Parboiled rice	78.8 ± 1.5	94.2 ± 0.32	74.2

[a] Per cent of absorbed nitrogen retained in animal body.
[b] True coefficient of digestibility obtained by subtracting nitrogen.
[c] Obtained by multiplying true coefficient of digestibility by biological value and dividing by 100.
[d] Standard deviation of means.

Table IV. Determination of Amino Acids

	In Milled Nonconverted Rice, %				In Milled Nonparboiled Rice, %			
	6.01% Protein		6.19% Protein		6.78% Protein		6.90% Protein	
	In dry matter	In protein	In dry matter	In protein	In dry matter	In protein	In dry matter	In protein
Arginine[a]	0.62	10.31	0.64	10.33	0.68	10.03	0.71	10.30
Aspartic acid	0.29	4.82	0.30	4.84	0.32	4.71	0.30	4.35
Cystine	0.09	1.48	0.10	1.61	0.11	1.62	0.11	1.60
Glutamic acid	0.68	11.31	0.69	11.14	0.74	10.91	0.81	11.74
Glycine	0.44	7.32	0.46	7.39	0.48	7.00	0.42	6.08
Histidine[a]	0.19	3.15	0.20	3.23	0.21	3.09	0.21	3.05
Isoleucine[a]	0.31	5.15	0.33	5.33	0.32	4.72	0.34	4.93
Leucine[a]	0.57	9.48	0.61	9.85	0.60	8.85	0.62	8.98
Lysine[a]	0.22	3.66	0.23	3.71	0.22	3.24	0.24	3.50
Methionine[a]	0.23	3.82	0.24	3.87	0.22	3.24	0.25	3.62
Phenylalanine[a]	0.29	4.82	0.30	4.84	0.31	4.57	0.39	5.65
Proline	0.28	4.65	0.31	5.00	0.29	4.28	0.35	5.00
Serine	0.30	4.99	0.31	5.00	0.34	5.01	0.40	5.79
Threonine[a]	0.31	5.15	0.33	5.33	0.33	5.00	0.32	4.64
Tryptophan[a]	0.05	0.83	0.06	0.96	0.06	0.88	0.08	1.16
Tyrosine	0.32	5.32	0.34	5.49	0.33	5.00	0.33	4.78
Valine[a]	0.46	7.65	0.47	7.59	0.49	7.22	0.51	7.40

[a] Nutritionally essential.

somewhat higher than that of nontreated milled rice; however, these differences are slight.

A number of vitamins were determined according to methods described by Barton-Wright (*4*). The results of these tests are given in Table V, which also contains data on calcium, phosphorus, iron, and other constituents, all determined by official methods (*1*).

This study confirms the results of previous investigations that the treatment of milled rice by either conversion or parboiling results in marked increases in the concentration of thiamine, riboflavin, and nicotinic acid. It also reveals that such methods of processing result in considerable increases in the concentration of biotin, folic acid (total and free), pyridoxine, choline, *p*-aminobenzoic acid, pantothenic acid, and inositol.

It was observed that the processing of milled rice produces significant increases in calcium, phosphorus, and iron. These results confirm those obtained by Vinacke and associates (*26*).

Acknowledgment

The commercial samples of milled rice (converted and nonconverted) were made available through the courtesy of Converted Rice, Inc., Houston, Tex. Thanks are due to Wonder Rice Mills, Inc., Houston, Tex., for the commercial samples of milled rice (parboiled and nonparboiled).

Table V. Vitamins and Other Constituents in Treated and Nontreated Milled Rice

	Milled Nonconverted, γ/G.	Milled Converted, γ/G.	Milled Nonparboiled, γ/G.	Milled Parboiled, γ/G.
Thiamine	0.45	2.85	0.55	2.30
Riboflavin	0.30	0.90	0.30	0.60
Nicotinic acid	11.00	32.00	10.0	30.00
Pantothenic acid				
Total	7.50	13.10	7.66	13.70
Free	3.00	5.90	2.82	4.63
Biotin	0.05	0.08	0.06	0.10
Folic acid				
Total	0.16	0.20	0.16	0.19
Free	0.05	0.15	0.07	0.14
Pyridoxine	0.37	0.68	0.37	1.00
Inositol	100.00	200.00	125.00	250.00
Choline	590.00	893.00	452.00	982.00
p-Aminobenzoic acid	0.140	0.230	0.160	0.385
	%	%	%	%
Calcium	0.008	0.064	0.027	0.061
Phosphorus	0.125	0.167	0.089	0.130
Iron				
Total	0.0008	0.0016	0.0011	0.0015
Available	0.0005	0.0010	0.0006	0.0010
Nitrogen	1.01	1.04	1.14	1.16
Protein (nitrogen × 5.95)	6.01	6.19	6.78	6.90
Fat	0.60	0.90	0.62	0.84
Moisture	7.50	7.50	7.50	7.50
Ash	0.45	0.65	0.45	0.72

Literature Cited

(1) Assoc. Offic. Agr. Chemists, "Official Methods of Analysis," **7th ed.,** 1950.

(2) Auriol, R. F., "Le riz étuvé. La préparation industrielle et ses sous-produits," Office Indochinois du Riz, Government General de l'Indo-Chine, Saigon, 1937.

(3) Aykroyd, W. R., *J. Hyg.*, **32,** 184–94 (1932).

(4) Barton-Wright, E. C., "Microbiological Assay of the Vitamin B Complex and Amino Acids," **2nd ed.,** Pitman Publishing Corp., New York, 1952.

(5) Conner, R. T., and Straub, G. J., *Ind. Eng. Chem., Anal. Ed.*, **13,** 385–8 (1941).

(6) Done, J., *Brit. J. Nutrition*, **3,** 355–45 (1949).

(7) Elvehjem, C. A., Hart, E. B., and Sherman, W. C., *J. Biol. Chem.*, **103,** 61–70 (1933).

(8) Fernandes, D., U. S. Patent **2,592,407** (April 8, 1952).

(9) Hennessy, D. J., and Cerecedo, L. R., *J. Am. Chem. Soc.*, **61,** 179–83 (1939).

(10) Horn, M. J., Jones, D. B., and Blum, A. E., U. S. Dept. Agr., Misc. Publ. **696** (1950).

(11) Kik, M. C., *Cereal Chem.*, **23,** 529–39 (1946).

(12) Kik, M. C., Eighth Pacific Science Congress, Pacific Science Association, Quezon City, Philippines, Abstracts of Papers, p. 367, 1953.

(13) Kik, M. C., *Rice J.*, **48,** 6–8 (1945).

(14) Kik, M. C., and Vanlandingham, F. B., *Cereal Chem.*, **20,** 569–72 (1943).

(15) Kik, M. C., and Williams, R. R.,

Bull., Natl. Research Council, **112,** 1–76 (1945).
(16) Mitchell, H. H., *Ind. Eng. Chem., Anal. Ed.*, **16,** 696–700 (1944).
(17) Mitchell, H. H., *J. Biol. Chem.*, **58,** 873–903 (1953).
(18) Rindi, G., and Ferrari, G., *Quaderni nutriz.*, **9,** 1–6 (1950).
(19) Rindi, G., and Giuseppe, G., *Ibid.*, **10,** 1–8 (1950).
(20) Roberts, R. L., Houston, D. F., and Kester, E. B., *Food Technol.*, **5,** 361–3 (1951).
(21) Roberts, R. L., Potter, A. L., Kester, E. B., and Keneaster, K. K., *Cereal Chem.*, **31,** 121–9 (1954).
(22) Simpson, I. A., *Ibid.*, **28,** 259–70 (1951).
(23) Sreenivasan, A., *Current Sci.* (India), **15,** 180–4 (1946).
(24) Sure, B., *J. Nutrition*, **22,** 499 (1941).
(25) Toepfer, E. W., Zook, E. G., and Richardson, L. R., *J. Assoc. Offic. Agr. Chemists*, **37,** 182 (1954).
(26) Vinacke, W. R., Harzler, E., and Tanada, Y., Hawaii Agr. Expt. Sta., Bull. **337** (1949).

Received for review January 26, 1955. Accepted April 18, 1955. Research paper 1150 Journal Series, University of Arkansas. Published with the approval of the director of the Arkansas Agricultural Experiment Station.

VITAMINS IN MEAT

Influence of Chilling Rate and Frozen Storage on B-Complex Vitamin Content of Pork

BEULAH D. WESTERMAN, BESS OLIVER, and D. L. MACKINTOSH

Departments of Foods and Nutrition and Animal Husbandry, Kansas Agricultural Experiment Station, Kansas State College, Manhattan, Kan.

Thiamine, riboflavin, pantothenic acid, and nicotinic acid contents of pork loins aged 1, 3, and 7 days at 30° F. and 7 days at 40° F. and kept in frozen storage for 48 weeks were reported. Animals slaughtered in January had more thiamine in the rib-eye muscle than those slaughtered in June, but the reverse was true for pantothenic acid and nicotinic acid. No seasonal differences for riboflavin were found. The greatest frozen storage losses for thiamine and riboflavin occurred in loins aged 3 days at 30° F. Pantothenic and nicotinic acid losses were the greatest in frozen storage in loins aged 1 day at 30° F.

AFTER SLAUGHTER, it is generally believed that hog carcasses should be chilled and processed as rapidly as possible. This procedure is not always followed. Hogs are sometimes slaughtered at home or at the locker plant and considerable time may elapse before the meat is stored. Many different practices have been followed in the chilling and processing of pork.

The object of the experiments reported in this paper was to compare the procedure, used in many locker plants, of aging the meat for a long period at rather high temperature (7 days at 40° F.) with aging for shorter periods at a lower temperature (1 and 3 days at 30° F.), and for a longer period at lower temperature (7 days at 30° F.).

The rate of chilling and processing, before placing in frozen storage, may produce changes in the vitamin B content of pork, and influence nutritive value. Data reported here deal with changes in the thiamine, riboflavin, pantothenic acid, and nicotinic acid contents of pork loins chilled and processed in four different ways. Comparisons were made on the vitamin content before and after storage.

Few data are available in the literature on this specific problem. The vitamin B content of pork has been reviewed in previous publications (*8–10*).

Experimental Procedure

The 48 animals used in the experiment were supplied by the Department of Animal Husbandry. The hogs were slaughtered, eight in a series, in January and June over a 3-year period. The treatments were as follows: Two hogs were slaughtered, chilled rapidly in a refrigerator at 30° F. for 24 hours, then cut, wrapped, and placed in frozen storage. Two hogs were slaughtered, chilled rapidly at 30° F., and held in a cooler 3 days before cutting and storing. Two hogs were slaughtered, chilled rapidly at 30° F. for 24 hours, then placed in a cooler for 7 days before cutting. Two hogs were slaughtered, chilled slowly at 40° F., and kept at this temperature 7 days. It required 3 days to reduce the internal temperature of the meat to 40° F. The thermometer was inserted in the thickest part of the carcass—i.e., the center of the ham—to determine the internal temperatures. The animals were slaughtered so samples from all eight carcasses were cut and placed in frozen storage the same day.

Each of the loins was divided into four roasts. The anterior roast from the left loin was used for analysis of the fresh pork and the right loin was cooked for palatability tests. The other roasts were weighed, wrapped, frozen, and placed in storage at 0° F. Samples were taken from the anterior to posterior end of the loin, alternating between the right and left loins. After removal from storage, at 8-week intervals up to 48 weeks, the roasts were cut in half and one half was cooked and used for organoleptic tests while the other was used for chemical and vitamin analyses. The meat was thawed, the outside fat removed, and the rib-eye muscle (longissimus dorsi) dissected out and ground three times in a food grinder. To equalize any changes due primarily to freezing, the fresh meat was frozen overnight and thawed before sampling. After thorough mixing, samples were taken for the determination of thiamine, riboflavin, pantothenic acid, nicotinic acid, fat, and water. To equalize some variables, all data were reported on a dry fat-free basis. The moisture was determined by the method recommended for the cooperative meat investigations (*6*) and the fat according to the method of the Association of Official Agricultural Chemists (*1*). The thiochrome procedure of Hennessy (*2*) was used to determine thiamine; the fluorometric method of Peterson, Brady, and Shaw (*5*) for riboflavin; and the microbiological methods of Strong, Feeney, and Earle (*7*) and Krehl, Strong, and Elvehjem (*4*) were used for pantothenic acid and nicotinic acid, respectively.