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THE NUTRITIONAL IMPROVEMENT OF WHITE RICE

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BULLETIN
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NATIONAL RESEARCH COUNCIL
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THE NUTRITIONAL IMPROVEMENT
OF
WHITE RICE

By
M. C. KIK and R. R. WILLIAMS

For The
Committee on Cereals
Food and Nutrition Board

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON 25, D. C.

FOREWORD

Mental and physical health in this country, as in all others, is dependent in large part on the quality of man's food. Since better nutritional welfare is so closely allied with economic circumstances and with traditional food habits, it follows that for widespread dietary improvement some of our inexpensive staple foods must be improved in nutritional quality. It is this philosophy of increasing the quality of simple, economical foodstuffs that has stimulated the Food and Nutrition Board and its Committee on Cereals to take the lead in recommending methods for providing more nutritious flour, bread, and corn food products.

Through the generous cooperation of the Arkansas State Agricultural Experiment Station, M. C. Kik, Ph.D., of its faculty, and Robert R. Williams, Sc.D., Chairman of the Food and Nutrition Board's Committee on Cereals have joined resources in preparing this report on rice. It is published as a National Research Council report with the approval of the Director of the Arkansas State Agricultural Experiment Station. The experimental data presented herein are from the Arkansas Station unless otherwise credited.

Dr. Kik is Associate Professor of Agricultural Chemistry, Department of Agricultural Chemistry, College of Agriculture, University of Arkansas, Fayetteville, Arkansas. Dr. Williams' interest in rice and in improved nutrition is of long standing; he was born in India and his early work in chemistry was with Colonel Vedder in the Philippines where he studied the effect of rice bran on beri-beri patients. Dr. Williams is now Chemical Consultant to the Bell Telephone Laboratories, Murray Hill, New Jersey. He is a member of the Food and Nutrition Board and is Chairman of its Committee on Cereals.

We are making this information on the nutritional improvement of white rice widely available for students of food, agriculture, health, and human welfare, in the hope of increasing both "the quantity and the quality of life."

FRANK G. BOUDREAU, M.D., *Chairman,*
Food and Nutrition Board.

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CONTENTS

TABLES

LIST OF ILLUSTRATIONS

FIGURES

PHOTOGRAPHS

Paddy fields of Bejraburi, Thailand. National Geographic Society, by special permission *National Geographic Magazine*

THE NUTRITIONAL IMPROVEMENT OF WHITE RICE

INTRODUCTION

The fact that beriberi is associated with white (well-milled) rice consumption is familiar to the reading public. It has been established for more than thirty years that if brown rice should replace white in the diet most of the forthright beriberi in the world would disappear. We do not know, however, to what extent this measure would relieve general malnutrition in lands in which beriberi occurs, nor have we sufficient evidence as a basis for adequate supplementary measures. Moreover, though the nutritional merit of brown versus white rice is well established, only slight progress has been made in realizing its advantages among Oriental peoples and this progress has been largely limited to public institutions and labor crews of organized industry. The incidence of beriberi among general civil populations is probably as high as it ever was, though mortality from it has presumably declined through earlier recognition and application of thiamine therapy.

Experience has shown that there are great obstacles to be overcome before preventive measures can be applied for the benefit of Asia's millions. Popular preference for white rice and also its better keeping qualities under tropical conditions of storage and shipment have effectively prevented the widespread utilization of brown or undermilled rice. Parboiling before milling as traditionally practiced in India is known to have kindred nutritional merit, but the product so far has not proved popularly acceptable where parboiling is not traditional. A modern version of parboiling called "rice conversion" has been recently developed, but the advent of the war prevented an extensive trial of it in the Orient. Recent years have also made available synthetic vitamins which might conceivably be incorporated in Oriental diets with excellent effect. None of these measures, however, has reached the stage of mass application to nutritional reform in rice-eating countries. Years of preparatory work may still be required. The application of synthetic vitamins to rice is much more difficult than enrichment of flour. External application will not suffice, for rinsing prior to cooking will remove the added substances. Economic handicaps are also much more severe in most Oriental rice-eating areas than in more highly developed Western countries.

In the United States, rice is a staple for only small segments of the population, chiefly in certain former and present rice-growing areas. In these areas, however, the shortcomings of white rice are nutritionally important and rice growing and milling has a substantial commercial standing. Whatever can be done for the nutritional improvement of rice in the United States will be well justified by benefits to consumers and producers alike within our own borders.

For many reasons the United States at present offers the best field for study of the white rice problem. Only within the past five years have laboratory methods of assay for the several vitamins become available. Facilities for such assay are more abundant in the United States than elsewhere. It is also an advantage that the rice industry in the United States is relatively highly mechanized and there is available some technically skilled personnel. The opportunity for the development of a rather intricate technical process such as rice conversion is certainly more favorable here than in less industrialized countries.

The fact is that, although we have known broadly for many years about the nutritional merits of retaining the vitamins of rice, very few precise data have been accumulated for guidance in commercial processing. For example, we have not known how much bran we must retain in order to conserve sufficiently the essential nutrients or how to do so with the least sacrifice of appearance and keeping qualities. We must learn how to set our hullers and brushes to achieve the best result and then determine whether this is sufficiently good from a public health standpoint. We must also know the extent of spoilage in storage and how to prevent it.

It is the purpose of this bulletin to collect, as far as possible, the essential facts that indicate the relative promise of each of the various expedients to improve the quality of milled rice and furnish criteria for future commercial practice. It is hoped that the rice industry of the United States will make profitable use of the information and find one or more practical solutions of the nutritional problem that rice presents. If the American rice industry can solve the problem it will not only insure its own future but also furnish guideposts for the larger and more difficult problem in the Orient.

RICE PRODUCTION AND CONSUMPTION

In the Orient[1]

Rice *(Oryza sativa L.)* is the great source-of-energy food of hundreds of millions of people in the Orient, including notably: China, French Indo China, Thailand, Burma, British Malaya, India, Ceylon, Philippines, Netherlands Indies, and Japan. Here 95 percent of the world's rice is produced and consumed. Rice probably originated in the southeastern part of Asia and was certainly known in India and China by 3000 B.C. In many Asiatic languages, rice and food are synonymous and in classic Chinese the term for "agriculture" is "rice culture." There are a dozen or more wild species of rice, but all cultivated varieties, of which there are several thousand, are of the species *Oryza sativa*. The wild rice of the United States *(Zisania aquatica)* is not a true rice. While the cultivated varieties of rice present a great range of characteristics, the most distinctive derivations from the common pattern are the glutinous rices. These are so called because they become very sticky when cooked. They are popular for special uses in various Oriental countries but are produced in minor volume. In parts of China perhaps 20 percent of the local supply is of this type.

All but a small fraction of the world's supply of rice is produced under

[1] Wickizer, V. D., and Bennett, M. K.: The rice economy of Monsoon Asia. Food Research Institute, Stanford University, California, 1941: 358 p.

Constructing a field levee with a disc plow in Southern United States. Levees follow contours. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

Sowing rice by airplane in California. A. Man on main levee marks successive swaths for the plane. B. Seed floats on the water briefly before sinking. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture irrigation and the product of this type of culture is called lowland rice. Upland rice is grown without irrigation on slopes or level land where rainfall is fairly high. Upland acreage, as well as upland yield per acre, is much less than lowland in all countries where rice is an important crop. During two or three months at the height of its growing season, lowland rice requires water in an amount equal to 15 to 30 inches of rainfall per month, depending on the extent of seepage, evaporation, etc. The fields are leveled and diked to provide for uniform submergence of the land. In broad flat valleys, the labor of leveling and diking is relatively low; on hillsides, extensive terracing may be necessary to provide small level patches. The culture of rice is accordingly a highly specialized form of agriculture. Yields per acre reach 30 barrels (162 pounds) under favorable conditions. Asiatic yields average about 12 barrels per acre.

Of a total world production of 95.6 million tons, 90.9 million tons of rice are produced in the Orient; 4.7 million tons in all other parts of the world, including the United States. Thirty-seven percent of the Oriental production is in China, 27 percent in India, 9 percent in Japan, and lesser percentages in other countries. The heaviest per capita consumption of rice is localized in Southeastern China, where it is said to be from 400 to 548 pounds per year. It falls below 10 pounds per year in wide regions of northern China and northwestern India, where the climate is not adapted to rice culture. In India, figures for the southern and eastern provinces range from 221 to 405 pounds; in other provinces the range is from 0 to 98 pounds. Chosen or Korea has a consumption level of 125 pounds. Java has an average of 200 pounds per capita, higher in the west and considerably lower in the east. Some 630 million Orientals derive more than 40 percent of their total food calories from rice; some 310 million Eastern people are non-rice eaters.

The international trade in rice remains, even in peacetime, mainly within the borders of Asia; less than one-third of the exports of Asia go outside of this region. Export countries are Burma, Thailand, Korea, and Indo China. Rice normally is imported to Japan, India, British Malaya, Ceylon, China, and Netherlands Indies, in volumes descending in the order named. Within each country domestic rice moves in trade from one region to another, from areas of surplus production to deficit and non-producing areas.

Where rice is grown primarily for local use rather than for export, the grower and his neighbor on farms and in nearby villages often secure their rice in paddy form and day by day pound off the hulls in mortars by hand at their homes as food is required. While well-milled white rice can be and often is produced by this primitive means, the tendency is for the home-pounded product to be undermilled. In areas where rice is grown extensively, machine milling predominates and relatively highly milled white rice is largely used even locally. In most cities rice comes exclusively from commercial mills and is highly milled. As industrialization proceeds in the Orient the hand mortar is replaced increasingly by machine milling except in remote areas. The use of parboiled rice, especially in India, is discussed on page 58. In the Dutch East Indies much rice is said to be consumed in brown form.

In the United States

Rice was introduced in the United States in 1685 at Charleston, South Carolina, and is now cultivated as lowland irrigated rice in Louisiana, Arkansas, Texas, and California. But little rice is now grown in South Carolina; it is upland and not irrigated. The estimated rice crop [2] of the United States in 1944 amounted to 19 million barrels (162 pounds), an increase of 95 percent during ten years. It is, however, less than 2 percent of the world production. Thirty percent of this commercial rice was grown in Louisiana; twenty odd percent was produced in each of the three states, Arkansas, Texas, and California. The average yield for the United States, as for the Orient, is about 12 barrels per acre. (One barrel=3.6 bushels.)

The method of culture is adapted from that of the Orient where hand labor is cheap and abundant. Under our labor conditions mechanization was indispensable to the extension of rice culture in the United States and great ingenuity has been displayed in this development. While rice for lowland planting in the Orient is sown in seed beds and seedlings are transplanted by hand into the flooded paddies, mostly by women and children wading in the mud and water, such use of labor in the United States would be impossible. Accordingly, the American practice is to prepare the land and drill in or broadcast the seed essentially as in the planting of wheat. Plowing and drilling is done over the tops of the low subsidiary dykes or levees. After the land is seeded, the levees are restored by a special plow and drag and the land is lightly flooded if necessary to promote germination of the seed. The excess water is drained off till the rice has grown to 4 or 5 inches in height, when the soil is again flooded and kept flooded for 2 to 3 months or till the grain is almost mature. The depth of water is maintained at 2 inches in the early stages of growth and at 4 to 5 inches at the later stages. Two or three weeks before harvest the land is drained and allowed to dry to facilitate the use of harvesting machinery. The binder is in most common use for harvesting.

The shocked rice, after two weeks or more of curing, is threshed like wheat. The "combine" is replacing the binder and thresher in the present manpower shortage. The use of the combine necessitates the installation of driers in rice-producing communities, as the "combine" rice has an excessive moisture content that would otherwise promote spoilage in storage of the threshed grain. By drying from 22 to 25 percent moisture down to 12 to 14 percent, spoilage is avoided. Except for flooding, the methods and machinery in all essential phases of rice culture are similar to those used in wheat production.

In California, rice culture is provided with a somewhat wider range of implements than in other states. There the ground is often fully prepared, the levees are fully formed, the land is flooded, and the seed is sown on the water by airplane.

Rice culture, like sugar culture, is a protected industry in the United States. There is a customs tariff of 2.5 cents per pound on milled rice imported into the United States and its possessions. The effect of this has been abated

[2] Reid, W. M. Estimate of the rice crop for the year 1944. The Rice Millers' Association, New Orleans, La.

A field of young rice in United States, soon after application of irrigation water. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

Cutting Rice With a Twine Binder, Southern United States. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

TABLE 1
CONSUMPTION OF RICE IN THE UNITED STATES, 1937

State	Population	Per Capita (Pounds)	Total Consumption (Pounds)
Alabama	2,646,248	9	23,814,000
Arizona	435,573	2	872,000
Arkansas	1,854,482	5	9,270,000
California	5,677,251	9	51,093,000
Colorado	1,035,791	2	2,072,000
Connecticut	1,606,903	1	1,607,000
Florida	1,468,211	20	29,360,000
Georgia	2,908,506	20	58,180,000
Idaho	445,032	1	445,000
Illinois	7,630,654	2	15,262,000
Indiana	3,238,503	2	6,478,000
Iowa	2,470,939	2	4,942,000
Kansas	1,880,999	2	3,762,000
Kentucky	2,614,589	2	5,230,000
Louisiana	2,101,593	40	84,200,000
Maine	797,423	1	737,000
Massachusetts	4,249,614	3	12,750,000
Maryland	1,631,526	2	3,264,000
Delaware	238,380	2	476,000
Michigan	4,842,325	2	9,684,000
Minnesota	2,536,953	2	5,128,000
Mississippi	2,009,821	5	10,050,000
Missouri	3,629,367	3	10,887,000
Montana	537,606	1	538,000
Nebraska	1,377,963	2	2,656,000
New Hampshire	465,293	2	930,000
New Jersey	4,041,334	3	12,123,000
New Mexico	432,317	1	423,000
New York	12,588,066	3	37,764,000
Nevada	91,058	2	182,000
North Carolina	3,170,276	20	63,400,000
South Carolina	1,738,765	20	34,780,000
North Dakota	680,845	1	681,000
Ohio	6,646,697	3	19,941,000
Oklahoma	2,696,040	5	11,980,000
Oregon	953,786	3	2,862,000
Pennsylvania	9,631,350	5	48,155,000
Rhode Island	687,497	2	1,374,000
South Dakota	692,849	2	1,386,000
Tennessee	2,616,556	3	7,851,000
Texas	5,824,715	10	58,245,000
Utah	507,847	2	1,016,000
Vermont	359,611	2	720,000
Virginia	2,421,851	3	7,266,000
Washington	1,563,396	4	6,252,000
West Virginia	1,729,205	5	8,645,000
Wisconsin	2,939,006	2	5,878,000
Wyoming	225,565	2	452,000
	122,290,000	5.6	685,123,000

locally to a minor extent by reciprocal trade treaties between the United States and various Central and South American countries during the past 5 years.

In Table 1 the per capita consumption for 1937, as furnished by Mr. G. A. Collier,* is given by states and for the nation as a whole. The average per capita consumption in 1937 amounted to 5.6 pounds per year. Louisiana, the leading rice-producing state, had an average consumption of 40 pounds; in the rice-growing districts in this state the consumption is from 90 to 100 pounds per capita, while in the northern part from 25 to 30 pounds per capita per year are eaten.[3] Relatively large average consumptions for the United States of 20 pounds per capita are found in Florida, Georgia, and the Carolinas, where little or no rice is now produced. While the per capita consumption is large in the Gulf and Southern states, it is by no means uniform in those regions. It is heaviest along the coast and diminishes inland. In some states, where the overall average per capita consumption is slight, there are certain sections in which it is relatively large.

The United States production far exceeds the domestic consumption. A fourth of the crop goes to Puerto Rico, Hawaii, and Alaska; a fifth is exported, now mainly to Cuba.

In Puerto Rico

In Puerto Rico (population, two millions) the rice consumption amounts to 140 pounds a year per person, of which approximately 2 percent is produced locally. The rice formerly consumed was almost entirely milled white rice, but there are at present tendencies in the United States to mill rice somewhat less and to sell an undermilled rice. Undermilled rice has long been preferred in Cuba, which until 5 years ago received its supply largely from the Orient. Relatively little beriberi has been seen in Cuba; Puerto Rico, on the other hand, is known for its generally bad nutrition. A great deal of beriberi has been reported there in the past, where highly milled rice from the United States has been imported for years because of the tariff on rice from other countries. It is felt that a change from milled white rice to undermilled rice or to specially processed rice (pages 58-71) will be of benefit to the people of Puerto Rico.

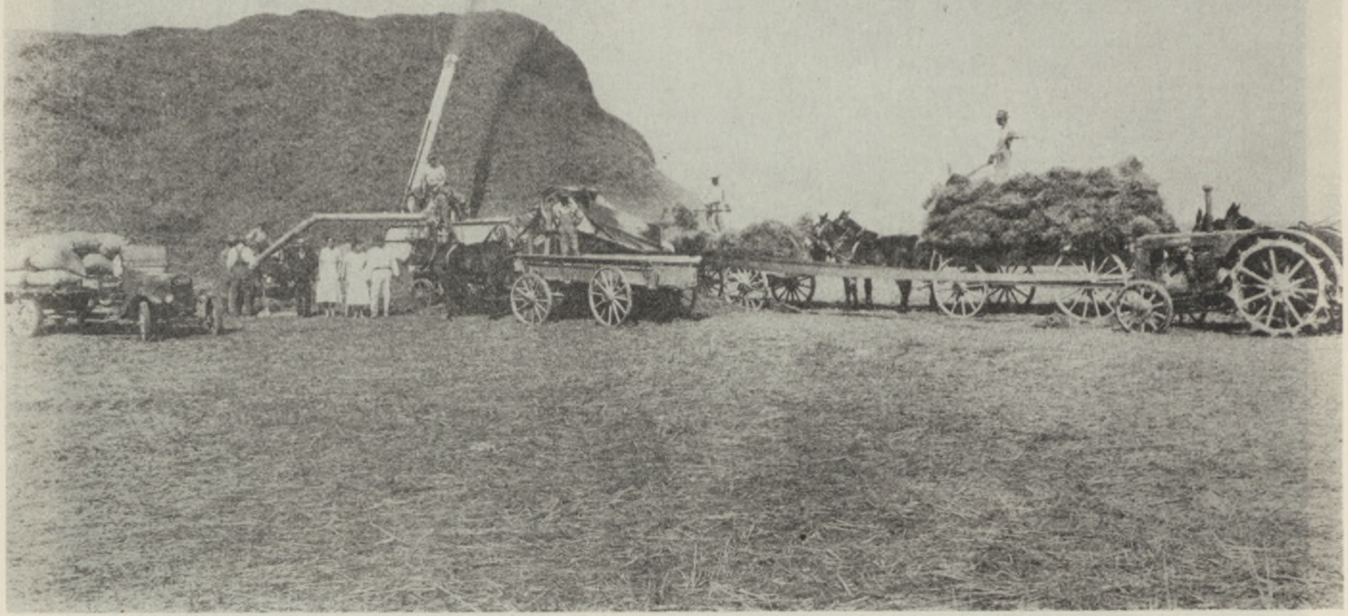
Because of the responsibility of the United States for the welfare of Puerto Rico we have examined its rice problem in a special way, as is indicated in the following and in some of the subsequent passages.

It is impossible now to estimate accurately the quality of rice previously supplied to Puerto Rico. However, several samples of milled rice were obtained from Puerto Rican retail stores in 1943 and tested for thiamine content. The results of these tests are given in Table 2.

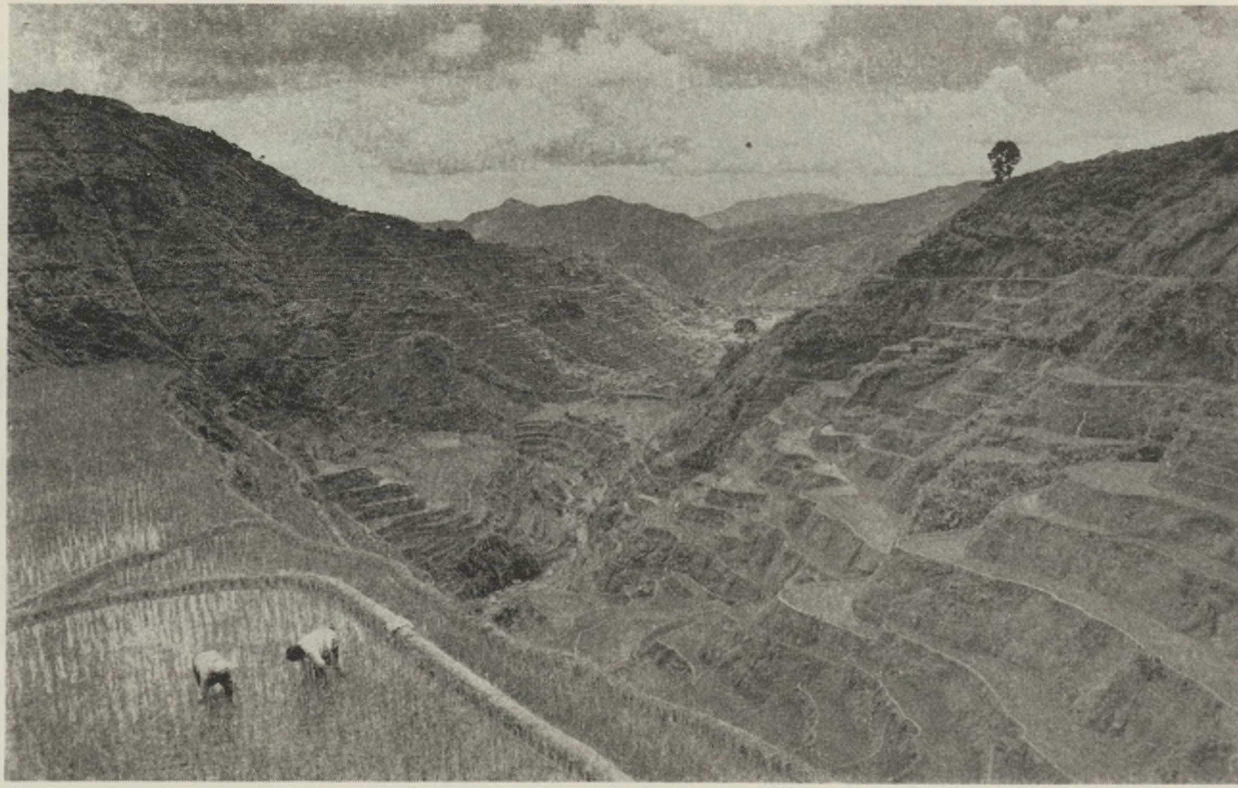
The rice recently shipped to Puerto Rico, represented by the analyses in Table 2, is obviously undermilled and furnishes more thiamine than that customarily consumed before the war. One pound of undermilled rice, such as

* Grain Products Branch, War Food Administration, Washington, D. C.

[3] Personal Communication of Mr. W. M. Reid, Executive Vice President, Rice Millers' Association, New Orleans, La.



Threshing rice in the United States. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture



Rice terraces in Banaue, Northern Luzon. National Geographic Society. By special permission, *National Geographic Magazine*

TABLE 2

THIAMINE IN RECENT RICE FROM PUERTO RICO

	μg/gm		μg/gm
San Miguel A—Blue Rose	0.90	Blue Rose Lara	1.00
Cavadonga—Prolific Mixed	0.85	Dominican rice	1.10
San Miguel A—Long grain	1.00	Lara—Choice Japan California	1.09
San Miguel A—Long grain Rexora	0.90	Andrade—Long grain	1.09
Puerto Rican	1.09	Cavadonga—Blue Rose Mixed	1.00
Lara—Long grain	1.05	Cavadonga—Long grain	1.09
San Miguel # 2—California rice	0.91	Blue Rose Lara	1.00

Puerto Rico now appears to be receiving, furnishes about 0.5 milligram of thiamine or about twice as much as highly milled rice. Since losses take place in rinsing before cooking and since there is a limited supply of vegetables and lean pork, which furnish thiamine, it is felt that this is inadequate insurance against thiamine deficiency. However, the change from the use of highly milled rice to that of undermilled rice is commended as useful.

A sample of Puerto Rican paddy or rough rice contained 3.40 micrograms of thiamine per gram, which is approximately the average for United States varieties of rough rice (page 41).

In Europe

In Europe rice is a grain of prime importance only in Italy and Spain. Egypt is an important consumer. An idea of its production and consumption in these parts of the world is given in Table 3.

TABLE 3

ANNUAL CONSUMPTION AND PRODUCTION OF RICE IN VARIOUS COUNTRIES[a]

Country	Per Capita Consumption Pounds	Per Capita Production Pounds
United Kingdom	6.20	None
France	8.90	None
Germany	11.20	None
Holland	5.10	None
Denmark	4.40	None
Sweden	1.90	None
Italy	13.80	22
Spain	14.50	18
Austria	10.03	—
Norway	1.80	None
Roumania	3.20	—
Portugal	5.00	approx. 5
Greece	10.00	None
Poland	5.50	—
All Europe (est.)	7.30	—
Egypt	25.90	51
Russia	1.10	0.05

[a] From the *Rice Journal*, July 1931.

RICE COOKERY

Methods of cooking rice are of considerable importance with respect to the nourishment derived from the grain, particularly where it constitutes a prime staple. It would be apart from the purpose of this publication to consider the great variety of rice dishes used in various parts of the world, but it is useful to note the modes of staple cookery in areas where rice is extensively used.

Plain boiled rice is the form in which rice is chiefly used. An objective in its preparation that is sought by people in many lands is the avoidance of stickiness in the cooked grain, so that it will not cohere in compact masses but the grains will remain loose and free. Many expedients are used to accomplish this purpose, some of them extremely detrimental to the nutritional quality of the rice. These expedients are summarized and explained:

1. Rinsing of the raw rice before cooking. This serves to remove the fine starch that is readily solubilized during cooking and thereby adds to stickiness.
2. Methods of cooking:
   (a) Large amounts of water are used and the excess drained away, carrying with it most of the starch which has been rendered soluble.
   (b) The rinsed raw rice is immersed in water just sufficient to swell the grains properly and cooked in a double boiler or over a slow fire, to avoid burning at the bottom, till the water is fully absorbed.
3. Rinsing of the cooked rice. This is often resorted to in order to remove further the films of soluble starch on the surface of the grains.
4. Rice is in some cases partly cooked according to 2a. After draining off the water, the half-cooked rice is steamed to a state of tenderness by supporting it in a pan or basket in an enclosed space over freely boiling water.

Rinsings and decantations of cooking waters profoundly deplete the nutrient contents of the rice as is shown in detail on pages 18-22. This is so much the case that the mode of cooking becomes one of the prime considerations governing the feasibility of effective nutritional improvement of white rice. Peoples who persist in drastic rinsings and in discarding of cooking water will of necessity sacrifice a large part of any nutritional improvement that can be achieved with present known methods. The situation is somewhat analogous to that of the proposed enrichment of macaroni and spaghetti for the use of people of Italian origin in the United States. The customary discards of cooking waters from these foods are so large as to cause a loss of nearly half the nutrients added. For enrichment to be equally effective, the nutrient additions must be nearly twice as great as in enriched flour or bread.

In the Orient, where rice is the chief source of calories for many millions of people, avoidance of stickiness in boiled rice is doubly prized. Especially is this true in India, Burma, and other South Asiatic countries where rice is often eaten with the fingers. The variety of the rice used has some influence upon its cooking quality; for example, the long-grained varieties popular in India are less prone to become sticky than the short-grain varieties preferred in Japan. Fortunately, cooking without discard of water is prevalent, though not universal, in most of these lands. Some details of prevalent customs are summarized below.

Rice Cookery in Various Countries:

China. We are indebted to Mr. Hsi Hsiang Chen,[4] Counsellor of the Ministry of Food of the Chungking Government, for the following information. Rice is the staple food of most Chinese who dwell in the Yangtze valley or south of it, living within 800 to 1000 miles of the sea. Along the sea coast and especially in and about the port cities, the Cantonese method of cooking rice is most popular and use of this method is growing. The Cantonese method employs for cooking a volume of water equal to that of the raw rice or perhaps one and one-half times as great. The rice is cooked over a slow fire in a thick-walled iron or clay pot till all the water is absorbed. The resulting rice is loose and free and, like most solid foods, is eaten with chopsticks. The losses of nutrients in such cooking of rice are negligible. However, there are significant losses due to rinsing, which precedes cooking by the method above described. Mr. Chen is of the opinion that the Cantonese method applies to only 10 to 15 percent of the rice consumed in China; others incline to a higher figure.

Another method that is desirable also from a nutritional viewpoint is the use of rice in gruel form, which in Mr. Chen's opinion applies to 20 to 30 percent of China's rice consumption. This method is regarded by the Chinese as the most economical, since the greatly swollen and softened grain fills the stomach and is most fully utilized by the body. Rinsing of rice for gruel making is not generally practiced. This results in a further economy of nutrients. However, consumption of at least the noonday rice in grain form is considered desirable from the standpoint of palate appeal.

Mr. Chen assumes that 50 to 70 percent of China's food rice is steamed somewhat according to method 4 (page 14). After boiling briefly in 3 parts of water, the rice is drained and transferred onto a bamboo grill supported in a wooden cylinder. The lower end of the wooden cylinder rests in boiling water above which is the rice resting on the grill and exposed to the steam till it is fully cooked. Choice of the proper wood for the cylinder is thought important for its flavoring effect on the rice. It is unfortunate that this most undesirable method should be so popular.

Comments by Dr. Frank Co Tui[5] of New York University Medical School tend to confirm the opinions of Mr. Chen. Dr. Co Tui mentions the practice in Amoy of straining the cooked rice through a sieve and using the starchy fluid as a liquid food. In this area, lentils or sweet potatoes are often cooked with rice.

[4] Private Communication.
[5] Private Communication.

Philippines and Malaya. It is difficult to generalize about so vast a region as that occupied by the Malay peoples. However, it appears that rice is generally rinsed before cooking and that much of it is cooked without excess of water as in the Cantonese method above described. Sometimes a moderate excess is used and this is drained off when the rice is half cooked, often for feeding to smaller children or to domestic pets. The drained rice is then cooked further over a slow fire to the desired loose consistency. Malayan cookery on the whole conserves the food values better than does the Chinese, excess water being discarded much less frequently.

Burma. According to a private statement of Mrs. C. E. Chaney, long a resident of Southern Burma, rice is washed thoroughly, often with seven or eight changes of water, and "is then put into a clay pot of boiling water, the water being in great excess of the rice." After the minimum amount of boiling (five to eight minutes), sufficient to soften the interior of each grain, the pot is thoroughly drained. The pot, closely covered, is then placed near the fire and thus steamed for a long time. Every ten minutes or so the covered pot is inverted and shaken well. The cover is raised momentarily to release the steam and the pot is replaced with another side near the fire. The cooking water is usually thrown away, though it contains enough starch to form a solid gel when cold.

Mrs. F. T. Strait describes rice cookery in the hills of Upper Burma in remarkably similar terms. She says, however: "Usually most of the water is used in the cooking but not all, as they drain the rice before it is thoroughly cooked." Mrs. H. W. Smith, also speaking of the Kachins of Upper Burma, refers to steaming in cane baskets above boiling water as a familiar practice with some families; others cook rice "with the small amount of water needed to do the job and be absorbed when done."

India. Indian practice in rice cookery appears to be extremely varied and it has not been possible to secure an estimate of the relative prevalence of different methods. Banerjee [6] states: "In the ordinary process of cooking rice, the rice is boiled with water and the excess water is thrown away as waste." On the other hand Swaminathan [7] offers the following: "Methods of cooking rice in India vary in different communities and districts; it is often the practice to use as little water as possible and the 'conjee' (rice water) is often taken. On the other hand rice is usually washed before cooking, and washing is regarded as essential by the rice-eating population. The losses from washing are thus more important and constant than the losses from cooking."

United States. We shall concern ourselves with methods of cooking only in the states of high rice consumption. Here rice is used in many ways, but most of all as a basal accompaniment to a meat dish much as potatoes are served in other parts of the United States. In the coastal areas of the

[6] Banerjee, S. Losses of protein and minerals in cooked rice. Science and Culture, 5: 262 (1939).

[7] Swaminathan, M. Effect of washing and cooking on nicotinic acid content of raw and parboiled rice. Indian Jour. Med. Research 29: 83-88, (1941).

Carolinas, Georgia, Louisiana, and Eastern Texas, rice appears on the table daily at one or more meals. A staple dish of wide use, both in Southern Louisiana and the coastal Carolinas, is the combination of rice and black-eyed peas (or beans) cooked separately but served together. The rice-peas combination is known as "hoppin' John," especially in the Carolinas. Other leguminous seeds may replace the usual black-eyed peas or red beans. Other vegetables as well as meat juices often provide sauces or gravies for rice. In Louisiana rice is often eaten with milk but without sugar for breakfast and supper.

Those familiar with southern customs, among them Miss Myra Reagan, Miss Ellen LeNoir, and Dr. Hilla Sheriff, give us to understand that there is a tendency throughout the South for the negroes to cook their rice without an excess of water. This is also the general practice of all classes in Southern Louisiana (except in New Orleans) and Eastern Texas. However, the practice of cooking the rice in a large excess of water is generally prevalent among the whites of the Carolinas and in parts of Texas. Steaming after partial cooking in an excess of water is also very popular in the Carolinas. Throughout the South, rice is usually rinsed by all classes before cooking, and rinsing after cooking is widely prevalent except in rural areas surrounding New Orleans.

In the fall of 1943, a survey * was made of rice consumption and cooking practices in the State of Arkansas. This survey was limited to eighteen counties, fourteen of which are in the rice-growing areas and four in the non-rice-producing districts. The average rice consumption per year per person in the four non-rice-producing counties was 5.45 pounds compared to an average consumption of 5.83 pounds in the fourteen where rice is produced.

Open vessel cooking with excess water and double boiler cooking in a minimum of water were equally used. Half of the consumers washed the rice three times before cooking. Forty percent of the rice eaters discarded the cooking water. Rinsing of the cooked rice took place in thirty percent of the cases. From these practices it appears that little thiamine is left in the white milled rice finally used for human consumption. The extent to which losses occur during washing, cooking, and rinsing are discussed elsewhere (pages 18-22).

The average time of soaking of rice before cooking reported in this survey was more than four hours and this soaking took place in 33 percent of the cases. The extreme soaking time was twelve hours. It is not certain whether such soaking is detrimental. According to Van Veen,[8] the water-soluble vitamins penetrate deeper into the kernel through soaking and are less easily lost during careless handling in cooking.

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* Credit is due to the Extension Service of the College of Agriculture, University of Arkansas, Fayetteville, Ark., for their cooperation in conducting this survey.

[8] Van Veen, A. G. De invloed van wasschen en stoomen op het B_1 vitaminegehalte van rijstsoorten van verschillenden slijpgraad. Geneeskundig Tijdschrift voor Nederlandsch-Indie, 73: 945-957 (1933).

Puerto Rico. In Puerto Rico,[9] some rice is used in the preparation of special dishes, but most of the rice is either plain boiled or stewed. Rice is rinsed about two or three times before cooking. Plain boiled rice is rice cooked in water with salt and lard added and is usually eaten with stewed beans or peas. Salt pork is often used in the place of lard. Stewed rice is rice cooked with annatto lard (manteca de achiote) which gives it an orange color. Poor people sometimes stew rice with salt, water, and annatto lard. However, rice is usually stewed with a "sofrito" and a legume or with a "sofrito" and meat or fish product.

In cooking rice, two methods are used. In the first method, white rice is added to boiling salted water and allowed to boil uncovered until a large amount of water has been absorbed by the rice. Lard is then added, the rice is stirred a little and then covered and allowed to cook over a low flame.

In the second method, fat is first melted, rice is added and slightly fried. Water is added and the rice is boiled until it has absorbed a large amount of water. It is covered and cooked slowly over a low flame. The first method is used in the preparation of stewed rice. Both methods are used in the preparation of plain boiled rice. Water is added as needed for the desired consistency and no water is poured off after the rice is cooked.

Losses of Nutrients in Rinsing and Cooking of Rice.

McCarrison and Norris [10] found that washing of rice causes a great loss of minerals and of thiamine. These authors were of the opinion that the occasional occurrence of beriberi in spite of the use of parboiled rice is due to the practice of washing the rice prior to cooking.

The effects of repeated washing and of boiling on the thiamine content of rice milled by the usual method have also been studied by Van Veen [8] and others. They also reported considerable losses; it has been said by some investigators (Van Veen 1940) [11] that the manner of washing and cooking can be of greater importance than the degree of milling. Particularly, the discarding of the water in which the rice is boiled should be prevented, since it involves the loss of valuable materials.

Aykroyd [12] reports that the average losses of thiamine and niacin during washing and cooking of raw milled rice are from 40 to 50 percent and Swaminathan [7] found that raw rice samples lost an average of 60 percent of niacin on first washing; the second and third washings did not remove much. Parboiled rice samples lost only 12 percent of their niacin; even washing three to four times failed to remove more than 16 percent. Niacin analysis methods of that period were not well adapted to cereals, but these results

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[9] Mrs. Josefina de Royo, assistant nutritionist, F.D.A., San Juan, Puerto Rico, furnished the information regarding food habits in Puerto Rico.

[10] McCarrison, R. and Norris, R. V.: The relationship of rice to beri-beri in India. Indian Medical Research Memoir No. 2 (1924).

[11] Van Veen, A. G.: De rijstkwestie, Geneeskundig tijdschrift voor Nederlandsch-Indie, 80: 1696-1704 (1940).

[12] Aykroyd, W. R., Krishnan, B. G., Passmore, R., and Sundararajan, A. R.: The rice problem in India, Indian Medical Research Memoir No. 32 (1940).

[7] *Supra.*

are considered indicative in a relative sense. The losses caused by cooking alone depend on whether the cooking water is discarded or not. The losses are small if only as much water is used as will be absorbed by the rice in cooking. The prevailing practices of washing and cooking rice result also in appreciable losses of protein and phosphorus. Parboiled rice loses less of these constituents during these manipulations.

The use of unwashed rice for the prevention of beriberi in India has been advocated by Platt.[13] He implies that the need for washing can be eliminated if polishing powders, such as glucose and talc, are abolished. However, the use of such powders has not been encountered in recent literature by the present authors except in Spain, Italy, and the United States, where their use is very limited. Platt states that storage of the brown rice in hermetically sealed containers prevents development of undesirable flavors and that no washing is required with this good storage. He also recommends milling of rice shortly before consumption. He regards improvement of the cleanliness of mills and storage places as important, since washing is unnecessary in case of clean milled rice of good commercial quality; the milling is in itself a cleaning process.

Washing and cooking experiments were performed by one of the authors (M. C. Kik). The data on losses of thiamine, riboflavin, and niacin in washing brown, white, white (enriched), parboiled (Malekized and Converted, see pages 71 and 61) and Earle (undermilled) rice are presented in Table 4. The methods of analysis are described on page 40. One cupful of rice was covered with one cupful of water and stirred and the supernatant liquid discarded. This was repeated twice.

Brown rice so treated lost 21.14 percent of its thiamine, 7.70 percent of riboflavin, and 13 percent of niacin. The losses in milled white rice were higher. Such rice lost 43 percent of the thiamine, 25.92 percent of the riboflavin, and 23.04 percent of the niacin that it contained. The losses of thiamine in rice superficially enriched with thiamine ranged from 45 percent to 75 percent, depending on the degree of enrichment. The high losses are due to the fact that the water-soluble thiamine has been put on the surface of the grain and is easily removed during the washing. Malekized (parboiled) rice lost 15.42 percent, and converted and undermilled rice each lost 6 percent of their thiamine. Both the parboiled and undermilled rice samples lost less thiamine during washing than the brown rice and the enriched rice. Riboflavin and niacin losses in the milled white rices amounted to more than 20 percent and were higher than those of parboiled rice and of brown rice. Malekized and converted rice have lower losses during washing. This is a confirmation of an observation made by Swaminathan[7] on parboiled rice.

In another set of experiments a study was made of the effect of the volume of water used in cooking on the loss of thiamine, riboflavin, and niacin in

[13] Platt, B. S. Nutrition in the Colonial Empire. Economic Advisory Council Report. App. 6, p. 786.

[7] *Supra.*

TABLE 4

EFFECT OF WASHING ON THE THIAMINE, RIBOFLAVIN, AND NIACIN CONTENT OF RICE

Type of Rice	Thiamine			Riboflavin			Niacin		
	Before µg/g	After µg/g	Loss Percent	Before µg/g	After µg/g	Loss Percent	Before µg/g	After µg/g	Loss Percent
Brown	4.40	3.47	21.14	.65	.60	7.70	54.00	47.00	13.00
White	.65	.37	43.07	.27	.20	25.92	20.57	15.83	23.04
White (spray enriched)	1.40	.77	45.00	.29	.23	20.70	19.50	15.03	22.92
White (spray enriched)	3.00	.70	70.00	.28	.22	21.42	20.00	16.07	19.65
White (spray enriched)	3.20	.80	75.00	.32	.25	21.90	19.20	15.05	21.61
Malekized (parboiled)	2.01	1.70	15.42	.40	.34	15.00	40.20	35.00	13.00
Converted (parboiled)	3.02	2.82	6.62	.41	.36	12.19	49.00	44.00	10.20
Earle (undermilled)	2.94	2.75	6.46	.38	.34	10.52	50.00	42.00	16.00

TABLE 5

EFFECT OF COOKING IN EXCESS WATER ON LOSS OF VITAMINS

Type of rice	Method of cooking	Cooking time minutes	Thiamine Before µg/g	Thiamine After µg/g	Thiamine Loss Percent	Riboflavin Before µg/g	Riboflavin After µg/g	Riboflavin Loss Percent	Niacin Before µg/g	Niacin After µg/g	Niacin Percent Loss
Brown	double boiler [a]	50	4.40	4.00	9.00	.81	.75	6.17	54.00	52.00	4.00
	open vessel [b]	40	4.40	2.98	32.20	.81	.60	26.00	54.00	35.70	31.00
White	double boiler [a]	30	.65	.64	1.34	.27	.25	7.40	20.57	19.86	3.45
	open vessel [b]	20	.65	.30	54.00	.27	.13	48.15	20.57	20.00	41.00
Malekized	double boiler	27	2.01	1.88	6.46	.40	.37	7.50	40.20	39.30	2.23
	open vessel	22	2.01	.86	57.21	.40	.20	50.00	40.20	25.00	37.80
Earle	double boiler	45	2.94	2.90	1.36	.38	.36	5.20	50.00	48.50	3.00
	open vessel	30	2.94	1.70	42.17	.38	.18	36.00	50.00	31.15	37.70
Converted	double boiler	30	3.02	2.86	5.30	.41	.30	7.30	49.00	48.50	2.04
	open vessel	22	3.02	1.70	43.71	.41	.29	29.44	49.00	30.60	37.55
Brand (enriched)	double boiler	30	3.00	2.90	3.33	.25	.23	8.00	20.00	19.20	4.00
	open vessel	20	3.00	1.63	45.66	.25	.16	36.00	20.00	12.00	40.00
White (enriched)	double boiler	30	1.40	1.36	2.85	.29	.27	6.80	19.50	18.62	4.51
	open vessel	20	1.40	.65	53.57	.29	.18	37.93	19.50	11.00	41.00
White (enriched)	double boiler	30	3.20	3.05	4.70	.32	.30	6.20	19.20	18.50	3.64
	open vessel	20	3.20	1.59	50.00	.32	.20	37.50	19.20	10.00	47.90
Brand (enriched)	according to [c] directions on container	20	3.00	1.09	63.70	.25	.17	32.00	19.20	10.00	47.00
Converted	according to [d]	20	3.02	2.44	19.21	.41	.30	26.83	49.00	38.18	25.12

[a] One cup of rice and three half-cups of boiling water are placed in the top of a double boiler cooker. All the water is absorbed in the cooked rice, which is not rinsed afterwards.

[b] One half-cup of rice is placed in an open vessel, covered with eight cups of boiling water, cooked, placed in a colander and drained.

[c] One cupful of _____ "enriched" rice is placed in an open vessel with ten cupfuls of water (boiling), cooked, placed in a colander and drained.

[d] One cup of rice is cooked in one quart of boiling water, drained in a colander and quickly rinsed in cold running water.

brown, white, and processed rices, including white rice "enriched" by spraying with a solution of vitamins. For convenience and in accordance with widespread practice in the United States, two contrasting methods were chosen. A double boiler was used for cooking the rice in a small volume of water, as this makes it easy to avoid burning the rice at the bottom of the vessel. An open single vessel was used for cooking the rice in a large volume of water. One cup of rice and one and one-half cups of boiling water were placed in the top of the double boiler and cooked until all the water was absorbed in the cooked rice, which was not rinsed after cooking. In open-vessel cooking, one-half cup of rice was added to eight cups of boiling water, the rice was cooked, transferred to a colander and drained.

Double boiler cooking was used as a demonstration of a good method of cooking and the open vessel type was employed as an example of a poor method of cooking. The results of this experiment are given in Table 5, which shows that all types of rice lose an average of 4.29 percent of thiamine in the double boiler method, compared to 46.85 percent in the open vessel type. The loss is more than eleven times as great in the latter case. Similar observations were made for riboflavin and niacin. The average losses in riboflavin and niacin using the double boiler type of cooking were 6.74 percent and 3.35 percent respectively, versus 43.00 percent for riboflavin and 44.80 percent for niacin when the open vessel type of cooking was used. The average percentage losses of thiamine, riboflavin, and niacin in open vessel cooking in the group of processed, brown, and undermilled rice were 38.9, 33.6, 33.8, respectively, compared to 53.4 percent, 39.4 percent and 43.4 percent in milled white rice. This would indicate that water-soluble vitamins, though somewhat better retained in parboiled, brown, and undermilled rice than in milled white rice, are extensively lost when rice is carelessly cooked. Practically all the vitamins present in rice before cooking can be saved and benefit the consumer when a good method of cooking is employed, using the minimum amount of cooking water and doing no rinsing after cooking. However, much of the vitamin content can be lost in careless handling of the rice in the kitchen.

Poor directions for cooking often appear on packaged rice sold in the United States. An artificially but superficially enriched rice was found to bear the following instructions: "One cup of rice is placed in an open vessel with ten cupsful of water (boiling), cooked, placed in a colander and drained." Cooking this rice by these directions resulted in the loss of over 60 percent of the thiamine and a large fraction of the riboflavin and niacin. By careful cooking, these losses were reduced to 3.3 percent thiamine, 8.0 percent riboflavin, and 4.0 percent niacin.

Similarly, a brand of converted rice sold in package form bears the following: "Pour slowly 1 cup of rice into 1 quart of fast boiling water, adding 1 teaspoon salt. Cook 20 minutes or longer. Drain in colander, rinse quickly with cold running water and each grain stands apart." Table 5 indicates the extent of losses which such a method involves.

THE NUTRITIVE QUALITIES OF RICE

In view of the fact that rice and wheat are the staple cereals of large segments of the population of the globe, it is of interest to compare their nutritional qualities. One may compare the two grains in their brown whole-grain form. This is of considerable academic interest from the standpoint of the inherent properties of the two cereals. However, from a practical standpoint, a comparison of the two in their white refined form is more important as this white form constitutes a large part of the world consumption of each. In the following paragraphs, some comparisons appear both on the whole grain and on the refined grain basis and an intercurrent discussion is included of corn (maize), the world's third great cereal.

The nutritive importance of the cereals lies primarily in their high fuel value and in their low cost, but whenever they constitute a large fraction of the caloric intake, consideration must be given to their special nutritive qualities. The nutritive qualities of rice as compared with those of wheat

TABLE 6

AVERAGE COMPOSITION OF CORN, RICE, AND WHEAT

	Corn[b]	Rice[b]		Wheat[b]	
	Whole	Brown	White milled	Whole	White Flour
100 calorie portions (in grams)	27.0	28.0	29.0	28.0	28.0
Protein (percent)	10.0[a]	8.9	7.6	11.1[a]	9.3
Fat (percent)	4.3[a]	2.0	0.3	1.7[a]	1.0
Carbohydrate (percent)	73.4[a]	77.2	79.4	75.5[a]	77.2
Fuel value per hundred grams (in calories)	372.0[a]	356.0	351.0	362.0[a]	355.0
Ash (percent)	1.50	1.90[d]	0.4	1.8	0.5
Fiber (percent)	2.3	1.0	0.2	2.4	0.4
Minerals (perce t)					
Calcium	0.015	0.084	0.0[illegible]9	0.050	0.020
Magnesium	0.160	0.119[a]	0.028[a]	0.170	......
Potassium	0.400	0.342[a]	0.079[a]	0.480	......
Sodium	0.050	0.078[a]	0.028[a]	0.100	......
Phosphorus	0.430	0.290	0.096	0.400	0.092
Chlorine	0.[illegible]2	0.023[a]	0.006[a]	0.090	......
Sulfur	0.14	......	......	0.180	......
Iron	0.003	0.0020	0.0009	0.004[a]	0.00084
Manganese (parts per million)	6.83[a]	......	10.14[a]	45.91[a]	......
Copper (parts per million)	4.49[a]	3.60	1.90	7.87[a]	1.70
Vitamins (parts per million)					
Ascorbic acid	0[a]	0[a]	0[a]	0[a]	......
Thiamine	4.4[f]	3-5[d]	0.6-1.0[d]	3.2-7.7	0.87
Riboflavin	1.3-1.5	.8-1.0[d]	0.28[d]	1-1.2	0.40
Nicotinic acid	21[c] (yellow)	55[d]	15-20[d]	53	10.00
Pantothenic acid	8[c] (yellow)	17	6.4	13.4	5.70
Pyridoxine	......	10.3	4.5	4.6	2.20
Choline chloride	370[c] (yellow)	......	880[c]	920[c]	520[c]
	0[a] (white)	.5-1.0[a]	0[a]	0.2-0.25[a]	
Vitamin A (International units per gram)	7-7.5[a] (yellow)				
Tocopherol	25.0[e] (white) 31.0[e] (yellow)			9.10	0.30

[a] Sherman, H. C. Chemistry of Food and Nutrition. The Macmillan Company. New York, 1941.

[b] Jacobs, M. B. The chemistry and technology of food and food products. Interscience Publishers, Inc., New York, N. Y., 1944. Values are from this source when not otherwise indicated.

[c] Adams, G. and Smith, S. L. Experiment Station Research on the Vitamin Content and the Preservation of Foods. U. S. Dept. of Agr. Miscellaneous Publ. No. 536, 1944.

[d] Data from own analysis (M. C. Kik).

[e] Shollenberger, T. S. and Jaeger, Carol M. Corn, Its by-products and uses. Commodity Development Division, Northern Regional Research Laboratory, Peoria, Ill., 1943.

[f] Connor and Straub, Cereal Chem. 18: 671 (1941). This value is for white corn which showed a range from 2.54 to 7.4.

and corn can be estimated from a knowledge of their content of the major nutrients: proteins, fats, carbohydrates, mineral constituents, and vitamins, corrected more or less for failure of the body to assimilate these constituents completely. The average chemical composition of corn, rice, and wheat in both whole grain and refined form is presented in Table 6.

We shall now compare briefly the composition of the three grains in the whole grain form and then discuss more fully the comparison of their white form, with special emphasis on rice and wheat.

In comparison with corn and rice, wheat is the best source of protein and also has a higher content of thiamine, riboflavin, and niacin. Corn is deficient in niacin compared to the other grains and accordingly is often a contributing factor in pellagra.[14] In spite of a relatively low niacin content in milled rice, there has been little association of pellagra with polished rice diets. There is little to suggest historically a specific association of ariboflavinosis with any one of these grains. It is liable to occur when any of them predominates in the dietary to high degree. All the cereals are low or lacking in vitamin A (except yellow corn), vitamin C, and vitamin D. They are fair sources of iron, the availability of which is 50 percent in wheat. Wheat germ oil is the richest source of vitamin E and rice oil contains some vitamin E and vitamin A.

TABLE 7

AMINO ACID CONTENT OF RICE, CORN, WHEAT, AND CASEIN

Material	Cystine percent	Tryptophane percent	Lysine percent	Arginine percent	Histidine percent
Brown rice	0.090	0.074	0.260	0.254	0.064
Polished rice	0.073	0.066	0.280	0.251	0.059
White corn	0.096	0.047	0.107	0.212	0.089
Whole wheat	0.157	0.080	0.872	0.356	0.080
Casein	0.3C0	0.950	7.120	3.540	2.340

The quality of the proteins of these cereals in whole grain form is about the same. At approximately the same level of protein intake (5 percent) the biological value of the proteins of these cereals is 72 for corn and 73 for rice, compared with 67 for wheat at an 8 percent level. A value for wheat at a 5 percent level is unavailable but a somewhat higher value than 67 would be expected at this lower level of intake. Supplementation of white wheat flour with milk, eggs, or meat and of rice[15] with milk powder, leads to better utilization of total protein. In addition, it has been reported that calcium increases the biological value of rice proteins. The content of tryptophane, arginine, and histidine in rice is comparable to the content of those essential amino acids in wheat and corn; the lysine content is low, even lower than that of wheat. This is probably the most serious amino acid defect of rice. Wheat protein is deficient in lysine; corn protein, in both lysine and tryptophane. Brown and polished rice are low in cystine compared to casein and to wheat.

[14] W. A. Krehl, L. J. Teply and C. A. Elvehjem. Corn as an etiological factor in the production of a nicotine acid delinquency in the rat. Science 101: 283 (1945).

[15] Arkansas Agr. Exp. Sta. Bulletin, December 1942, No. 428, page 21.

Table 7 shows the available data on the contents of these essential amino acids in the three cereals.[16]

A diet in which any cereal predominates requires supplementation with a good selection of other foods. This is true of rice. In addition to cereals, a diet should include milk, vegetables, fruit, fish, and meat. These foods are not only richer than cereals in certain minerals and vitamins, but contain them in proportions more suited to the body needs.

All three cereals are low in calcium and addition of calcium to cereal diets has a beneficial effect.[12] The ratio of calcium to phosphorus in rice is approximately 1:10, which is unfavorable for maximum availability and utilization in nutrition. The optimum ratio is 1 : 2 or 1 : 1. The phosphorus content of rice is satisfactory in point of quantity; however, it occurs in rice, as in other cereals, mostly as phytin, an organic combination, and in this form it is not easily absorbed by the animal organism. Supplements of calcium in the form of milk and vegetables favorably influence assimilation of the phosphorus compounds in rice. Vegetables have an acid-base ratio inverse of that in rice and other grains; they are also a good source of phytase, an enzyme which renders available the phytin of the grains.

Nutritional Status in Rice Areas of Asia

The best insight into the shortcomings of rice as a food grain is to be found in practical experience in Asia, in view of its extensive use in that country. The most satisfactory analysis of this question is presented in a memoir by Aykroyd et al., "The Rice Problem in India."[12] This takes into account the known facts of modern nutritional principles. The study is, however, confined largely to India, where conditions are somewhat peculiar in that parboiled rice is preferred in the greater part of the country. The use of raw rice, according to Aykroyd et al., is limited to the coastal area on the Bay of Bengal extending from a point about 50 miles north of the city of Madras northward for about 600 miles in a band averaging 100 miles in width. This area of the Northern Circars has a population of about 14 million, less than a tenth of the total rice-eating population of India, which tends to make the Indians as a whole rather atypical of rice-eating populations. Parboiled rice is superior to machine-milled white rice not only in its content of the B vitamins, but also in retention of the superior proteins of the bran and germ. However, these differences, aside from the B vitamins, are not large compared with the variations from country to country in the character and quantity of components of the dietary other than rice. Accordingly, one will presumably form a reasonably correct opinion of rice as a staple cereal from this study of India.

Nutritional edema has been observed in China[17] among soldiers during the civil wars. Its occurrence has been frequent during famines in India, China, Mexico, and Russia and it was well described during World War I. Even

[16] Arkansas Agr. Exp. Sta. Bulletin, 1942, No. 416, page 21.

[12] *Supra.*

[17] J. Heng Liu, Dietary Habits of the Chinese. From "A Brief Review of Food and Nutrition in Five Countries", War Food Administration, U. S. Dept. of Agriculture, 1944.

as late as 1914, its specific cause was still unknown. Lack of protein in the diet, a condition which one would suppose liable to occur in the Orient where such an abundance of rice is eaten, causes a disease known as nutritional edema, hunger edema, war edema, or prison dropsy. It is most conspicuous in war time or during famines. The lack of protein leads to depletion of albumin in the blood serum. A normal concentration of the albumin is needed for the efficient maintenance of the blood volume. If, however, the concentration of the albumin falls, large amounts of fluid escape from the blood into the body tissues and swell them to a puffy condition especially noticeable in the extremities. Tremendous intakes of protein are frequently required for the correction of these conditions. Milk, meat, eggs, and soybeans, or sometimes an injection of an amino acid mixture, are given. Either course will correct the condition.[18]

Aykroyd [12] says that in India a deficiency of protein in typical rice diets is of minor importance. Calcium deficiency is one of the major faults in the Indian rice eater's diet. Beriberi, night blindness, and keratomalacia (softening of tissues in the cornea) due to vitamin A deficiency, and stomatitis (inflammation of the mouth), in which deficiency of nicotinic acid plays a role, are very common. Anemias of varying kinds, probably due to the low iron content when extra demands are imposed by such conditions as malaria and hookworm, appear among rice eaters. Riboflavin deficiency, due to the low milk consumption, is common.

POLISHED RICE AND BERIBERI

Beriberi is caused by a pronounced deficiency of the antineuritic vitamin, vitamin B_1 or thiamine. Up to 80 percent of this vitamin is removed during the process of milling brown rice to white polished rice and the disease is found principally in those regions where people live on diets containing large amounts of polished rice. Beriberi occurs abundantly in south China, southeastern India, Japan, Netherlands India, Philippines, Burma, Siam, Indo-China, and scatteringly elsewhere throughout the world. In several Oriental cities, beriberi is among the foremost causes of death. Women of child-bearing age are generally affected by it in mild chronic form. Infantile beriberi in breast-fed babies is extremely prevalent. Acute beriberi often breaks out in large labor gangs. The extent of partial incapacitation of all classes by the disease is incalculable because of lack of adequate clinical surveys, but it must be very large.

The substitution of parboiled rice for polished rice is an effective prophylactic against the forthright disease as was demonstrated by Fraser and Stanton in 1909 in the Malay States. Another very striking illustration of the relation of beriberi to white polished rice was provided by the Philippine Scouts. Prior to 1910, the ration of these troops consisted essentially of beef, white flour, potatoes or onions, and polished rice. From 100 to 600 of a total of 5000 scouts developed symptoms of beriberi annually. The number of

[18] Elman, R. Protein deficiency in surgical patients and its correction. Journal of the Am. Diet. Assoc. 18: 141 (1942).

cases was decreased to 50 within a year and later fell to nearly zero when the polished rice was replaced with undermilled rice, beans, and sweet potatoes. These and other evidences of the causal relation between white rice consumption and beriberi are critically reviewed by Vedder.[19] While his book reflects the then immature state of knowledge of deficiency disease, his principal thesis is well supported and has now been universally accepted.

TABLE 8

RECENT PREVALENCE OF BERIBERI IN THE ORIENT

Year	Madras Presidency[a] Northern Circars Pop. 13.9 million Cases	Deaths	Remainder Pop. 32.9 million Cases	Deaths	Japan[b] Pop. 70 million Deaths Infant	Adult	Philippines[c] Christian pop. 14 million Deaths Infant	Adult
1924	......	..	...	..	......	......	13,193	5,820
1925	......	..	...	..	11,866	15,130	13,493	5,048
1926	......	..	...	..	8,720	9,613	14,027	5,182
1927	......	..	...	..	7,453	6,456	12,575	4,500
1928	......	..	...	..	6,976	5,133	12,291	4,492
1929	......	..	...	..	9,920	9,116	15,141	5,084
1930	......	..	...	..	8,649	6,807	16,485	5,089
1931	......	..	...	..	8,277	7,142	15,018	4,520
1932	16,091	93	665	3	9,770	7,997	13,302	3,871
1933	20,513	55	822	2	7,162	4,643	14,720	3,962
1934	21,849	42	711	5	8,074	5,754	17,054	4,365
1935	34,639	89	382	8	6,720	4,774	14,299	4,315
1936	20,814	94	452	7	......	......	11,316	3,506
1937	27,488	65	748	5	6,791	4,306	13,004	3,793
1938	32,717	64	649	4	......	......	13,217	3,833

[a] Aykroyd, W. R., Krishnan, B. G., Passmore, R., and Sundarajan, A. R., The rice problem in India. Indian Medical Research Memoir 32, 1940, p. 4.
[b] Japan. Annual Health Reports of the Sanitary Bureau.
[c] Philippine Islands. Annual Reports of the Bureau of Health.

Beriberi is still an important disease in the Orient, as shown by the statistics of Table 8. Beriberi is of less importance outside of the Orient. However, it occurs sporadically in many places, notably where a refined starchy diet is used. Local epidemics have occurred in Africa and South America. Sailors on sailing vessels, supplied with a diet composed largely of hard tack, used to be very subject to so-called "ship's beriberi." Beriberi was also often reported in Newfoundland[20] where white bread was a primary staple and other foods were scanty during hard times.

Many cases have been reported in various parts of the United States under varied circumstances. The occurrence of beriberi among farmers in Louisiana has been described as specifically associated with rice. Though farmers are rice growers, they sell their rice crop, and polished rice is bought as their staple cereal. It is said that in autumn their diet consists mainly of polished rice and bacon grease (riz et sauce) and they develop symptoms of the dis-

[19] Vedder, E. B. Beriberi. William Wood, New York, 1913.

[20] Aykroyd, W. A. Beriberi and other food deficiency diseases in Newfoundland and Labrador. Jour. Hyg. 30: 357 (1930).

ease. In winter, they eat potatoes, bread, and meat from home-slaughtered animals, and no new cases of the deficiency disease occur.[21]

PROPOSED CORRECTIVE MEASURES AGAINST BERIBERI [12]

The investigations of Fraser and Stanton first demonstrated that beriberi resulting from the consumption of highly milled rice can be prevented by eating undermilled rice. Measures designed to encourage the use of such rice have been repeatedly proposed at various congresses of the Far Eastern Association of Tropical Medicine. The idea of legislative encouragement of undermilling was tentatively advanced at its first meeting in Manila in 1910. In 1921, the fourth congress was held in Batavia and an international commission was appointed to study the control of beriberi by the use of undermilled rice. The governments concerned were urged at that time to consider discouragement of the use of rice with less than 0.4 percent of phosphoric acid, for, according to Fraser and Stanton, approximately this percentage of phosphoric acid is present in rice which is sufficiently undermilled to be prophylactic for beriberi.

At the next congress held in Singapore in 1923, the recommendations of this commission were received, but for several reasons the government representatives declared that international legislative action designed to prohibit the use of highly milled rice was impracticable. Doubts were still expressed about the etiology of beriberi; the phosphoric acid test was shown to be more or less unreliable; undermilled rice was unpopular because of its unpleasant taste and its deterioration in storage and the trade was still inclined to resist any change. It was, accordingly, recommended that more research work be done on standardization of rice and on the effects of transport and storage.

In 1937, the League of Nations' Inter-Governmental Conference of Far Eastern Countries on Rural Hygiene met in Java. It was agreed that there was still a growing tendency for less use of undermilled, or home-pounded, rice, and more use of highly milled rice. This was condemned from the standpoint of nutrition but it was felt that economic and other factors should be studied further before an effective policy could be formulated. The Conference recommended the use of undermilled rice in government institutions and popularization of its use elsewhere by education and propaganda. Attention was called to the desirability of checking the spread of mechanical rice mills in rural areas and promoting the availability of home-pounded rice to consumers.

In November 1937, the Nutrition Advisory Committee of the Indian Research Fund Association met and recommended that investigations be undertaken in India along the lines indicated by the Java meeting. The subsequent studies made in India are summarized in the memoir by Aykroyd et al. previously mentioned. The principal findings with respect to their bearing on the general problem of beriberi are outlined below. Forthright beriberi in India is limited to the Northern Circars, an area of Madras Presidency com-

[21] Scott, L. C., and Herrmann, G. R. Beriberi . . . in Louisiana. J. Am. Med. Assoc. 90: 2083 (1928).

prising the coastal region extending from a point 50 miles north of Madras to the borders of Orissa. This is the area in which rice is milled in the raw state, that is without parboiling. Elsewhere throughout the southern and eastern parts of India rice parboiled before milling is used. Retention of vitamin B_1 is far greater in parboiled rice (see page 58), and only very mild forms of beriberi are present where it is used. The practice of preparing rice for consumption by home pounding is still largely followed in many parts of India. In this type of milling, a substantial fraction of the pericarp is retained whether the rice has been parboiled or not. This is especially important in the case of raw rice. The custom of using machine-milled rice, both raw and parboiled, is spreading in rural as well as urban areas; in 1939 about 70 percent of the rice-eating population of Madras Presidency consumed such rice. The reasons for the abandonment of home pounding are many: small rice mills are increasing as cheap electricity becomes available; better roads and transportation facilities enable the paddy grower to bring his rice to a mill; the malnourished and exhausted village women, who do the pounding, seek to avoid that hard labor; undermilled or home-pounded rice is unavailable in cities. There the industrial town laborer has no facilities for pounding rice and machine-milled rice is bought almost exclusively. Even small rice growers sell their products and buy machine-milled rice. Often there is lack of storage space for paddy and lack of equipment for pounding. Many villagers have sold their pounding equipment after the arrival of small mills. Furthermore, home-pounded rice is more expensive and cannot meet the competition of the cheaper kinds of rice which are eaten in highly milled form by the poorer classes.

From the present authors' study of the subject it seems doubtful that the degree of undermilling can be adequately controlled unless milling is eliminated entirely and provision is made for expeditious transit of the whole brown rice from the rice-shelling mill to the consumer to avoid spoilage in storage. This is said to have been done in recent years with large amounts of rice produced in Java, but we cannot vouch for the authenticity of the statement.

While the thought of public health authorities in the Orient has centered largely about the encouragement of undermilling, other expedients have at least been mentioned. Van Veen [22] considered the incorporation of synthetic thiamine in the salt supply but dismissed it on the ground of cost and because of deterioration of thiamine in admixture with salt during long storage. The cost factor is much less serious than formerly, since 1 milligram of thiamine per capita daily can now be supplied at a cost of 5.8 cents per annum at the price in the United States. The problem of stability is not fully resolved. According to a progress report furnished by Dr. R. T. Major, thiamine present in salt in a concentration of 1 part in 5000 lost activity during storage for 4 months to the extent of 2.7 percent to 29 percent, depending chiefly on the purity of the salt and secondarily on temperature of storage. The higher loss

[22] Van Veen, A. G., Technical Commission on Nutrition, League of Nations. C. H. Com. Exp. Alim. 66 (1939).

was encountered at a storage temperature of 40°C, when thiamine was mixed with a sea salt of Indian origin supplied by Dr. W. R. Aykroyd. Further experimental work is in progress. This has already indicated that this loss can be reduced to one-fifth or one-tenth of the higher figure by relatively simple compounding expedients. A fuller report will be awaited with interest when the work is completed.

Another expedient that has been advocated less intensively than under-milling is the more widespread use of parboiled rice. Parboiled rice is customarily used in the larger part of India and in these areas the product is preferred to white rice by the people accustomed to it. The process consists in soaking the rough rice or paddy in warm or hot water for some hours or days, after which the water is drained off and the rice is dried and milled in the usual way. Often steaming follows or replaces steeping. More detailed discussion of this topic is given on page 58. This practice has spread to points in Malaya where Indian immigrants are numerous and is followed in Ceylon and in British Guiana. It is practiced in Burma on rice for export to India and is under trial in China at Chungking, but the product is not accepted there with favor. There are two large parboiling plants near Buitenzorg, Java.

COMMERCIAL MILLING OF RICE

The Milling Process

In the Orient a vast quantity of rice is milled by manual labor, utilizing primitive devices. The most important of these is the wooden mortar and pestle, the latter being lifted by hand or with the foot by means of a lever. The mortar and pestle is even harnessed to mechanical power generated by steam or hydrostatically. However, in the larger mills machinery has been introduced from the West. The milling process used in the United States is little more refined than that of the larger commercial mills in the Orient and is essentially the same in principle. In the following discussion of the milling process proper, it may be well to have in mind the structure of the rice grain. This is illustrated in Figure 1.

The rice is first cleaned mechanically. Sifting removes sticks and stones, aspiration with an air stream takes out dust beards, stems, and light blighted grains. The resulting cleaned paddy is now subjected to removal of the hulls by machines called shellers. These consist of a stationary plate and an opposed plate rotating at about 190 rpm, both plates being mounted in a horizontal plane. The paddy passes through a central hole in the upper plate which in some machines is stationary; in others it is the rotating member. The plates are usually of steel about four or five feet in diameter and are coated on their inner surfaces with a mixture of cement and coarse carborundum. Formerly these plates consisted of stones with suitably chipped inner surfaces. In either case it is necessary to renew the roughness of the surfaces periodically by rechipping with a special hand tool for the purpose.

The plates operate with their inner faces about ¼ inch apart, but this spacing is closely adjustable to the mean length of the grains to be shelled. Ad-

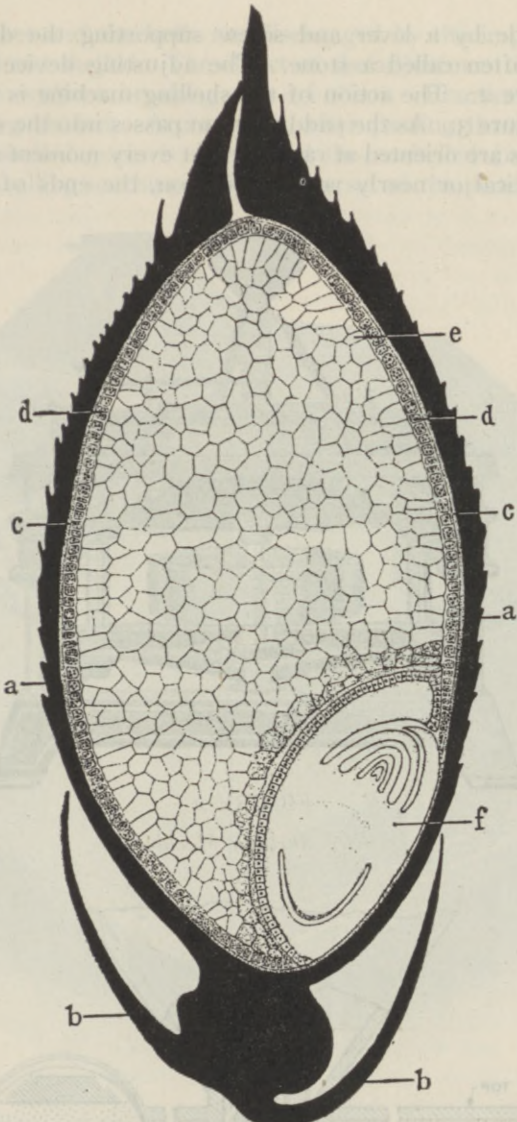

FIGURE 1

Longitudinal Section of a Rice Grain *

The hull or husk (a) consists of two ridged inner glumes called the palet and the lemma and of two empty sterile outer glumes (b).

The next layer (c) is a thin cover consisting of the remains of the ovary walls (pericarp) and of the seed coat. Then follows the aleurone layer (d) which is rich in nutrients. These two layers are removed in the milling process by the skinning machines and form the bran. The major part of the rice kernel is the endosperm and even some of this must be removed in order to get rid of all the tightly adhering coats. The embryo or germ (f) is situated at the base of the kernel and is also rich in nutrients. The side in close contact with the endosperm is called the scutellum and aids in nourishing the embryo.

* Yampolsky, Cecil. II Rice Grain and its Products. Wallerstein Laboratories Communications, Vol. VII, number 20. April 1944. Reproduced with permission of Wallerstein Laboratories, 180 Madison Avenue, New York City.

justment is made by a lever and screw supporting the driving shaft and rotating plate, often called a stone. The adjusting device is shown at the bottom of Figure 2. The action of the shelling machine is diagrammatically portrayed in Figure 3. As the paddy stream passes into the space between the plates, the grains are oriented at random. At every moment some of them are turned to a vertical or nearly vertical position, the ends of these grains are

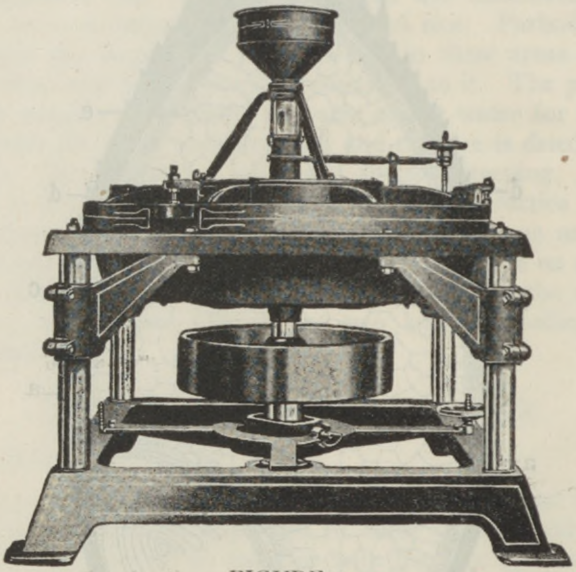

FIGURE 2

Rice Shelling Machine

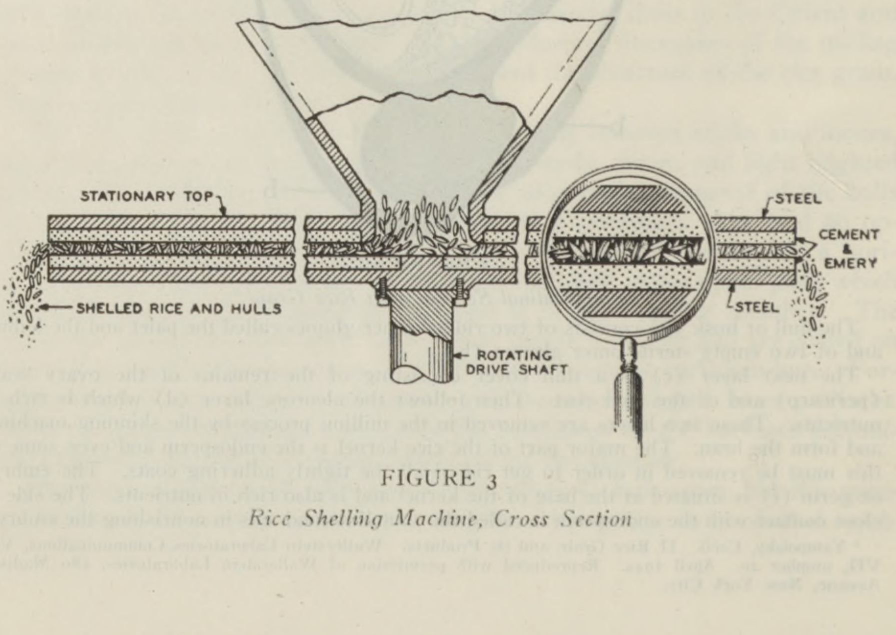

FIGURE 3

Rice Shelling Machine, Cross Section

caught by the stones and the hulls are disengaged by the impact. Others in turn are upturned and shelled. The object of the adjustment is to shell all the grains if possible without breaking any of them. Practically, the shorter grains escape being shelled. Accordingly, after passing through the sheller, the incompletely shelled grain is sorted and the unshelled fraction is passed through another shelling machine with a closer set of the plates.

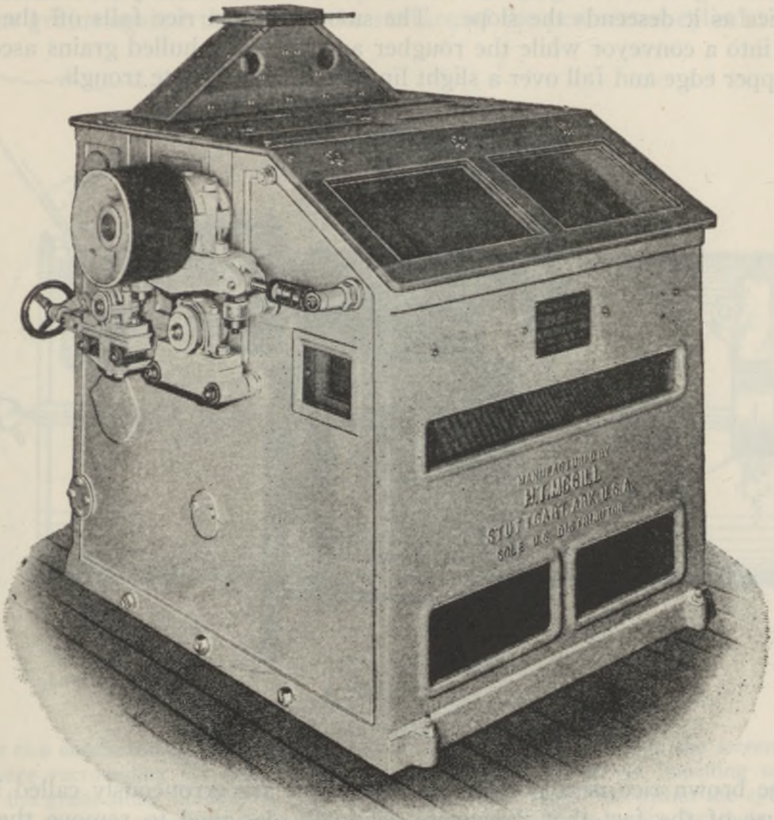

FIGURE 4

McGill Rice Sheller

Such shellers have long been in use in the rice industry and apparently relatively little effort has been devoted to their improvement. In recent years a different type of sheller is being offered and is meeting with considerable favor. A lower breakage of rice is claimed for this machine, which is illustrated in Figure 4. Its mode of operation is as follows: The knifed upper roller rotates at a peripheral speed of about 1800 to 2000 feet per minute, while a rubber belt carrying the paddy in a thin layer on its upper surface travels over a lower smooth steel roller at a speed about one third as great as the knives which strike the paddy grains on their sides and remove the hulls.

After being shelled, the hulls are removed by strong aspiration and the unhulled rice is separated from the brown hulled rice by a paddy machine. This clever machine consists essentially of a slightly tilted, smooth, steel plate with a horizontal reciprocating motion and provided with baffles which serve to distribute the rice over the entire surface and to insure ample overturning of the rice as it descends the slope. The smooth brown rice falls off the lower edge into a conveyor while the rougher and lighter unhulled grains ascend to the upper edge and fall over a slight lip into an appropriate trough.

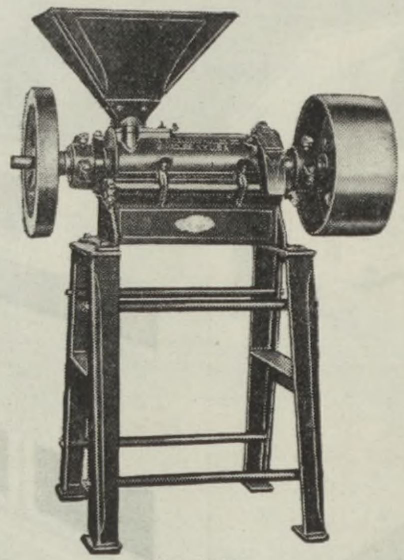

FIGURE 5

Engelberg "Huller" for Scouring Rice

The brown rice next goes to machines that are erroneously called hullers because of the fact that they were originally designed to remove the outer coverings from coffee beans. Although the term is not used in the trade, we shall refer to this operation as scouring, as this word best describes the nature of the operation. The machine (Figs. 5, 6, and 7) consists of a solid heavy fluted cylinder, E (discernible in Fig. 6 but best seen in Fig. 7), rotating at 500-600 rpm within a stationary hollow cylinder of thin sheet steel, F, uniformly perforated by closely spaced slots about 0.060 x 0.300 inches (a range of sizes is provided). The perforated cylinder is composed of upper and lower halves, the edges of which abut. The flutes on the rotating cylinder, E (Fig. 7), are so disposed as to carry the rice along the length of the cylinder and to cause it to travel around and around the inner surface of the perforated cylinder. A suitable opening, A^1, through the perforated screen admits the rice at the top at one end of the cylinder and another permits its egress at the top of the other end, I. However, in operation the entire machine is continuously packed full of grain. The outflow and accordingly the packing force is regulated by a blade, H, the full length of the barrel, which protrudes between the upper and lower halves of the perforated cylinder, F, and approaches the flutes of the cylinder, E, within it, thus retarding the movement of the grain lying next to the perforated cylinder. The action of the machine is, therefore, essentially one of scouring the moving inner mass of rice grains against those near the surface of the perforated cylinder which

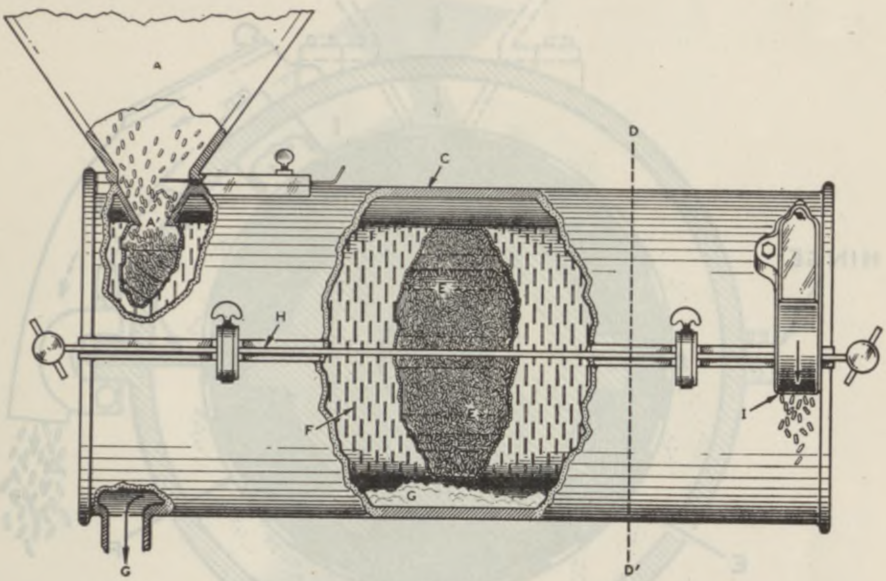

FIGURE 6

Rice Scouring Machine, Longitudinal View of Barrel

The rice enters through hopper *A* and passes through aperture A^1 in the screen *F* into the space surrounding the fluted solid cylinder *E* which acts as an impelling worm to carry the grain along the hollow cylinder *C* from left to right but within the cylindrical screen *F* through which the bran falls as it is scoured off the grains by their friction on one another and against the screen. Bran, *G*, is removed by an aspirator while the scoured rice exits at *I*. The effect of the huller blade *H* (see also figure 7) is to retard the motion of the grain lying against the screen relative to that carried along by the flutes on the screw. Scouring is therefore largely achieved by rubbing the grains against each other.

are retarded by the blade. By this means the bran is progressively scoured off the grains, falls through the perforated screen and is carried away by aspiration. When the blade is set closer, the rice within the machine is subjected to denser packing and the effluent rice is caused to become whiter. Great skill and constant observation on the part of the miller are necessary to secure efficient removal of the bran without excessive breakage of the grain. The grain is markedly heated by the friction. This must be kept within bounds.

The adjustment of the blade is governed entirely by the appearance of the outgoing grain.

The bran is continuously removed by suction as it falls through the perforated cylinder. Usually the grain is passed through a succession of such

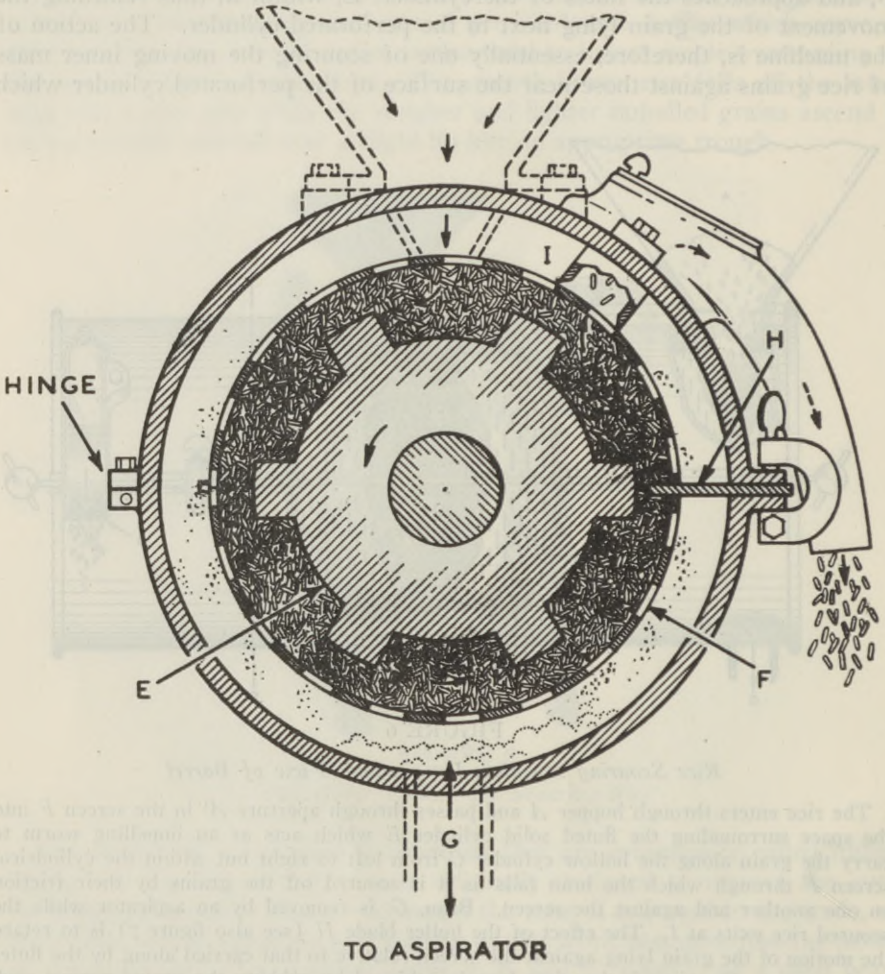

FIGURE 7

Rice Scouring Machine, End View

The lettering of Figure 7 corresponds to that of Figure 6. Alternate reference to Figure 6 and 7 will be helpful to understanding the operation of the machine.

scouring machines. It comes out nearly free of germ and retains only a small fraction of the bran, consisting largely of the inner layers. Some of the grains are broken at this stage, the amount depending on the variety and quality of the rice, its moisture content, and the skill of the miller.

In some mills a pearling cone is used instead of, or in addition to, a scouring machine. This is an inverted, truncated cone about 28 inches high, covered with a mixture of emery and cement, which revolves inside a steel wire screen forming another truncated cone with walls parallel to the inner cone. The whole is encased in an iron casting with openings for the grain to enter and leave as the cone spins. Rice is fed in from the top, rubbed between the cone and the sieve, and released at the bottom. By raising or lowering the revolving cone, thus adjusting the distance between the cone and screen, the amount of

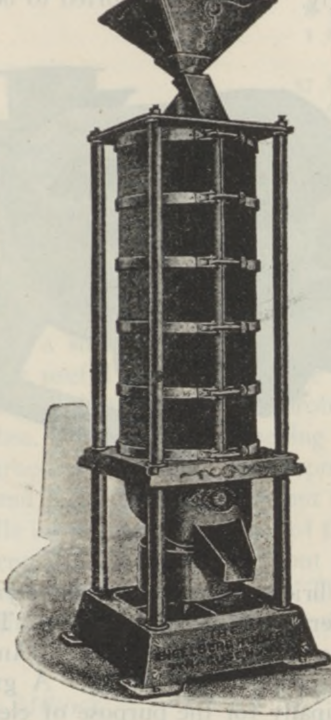

FIGURE 8

Rice Brush or Polisher

scouring can be regulated. To minimize the breakage, rice is usually passed through a series of these pearling cones in order that the scouring action may be gradual and gentle rather than rapid and harsh. The pearling cone is used extensively in Europe and to some extent in the Orient.

The scoured rice may pass to a polishing machine called a brush. This consists of a vertically disposed wooden cylinder about 8 feet high and 4 feet in diameter, rotating within a fairly close-fitting stationary cylindrical screen. The entire surface of the wooden cylinder is covered with strips of leather laid on the full length of the cylinder. The strips are four inches wide and each, shinglewise, overlaps its neighbor on one side and is overlapped by its neighbor on the other. Rotation is with the lap, not against it, so that the grains tend to wedge between leather and screen as they approach each successive overlap. The inner bran layers are removed, falling through the screen. They constitute the so-called rice polishings. The brush is shown in Figure 8. Its use is now often omitted.

White rice may be coated to improve its appearance by slight oiling and glazing with powdered talc, glucose, and other materials. This coating also improves its keeping quality in storage, as it offers some protection against attack by insects. It is, however, an objectionable sophistication and is now practiced less than formerly. Its use is reported to be limited to the United States, Italy, and Spain.

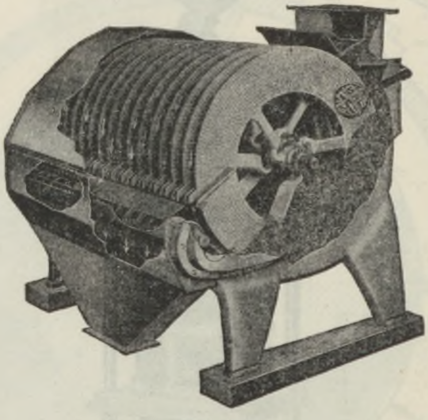

FIGURE 9

Disc Separator

The foregoing is a very brief account of a relatively complicated mechanical process that varies considerably from mill to mill. The fundamental operations, however, follow the same principles in all American mills and have endured without material change for decades. A great variety of supplementary machinery, principally for the purpose of cleaning rice, for removal of weed seeds, for sorting of broken rice grain fragments according to size, etc., are in use. Size classification is often accomplished by some form of rotating device involving surfaces with pockets of graduated size capable of elevating small particles and rejecting larger ones. The disc separator, Figure 9, is such a device of wide application.

Variation of yield of products of milling is considerable, depending on variety and quality of rice and on seasonal influences. There are about 10 varieties of rice grown in commercial quantities in the United States, usually classified into long, medium, and short grain. The 5 principal long grain varieties constitute about 25 percent of the crop, 3 medium grain varieties over 50 percent of the total, and the short grain "pearl" type of Japanese origin, grown mostly in California, represents the remainder. Breakage is rather higher in the long grain varieties.

A barrel of rough rice of 162 pounds weight represents the quantity originally considered necessary to produce 100 pounds (a pocket) of finished rice. Yields have increased so that 105 to 108 pounds of milled rice from a barrel is now common. The usual proportions of the various products for all varieties are as follows:

	Weight percent	Money Return percent	
Invisible loss and trash	2.0		
Brown Rice	79.0		
Hulls	20.0	1–2	
Bran	8.5	2–3	5
Polish	1.8	1	
Head Rice	57.8	83	
Second Head	2.6	4	95
Screenings	6.0	6	
Brewers	2.1	2	

Head rice, consisting of whole grains in milled form, represents the major value obtained. Second head, consisting of half and three quarter grains, screenings of quarter up to half grains, and brewers rice of less than quarter grain size, command successively lower prices. Bran and polish are used for stock feeds and bring in a small additional revenue. Their possibilities as human food or for other useful purposes deserve further exploration. The disposal of the large weight of hulls presents a problem. To some extent they are used as fuel, mulches, heat insulation, packing material, etc., but for the most part they are burned or scattered for disposal. They are used to a limited extent in a ground form in stock feeds, but this practice is frowned on as adulteration; the hulls injure the membranes of the alimentary tract. They contain nearly 20 percent ash, mostly silica, about 40 percent crude fibre, 30 percent carbohydrate and 2.5 percent protein. Their fuel value is actually sufficient to supply all the power required in the mill. The mills of Bangkok are so operated.

Losses of Nutrients in Milling

The process of milling of raw brown rice to white rice has been outlined in the foregoing pages. On the pages that follow we shall set forth the results of reexaminations of the problem of losses of nutrient values during milling. These have been conducted during the past four years with the aid of modern methods of vitamin analysis, including assays for thiamine, riboflavin, and niacin. The data come largely from the University of Arkansas, but in addition we have included data from modern literature when available.

In the process of milling to white polished rice, 76.3 percent of thiamine, 56.6 percent of riboflavin, and 63 percent of niacin are removed and lost for human consumption. The data of Table 9 represent the average of 44 samples of brown and 45 samples of white rice collected from numerous mills in the four rice-producing states during the years 1941, 1942, and 1943. The data on the individual samples here averaged are published in part;[23] additional previously unpublished data appear in Table 10 and Table 13. All these results are summarized in Table 9, which therefore gives a fairly representative picture of the fate of these three nutrients in the milling process.

The methods of analysis used were as follows:

Thiamine:—The samples were analyzed for thiamine by the thiochrome method, with an adaptation of the Hennessy and Cerecedo procedure.[24] The method as used in the laboratory at the Arkansas Agricultural Experiment Station is briefly as follows: Samples of 1 to 15 g. (depending on vitamin content) are suspended in 75 ml. of 0.1 N H_2SO_4, autoclaved in a pressure cooker for 20 minutes at 15 pounds pressure, cooled, adjusted to pH 4.0-4.5 with 2 N sodium acetate solution with brom cresol green as indicator. Five ml. of 10 percent takadiastase solution is added, mixed, and incubated at 50°C. for at least 1½ hours. After incubation the mixture is cooled, made up to 100 ml., and filtered. Aliquots of the clear extracts are used for the thiamine determination.

Riboflavin:—The samples were analyzed for riboflavin by a fluorometric method (Conner and Straub).[25] The method, as used in the laboratory at Arkansas, is briefly stated as follows: Samples of 5 to 10 g. (depending on vitamin content) are transferred to 200 ml. amber-colored Pyrex Erlenmeyer flasks, suspended in 75 ml. of 0.1 N H_2SO_4, autoclaved in a pressure cooker for 20 minutes at 15 pounds pressure, cooled, adjusted to pH 4.0-4.5 with 2 N sodium acetate solution with brom cresol green as an outside indicator. In order to obtain a clear filtrate, 125 mg. of takadiastase is added, mixed, and incubated at 50°C. for 1 hour. After incubation the mixture is cooled, made up to 100 ml., and filtered in the dark. Thirty-milliliter aliquots of the clear extracts are used for the riboflavin determination, with florisil used as a means of absorption and pyridine-acetic acid as an eluting agent. A blank determination containing reagents and takadiastase is run simultaneously with the samples.

Nicotinic Acid or Niacin:—Nicotinic acid was determined by the colorimetric method of Melnick (1942);[26] the analyses were made in duplicate, employing 1.0 g. samples of the main products and 250 mg. of the by-products. As a test of the suitability of the colorimetric method, the samples of whole

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[23] Kik, M. C. Thiamin in products of commercial rice milling. Cereal Chemistry 20: 103 (1943).

Kik, M. C., and Van Landingham, F. B. Riboflavin in products of commercial rice milling and thiamine and riboflavin in rice varieties. Cereal Chemistry 20: 563 (1943).

Kik, M. C., and Van Landingham, F. B. Niacin in products of commercial rice milling and in rice varieties. Cereal Chemistry 21: 154 (1944).

Kik, M. C. Effect of milling, processing, washing, cooking, and storage on thiamine, riboflavin, and niacin of rice. Arkansas Agr. Expt. Sta. Bulletin No. 458 (1945).

[24] Hennessy, D. J., and Cerecedo, L. R. The determination of free and phosphorylated thiamine by a modified thiochrome assay, J. Am. Chem. Soc. 61: 179-183 (1939).

[25] Conner, R. T., and Straub, G. J. Combined determination of riboflavin and thiamine in food products. Ind. Eng. Chem., Anal. Ed. 13: 385-388 (1941).

[26] Melnick, D. Collaborative study of the applicability of microbiological and chemical methods to the determination of niacin (nicotinic acid) in cereal products. Cereal Chemistry 19: 553 (1942).

brown rice employed in this study were submitted to another laboratory for microbiological assay. Credit is due John S. Andrews, Research Department, General Mills, Inc., Minneapolis, Minnesota, for the Microbiological Assays of these samples. The following values in micrograms per gram were obtained for samples of whole brown rice by the microbiological method: 57.1, 55.1, 53.3, 47.3, 53.5, 58.4, and 50.0; average 53.5. These values are in fairly good agreement with those obtained by the colorimetric method on the same samples, namely, 57.4, 56.4, 51.2, 52.8, 49.2, 64.7, 55.1 respectively; average 55.2. For these assays the method described by Andrews, Boyd, and Gortner [27] was used.

TABLE 9

AVERAGE THIAMINE, RIBOFLAVIN, AND NIACIN IN RICE (ROUGH, BROWN, AND WHITE) 13 Varieties, Harvests 1941, 1942, 1943

Type, and number of samples	Thiamine	Riboflavin	Niacin
Rough (34)	3.35 μg/g 1.51 mg/lb.	.73 μg/g .33 mg/lb.	53.40 μg/g 23.93 mg/lb.
Brown (44)	3.55 μg/g 1.60 mg/lb.	.60 μg/g .27 mg/lb.	53.08 μg/g 23.89 mg/lb.
White (45)	.84 μg/g .38 mg/lb.	.26 μg/g .12 mg/lb.	19.62 μg/g 8.83 mg/lb.

Table 11 gives recent data on pantothenic acid, pyridoxine, and biotin in brown and white * rice.

In previous studies [28] on amino acid content of rice proteins, it was found that the content of protein and of the essential amino acids, cystine, tryptophane, arginine, and histidine, is lower in white rice than in brown rice. These data are reproduced in Table 7, page 24.

Feasibility of Standardized Undermilling

The problem of improving rice nutritionally is beset with many obstacles. It is more difficult to restore vitamins and minerals to white rice than to flour because rice is rinsed before cooking. This leads to great losses when vitamin and mineral preparations are applied only to the surfaces of the grains. Restoration, or even retention, must be internal if it is to be thoroughly effective. Reduced polishing or undermilling † of rice, however,

[27] Andrews, J. S., Boyd, H. M., and Gortner, W. A. Nicotinic acid content of cereals and cereal products. Ind. Eng. Chem., Anal. Ed. 14: 663 (1942).

* Williams, V. R., Knox, W. C., and Fieger, E. A. A study of some of the vitamin B complex factors in rice and its milled products. Cereal Chemistry 20: 560 (1943); 21: 540 (1944).

[28] Kik, M. C. Nutritive studies of rice and its by-products. Arkansas Experiment Station, Bulletin No. 416, February 1942.

† We use the terms unpolished and undermilled substantially interchangeably in the present publication in the belief that any distinction between them is not significant in present American practice. Either term implies a partial retention of the bran coats, which is not assured by mere avoidance of the use of the brush or polisher. Virtually complete removal of the bran coats may occur in the scouring machine ("Huller"). The use of the term unpolished rather than undermilled was recommended by the Rice Millers' Association at a meeting in New Orleans December 5, 1943.

TABLE 10

THIAMINE, RIBOFLAVIN, AND NIACIN IN COMMERCIAL RICE (1942)

Name and location	Variety	Type	Thiamine mg per lb.	Riboflavin mg per lb.	Niacin mg per lb.
Imperial Rice Milling Co.,	Blue Rose	brown	1.37	0.16	25.25
Crowley, La.		white [1]	.32	.05	9.42
Republic Rice Mill,	Blue Rose	brown	1.58	.21	24.27
Guedan, La.		white	.35	.13	8.55
		brown	1.91	.24	28.13
		white	.45	.12	7.92
International Rice Milling Co.,	Blue Rose	rough	1.42	.27	21.84
Crowley, La.		brown	1.37	.20	26.51
		white	.32	.10	9.51
		second head	.28	.08	9.09
		screenings	.49	.17	10.57
		polish	10.48	1.19	117.00
		bran	11.56	1.94	119.19
Kaplan Rice Mill	Blue Rose	rough	1.80	.27	22.07
Kaplan, La.		brown	1.41	.23	25.33
		white	.27	.14	8.10
		bran	8.10	1.54	118.90
		polish	13.41	1.37	111.25
Lake Rice Mill,	Blue Rose	brown	1.57	.26	26.46
Lake Arthur, La.		white	.23	.15	8.50
Edmundson-Duhe Rice Mill,	Rexoro	rough	1.35	.25	26.10
Rayne, La.		white	.25	.11	9.32
United Rice Milling Products,	Rexoro	brown	1.35	.23	25.97
New Orleans, La.		white	.27	.10	6.75
Rickert Rice Mills,	Prolific	rough	1.53	.21	24.30
New Orleans, La.		brown	1.98	.22	23.40
		white	.47	.10	7.65
	Pearl	rough	1.73	.25	22.14
		brown	1.97	.22	26.28
		white	.39	.09	8.23
	Blue Rose	rough	1.80	.24	20.24
		brown	2.02	.23	26.82
		white	.57	.09	7.70
	Fortuna	rough	1.53	.30	37.50
		brown	1.99	.23	27.16
		white	.36	.14	8.25
	Rexoro	rough	1.46	.26	20.20
		brown	1.86	.25	26.62
		white	.36	.14	9.33
Adolphus Rice Mill,	Rexoro	brown	1.09	.23	25.98
Houston, Texas		white	.29	.14	9.62
Beaumont Rice Mills,	Rexoro	rough	1.35	.25	23.27
Beaumont, Texas		brown	1.46	.23	27.77
		white	.25	.11	8.42
		second head	.21	.08	6.79
	Blue Rose	rough	1.58	.25	30.83
		brown	1.53	.23	26.28
		white	.35	.14	8.82

[1] White rice is white milled, or head rice.

TABLE 10—Continued

Name and location	Variety	Type	Thiamine mg per lb.	Riboflavin mg per lb.	Niacin mg per lb.
Arkansas State Rice Milling Co.,	Blue Rose	brown	2.00	.39	26.15
Stuttgart, Ark.		white	.54	.11	9.37
Arkansas State Rice Milling Co.,	Blue Rose	brown	1.13	.18	22.28
Carlisle, Ark.		white	.18	.13	9.60
New Port Rice Mill,	Zenith	brown	1.85	.25	21.66
New Port, Ark.		white	.27	.11	9.27
Graham Bros. Rice Mill,	Prolific	rough	1.35	.25	27.00
Tuckerman, Ark.		brown	1.49	.22	26.07
		white	.23	.11	8.25
		second head	.23	.10	6.30
		brewers	.31	.09	11.31
		screenings	.67	.15	13.05
		bran	9.22	1.19	113.83
		polish	12.69	1.54	151.68
Rice Growers Association	Caloro	rough	1.35	.25	21.56
of California,		brown	1.98	.17	24.86
Sacramento, Calif.		white	.45	.13	7.90
		bran	10.84	1.19	132.47
		polish	10.03	.65	136.03
Woodland Rice Co.,	California	brown	1.47	.23	24.40
Woodland, Calif.	Pearl	white	.37	.13	10.17
Rosenberg Bros.,	California	rough	1.35	.25	30.65
San Francisco, Calif.	Pearl	brown	1.41	.28	27.75
		white	.41	.17	7.52
		bran	10.84	1.19	109.46
		polish	7.20	1.26	103.50

does present a possible way of retaining at least a portion of these special nutrients in the grain as consumed.[29]

A substantial fraction of the thiamine, riboflavin, niacin, and ash constituents of the bran coats of the grain are contained in undermilled or unpolished[29] rice. This is shown in Table 12;* lower values are obtained in the milled rice, compared to the unpolished rice.

Unpolished rice is at least an effective preventive of beriberi; this has been pointed out in a previous chapter. It seemed, therefore, of importance that the use of this nutritionally improved rice should be considered in those areas of the United States where rice is a staple food, unless a better approach can be devised.

There is at present a favorable attitude on the part of rice millers in the United States toward unpolished rice because yields of edible rice are larger with less milling and consumers are now less meticulous in their demands because of war shortages of supply. No new equipment or material is needed

[29] Vedder, E. B., and Feliciano, R. T. An investigation to determine a satisfactory standard for beriberi-preventing rices. Trans. Far Eastern Ass'n. Trop. Med. Seventh Cong. Dec. 1927, Vol. III, p. 375.

* Credit is due Miss Kathleen Smith for valuable analytical assistance in obtaining these and other data which follow in the text.

for its manufacture; it can be obtained simply by less drastic scouring in the mill, either by loosening the huller blades or by avoiding use of the pearling cone. The result is that the miller obtains a greater weight of rice that he is able to sell. It has been estimated that from eight to ten pounds more head

TABLE 11

OTHER VITAMINS IN BROWN AND WHITE RICE *

Variety	Vitamin Content, μg per Gram of Dry Weight, Pantothenic Acid Brown	Pantothenic Acid White	Pyridoxine Brown	Pyridoxine White	Biotin Brown	Biotin White
Blue Rose	16.5	6.5	9.4	2.0	0.114	0.050
Early Prolific	15.9	6.5	10.3	6.2	0.126	0.043
Nira	17.3	....	10.2	....	0.124	.....
Rexoro	15.4	....	10.7	....	0.133	.....
American Pearl	14.6	....	10.4	....	0.117	.....
Fortuna	18.6	6.3	11.2	5.3	0.123	0.034
Composite average	16.4		10.3		0.121	

*All figures represent averages of a number of samples.

rice is obtained from one barrel (162 pounds) of rough rice. The usual yield of highly milled head rice from a barrel of rough rice is about 87 pounds.

The Food and Nutrition Board of the National Research Council * has been concerned with the improvement of white rice from a nutritional standpoint

TABLE 12

DEPENDENCE OF VITAMIN CONTENT ON DEGREE OF MILLING

Variety	Type of Milling	Thiamine μg/g	Riboflavin μg/g	Niacin μg/g	Ash Percent
Early Prolific	unpolished	2.14	0.52	33.10	0.90
	unpolished	1.57	0.39	27.00	0.86
	milled	0.91	0.26	20.00	0.57
Lady Wright	unpolished	1.10	0.40	22.40	0.74
	unpolished	1.07	0.38	30.00	0.70
	milled	0.82	0.31	17.25	0.51
Fortuna	unpolished	1.90	0.51	32.00	0.84
	unpolished	1.00	0.38	30.80	0.68
	unpolished	0.97	0.37	22.53	0.80
	milled	0.80	0.30	18.00	0.48
Rexoro	unpolished	1.50	0.51	26.60	0.70
	milled	0.60	0.30	17.00	0.50
Nira	unpolished	1.65	0.55	24.50	0.80
	milled	0.74	0.35	19.00	0.44

under present conditions, and proposed for consideration the development and marketing of unpolished rice. To make this possible, both the rice industry

* The Food and Nutrition Board is concerned with the broad problems of nutrition in the United States, particularly under war conditions. It has had a large responsibility in connection with the establishment and promotion of enrichment of bread and flour. It has given consideration to rice for an essentially similar reason.

and the Food and Nutrition Board felt the need for the establishment of a standard for unpolished rice. To this end the Board addressed itself to the Grain Products Branch of the War Food Administration, urging the consideration of a suitable standard for an unpolished grade of rice.

There is no ready method whereby the vitamin and mineral content of unpolished rice can be estimated by visual inspection, and a standard requiring other than the simplest chemical laboratory test would not be satisfactory because of lack of facilities in the warehouses and because of the excessive time that would be consumed in grading rice. It would be most desirable to develop a simple test for the degree of undermilling. Without it one cannot specify a rice to a definite content of the essential nutrients by description of the degree of milling. One must resort to chemical analysis for each nutrient.

Rice has been tested at successive stages of milling and we thus have a general idea as to the point at which milling should be interrupted to obtain the best compromise between appearance on the one hand and nutritional quality on the other. In an endeavor to define unpolished rice more closely, data were obtained regarding the loss of weight of the grain and the loss of ash, thiamine, riboflavin, niacin, and fat in the course of the milling process. An attempt was then made to correlate these values with the degree of milling. This study included 19 samples of rough, brown, unpolished, and head rice (milling season 1943-1944) of six different varieties from six different mills in the rice-producing areas of Louisiana, Arkansas, Texas, and California. The weight of grains at successive stages was obtained by weighing 250 kernels from each sample.

The results of this investigation are given in Table 13 and the data clearly show that the nutrients decline progressively during milling. Below are given the average contents of these nutrients in rough and head rice and their percent losses as compared with the weight loss during the milling process.

	Av. Wt. of 250 Kernels Grams	Ash Percent	Ether Extract Percent	Thiamine μg/g	Riboflavin μg/g	Niacin μg/g	Iron μg/g
Rough..........	6.01	6.06	2.06	2.97	0.90	51.6	31.20
White...........	4.96	0.70	0.53	1.00	0.43	22.0	5.87
Loss (percent)....	17.50	88.40	74.20	66.30	52.20	57.2	81.10

These results show that the overall percent loss of the nutrient constituents of the grains during the milling process as a whole is only 3 to 5 times the percent weight loss. However, in the late stages of milling, the proportionate average percentage declines in weight versus those for nutrients from the unpolished to the head rice are quite different. The percent losses at this stage for all samples of Table 13 are as follows:

Weight of 250 Kernels Percent	Ash Percent	Ether Extract Percent	Thiamine μg/g	60 Riboflavin μg/g	Niacin μg/g	Iron μg/g
2.05	17.0	34.9	21.4	13.6	24.8	50.1

Here the percent nutrient losses are 6 to 25 times as great as the weight loss. Indeed, Table 13 shows instances in which the percent thiamine loss is 30 to

TABLE 13
COMPARATIVE DECLINE OF NUTRIENTS DURING MILLING OF RICE
(1943–1944 milling season)

No. of sample	Variety and type of rice	Weight of 250 grains Grams	Ash Percent	Ether extract Percent	Thiamine μg/g	Riboflavin μg/g	Nicotinic acid μg/g	Iron μg/g
1	Rexoro[a]							
	rough	5.29	5.84	2.15	2.70	0.84	46.29	27.90
	brown	4.27	1.28	1.98	3.00	0.63	42.18	23.90
	undermilled	4.05	0.80	0.81	1.10	0.45	31.94	17.90
	head	4.00	0.73	0.58	0.73	0.38	26.04	13.60
2	Zenith[a]							
	rough	5.95	5.56	2.07	3.82	0.76	51.71	29.50
	brown	5.08	1.20	2.00	3.09	0.70	44.80	22.30
	undermilled	4.67	0.72	0.80	1.09	0.51	30.58	14.30
	head	4.62	0.41	0.41	0.73	0.38	24.00	7.10
3	Rexoro[b]							
	brown	4.12	1.33	2.32	2.91	0.76	43.30	30.70
	first break	3.96	0.94	1.04	1.40	0.70	27.10	19.60
	second break	3.95	0.92	0.99	1.27	0.51	25.30	17.90
	head	3.93	0.86	0.48	1.09	0.42	24.34	4.28
4	Zenith[c]							
	rough	6.03	6.75	2.54	3.55	0.86	54.68	25.00
	brown	5.08	1.67	2.34	4.05	0.72	43.00	17.90
	undermilled	5.01	1.57	1.64	2.18	0.59	36.90	17.00
	undermilled	4.72	1.50	1.53	1.73	0.56	33.80	12.50
	first break	4.63	1.47	1.50	1.70	0.54	31.30	11.75
	second break	4.61	1.17	0.93	1.36	0.46	26.70	10.25
	head	4.51	1.06	0.64	1.27	0.44	21.00	6.10
5	Blue Rose[c]							
	rough	7.70	5.81	1.90	3.82	0.76	59.40	39.30
	brown	6.15	1.56	2.20	3.55	0.72	52.50	29.30
	first break	5.83	0.95	0.88	1.30	0.58	23.17	19.30
	second break	5.76	0.78	0.76	1.09	0.51	22.06	13.60
	head	5.53	0.70	0.70	0.82	0.43	16.00	1.78
6	Zenith[a]							
	rough	6.22	6.62	2.12	3.91	0.81	52.50	41.40
	brown	4.83	1.28	2.36	3.45	0.66	47.90	35.70
	undermilled	4.61	0.92	0.82	1.18	0.46	31.05	17.50
	head	4.53	0.53	0.58	0.91	0.36	22.41	5.30
7	Blue Rose[a]							
	rough	8.12	6.09	1.62	3.09	0.90	59.92	30.70
	brown	6.43	1.31	2.46	3.09	0.66	53.00	25.70
	undermilled	6.07	0.70	0.76	1.36	0.51	40.00	20.14
	head	5.97	0.56	0.44	0.82	0.46	24.13	9.60
8	Caloro[d]							
	rough	7.23	4.60	2.24	3.27	0.86	55.40	27.90
	brown	5.93	1.39	1.66	3.36	0.81	51.50	15.32
	first break	5.87	0.89	1.32	2.27	0.61	26.09	12.30
	second break	5.82	0.78	0.82	1.82	0.51	24.50	11.16
	head	5.26	0.56	0.50	1.55	0.46	20.15	5.35
9	Rexoro[b]							
	rough	6.00	5.99	1.66	3.09	0.94	51.24	23.60
	brown	4.41	1.30	2.44	2.73	0.66	49.00	19.30
	undermilled	4.32	1.19	1.30	1.82	0.48	41.00	15.00
	undermilled	4.26	1.12	1.22	1.73	0.44	40.00	12.90
	first break	4.23	1.08	1.12	1.36	0.40	33.85	9.30
	second break	4.21	1.03	1.07	1.27	0.38	30.00	7.70
	head	4.18	0.92	0.52	1.05	0.37	22.60	5.40

TABLE 13—Continued

No. of sample	Variety and type of rice	Weight of 250 grains Grams	Ash Percent	Ether extract Percent	Thiamine μg/g	Riboflavin μg/g	Nicotinic acid μg/g	Iron μg/g
10	Zenith [e]							
	rough	6.08	6.30	2.38	4.10	0.86	49.00	35.90
	brown	5.13	1.51	1.72	3.50	0.62	47.00	18.00
	first break	4.72	0.84	0.74	1.22	0.57	38.70	9.30
	second break	4.67	0.81	0.62	1.18	0.46	33.20	8.00
	head	4.56	0.78	0.32	0.73	0.40	21.50	3.50
11	Rexoro [a]							
	rough	5.48	6.79	1.78	2.64	1.07	45.00	31.01
	brown	4.45	1.38	2.08	3.36	0.90	43.00	17.14
	undermilled	4.21	0.79	0.62	1.27	0.56	35.00	9.30
	head	4.16	0.70	0.44	1.00	0.46	22.50	7.90
12	Blue Rose [a]							
	rough	7.67	6.06	2.24	3.73	1.27	53.30	33.20
	brown	6.17	1.40	2.28	3.91	1.00	46.70	17.71
	undermilled	5.85	0.76	0.98	1.18	0.66	34.12	11.29
	head	5.82	0.67	0.66	1.00	0.61	21.18	3.90
13	Lady Wright [e]							
	rough	7.86	6.73	1.84	3.64	1.00	50.00	30.70
	brown	6.83	1.50	1.42	3.55	0.76	47.00	21.40
	first break	6.27	0.89	0.92	2.18	0.61	36.90	13.40
	second break	6.12	0.78	0.82	1.55	0.55	31.81	12.90
	head	6.05	0.60	0.42	1.27	0.45	22.80	6.10
14	Blue Rose [f]							
	rough	7.55	5.28	2.04	3.55	0.96	55.00	27.15
	brown	6.85	1.56	2.14	4.35	0.81	39.11	23.20
	first break	6.11	1.00	1.14	2.65	0.70	30.00	15.40
	second break	6.03	0.72	0.80	1.27	0.62	25.00	8.90
	head	5.87	0.67	0.68	1.20	0.52	21.60	4.57
15	Early Prolific [e]							
	rough	7.01	6.28	2.14	4.27	0.76	46.70	35.00
	brown	5.92	1.47	2.70	4.55	0.72	43.50	22.50
	first break	5.56	0.94	0.98	1.82	0.57	29.40	15.00
	second break	5.50	0.89	0.62	1.09	0.44	26.22	5.00
	head	5.39	0.72	0.50	0.91	0.40	21.08	3.60
16	Zenith [e]							
	undermilled	4.73	1.24	1.26	1.45	0.61	36.40	6.70
	undermilled	4.71	1.19	1.22	1.27	0.56	31.90	5.70
	undermilled	4.58	1.02	1.04	1.18	0.50	27.50	4.70
17	Blue Rose [c]							
	undermilled	5.77	1.11	1.26	2.09	0.66	37.00	10.00
	undermilled	5.73	1.07	1.16	1.91	0.56	34.80	6.71
	undermilled	5.63	0.94	1.02	1.82	0.51	31.70	5.35
18	Caloro [d]							
	first break	6.05	0.91	1.46	2.64	0.54	34.50	8.50
	second break	5.88	0.73	1.02	1.82	0.50	30.00	7.60
19	Early Prolific [c]							
	undermilled	5.68	1.08	1.12	2.40	0.55	32.00	9.12
	undermilled	5.56	1.91	0.84	1.50	0.45	31.70	7.00
	undermilled	5.33	0.85	0.74	1.40	0.40	28.00	6.15

[a] Obtained through courtesy of Comet Rice Mills, Beaumont, Texas.
[b] Obtained through courtesy of Beaumont Rice Mills, Inc., Beaumont, Texas.
[c] Obtained through courtesy of the Arkansas Rice Growers Coop. Association, Stuttgart, Ark.
[d] Obtained through courtesy of Rosenberg Bros. & Co., San Francisco, California.
[e] Obtained through courtesy of the Walton Rice Mill, Stuttgart, Arkansas.
[f] Obtained through courtesy of the Rickert Rice Mills, Inc., New Orleans, La.

40 times the percent weight loss. This means that the rate of decline in the content of nutrients is greatest at the stage where the rate of weight loss is least. Obviously weight loss is a very insensitive index of the degree of milling in the nutritional sense. It cannot be recommended as a means of control.

None of the other indices which we have tried seems to offer better promise. Inspection of Table 13 reveals that there is a poor correlation between ash content and the content of the nutrients; for example, thiamine. The correlation of fat content with thiamine content is better, though not very good. Moreover, since a fat analysis is slow and requires a competent analyst and precautions against fire hazard from ether, it does not appear very practicable. The time factor also applies to assays for thiamine, riboflavin, niacin, or iron as means of controlling the degree of milling. While an assay is under way scores of barrels of rice would pass through the mill and the mill adjustments would be altered by attrition and vibration. The results of the tests would then merely serve to indicate that over-milling had occurred, if such were the case, but would provide no warning in advance. Accordingly, a virtually instantaneous test is needed for proper milling control. Unless such a test is developed, the outlook for an adequate nutritional quality control of unpolished rice is not auspicious.

A consideration of the scouring process in the so-called huller reminds us that there is no feature of the process which tends to interrupt or reduce the attrition on a particular grain of rice when that grain has reached the proper stage. All the grains in the huller continue to be subjected to attrition as long as they remain in the huller. The assumption is made that all grains are in the same state of milling when they enter the machine and that there is a statistical probability that they will be equally abraded during their passage through the machine. Both of these assumptions are only approximately true. If the bran adheres more strongly to one grain than to another the chances are that the former grain will enter the huller with more bran on it and that passage through the huller will only accentuate the contrast. If milling is achieved by passage through a succession of hullers, as is usually the case, it would be of great help if a process of sorting could be applied between each stage and the next, whereby the grains could be closely reclassified according to the fraction of the bran which they still retain. No scheme for doing this practicably has been devised.

In practice the miller constantly inspects visually the rice stream flowing from each huller and adjusts it for a little looser or a little tighter milling according to some mental standard of color which he endeavors to keep in mind. Most millers express considerable confidence in their ability to match a predetermined standard of milling. While it must be conceded that by training they acquire an amazing ability to detect fine differences in degree of whiteness, analysis of the products they produce does not confirm their predictions with exactitude. One miller has suggested the use of a separate motor on each huller and an ammeter which would indicate constantly the energy consumption. This might help the constancy of milling very greatly, but it does not reach the fundamental problem of equality from grain to grain.

Standard for Unpolished Rice

At a meeting of the members of the Rice Millers' Association at New Orleans, La. (see footnote page 41), a set of eighteen unpolised rice samples of known thiamine, riboflavin, niacin, and ash content was displayed. These samples represented a wide range of undermilling, as could readily be seen from their appearance. Table 14 gives the data expressed in milligrams per pound. The samples were arranged in a sequence according to their thiamine content, ranging from 1.21 mgs. for sample 11 to .44 mgs. for sample 9. A choice was made of a sample representing the best compromise between marketability as judged by appearance on the one hand and nutritional quality as shown by thiamine content on the other hand.

TABLE 14

NUTRIENTS IN UNPOLISHED RICE

Sample number	Variety	Ash percent	Thiamine mg. per lb.	Riboflavin mg. per lb.	Niacin mg. per lb.
11	Zenith[a]	0.90	1.21	.19	11.97
3	Early Prolific[b]	0.90	.96	.23	14.90
1	Early Prolific[b]	0.76	.96	.22	8.55
16	Rexoro[c]	1.00	.86	.26	14.54
6	Fortuna[b]	0.84	.86	.23	14.40
10	Zenith[a]	0.80	.78	.16	11.03
18	Nira[d]	0.80	.74	.25	11.03
15	Blue Rose[c]	0.80	.72	.25	11.79
4	Early Prolific[b]	0.86	.71	.17	12.15
13	Zenith[b]	0.80	.70	.18	11.07
17	Rexoro[d]	0.70	.68	.23	11.97
2	Early Prolific[b]	0.70	.68	.20	8.10
14	Zenith[c]	0.60	.63	.23	13.61
12	Early Prolific[b]	0.90	.63	.18	11.48
5	Lady Wright[b]	0.74	.50	.18	10.08
8	Lady Wright[b]	0.70	.48	.17	13.50
7	Fortuna[b]	0.68	.45	.17	13.86
9	Fortuna[b]	0.80	.44	.17	10.13

[a] Obtained through courtesy of the Producers Rice Mill, Stuttgart, Arkansas.
[b] Obtained through courtesy of the Arkansas Rice Growers Coop. Association, Stuttgart, Arkansas.
[c] Obtained through courtesy of the Comet Rice Mills, Beaumont, Texas.
[d] Obtained through courtesy of the Beaumont Rice Mills, Beaumont, Texas.

Sample No. 10 * was selected as the least-milled rice acceptable to the trade and an agreement was reached that a minimum thiamine level of 0.8 milligrams per pound be proposed as a standard for unpolished rice. The Food and Nutrition Board later inspected the same samples and data and agreed to this proposed standard as describing what is immediately attainable in an unpolished rice. The gain in nutritional quality by undermilling was disappointing to the Board, especially in view of the prospect of thiamine losses during storage (see page 53). It was further evident that the standard can be used under present conditions only for visual comparison purposes. Rice samples

* Credit is due Mr. W. D. Smith, Supervisor, Food Distribution Administration, U. S. Dept. of Agriculture, for aid in selecting this sample.

of similar appearance may vary considerably in thiamine content as well as in the content of other nutrients. In the final action of the Board, the greater yield of unpolished rice as compared with fully milled rice was emphasized in the following recommendation to the War Food Administration:

> "*RESOLUTION* January 29, 1944.
>
> Resolved that the Food and Nutrition Board of the National Research Council regards the promulgation of a standard for unpolished rice as a useful measure for the conservation of food supply during the war emergency because avoidance of polishing increases the yield of rice and improves the nutritional value of the product."

After the receipt of a copy of this resolution, the War Food Administration issued, effective April 1, 1944, its standard stated in the following terms:

> "Milled rice shall be whole or broken kernels of rice of the classes specified in these standards, from which, (a) in the case of milled rice other than milled rice of the special grade unpolished milled rice, the hulls and practically all of the germs and bran layers have been removed, or (b) in the case of milled rice of the special grade unpolished milled rice, the hulls and the outer bran layers, but not the inner bran layers, and a part of the germs, have been removed."

Clearly such a standard is not susceptible of rigorous enforcement and it must be anticipated that unpolished rice produced under it will of necessity be variable in nutritional quality. The emphasis of the Food and Nutrition Board on undermilling as a war emergency measure appears well justified by the facts. It is increasingly doubtful that undermilling can be relied on as a long-term, peacetime improvement in rice quality.

Earle Process of Undermilling

The Earle process (U. S. Patent 2,232,696, Feb. 25, 1941, to Theodore Earle) which is described as a peeling method, is not in commercial use. The rice is fed continuously into a tubular mill. The lining of this mill is rubber, about ¼ inch thick. Inside the mill several loose rubber-covered steel rods

TABLE 15

THIAMINE, RIBOFLAVIN, AND NIACIN IN "PEELED" RICE

	Thiamine µg/g	Riboflavin µg/g	Niacin µg/g
Brown rice	3.80	.47	53.0
Peeled rice (.27% bran removed)	3.00	.31	47.0
Brown rice	4.26	.52	49.0
Peeled rice (.47% bran removed)	2.73	.31	36.0
Brown rice	3.20	.53	47.2
Peeled rice (.57% bran removed)	2.55	.33	30.0

of 2 inches diameter are placed. These rods extend the full length of the mill shell and roll within it. The rods do not cascade, so the action is entirely one of rubbing rather than impact. As the peeled rice comes from the mill, it is passed in front of a blower and the bran and trash blown out. The peeling of rice is essentially a special form of undermilling which aims to limit breakage to a minimum and to retain valuable nutrients. More or less bran can be removed depending on the peeling time. Table 15 gives results obtained with this method.

No special heat treatment of the rice takes place, and it may be expected that this rice will be susceptible to attack by weevils and to rancidification due to presence of fat in the remaining bran layers and embryos.

DETERIORATION OF RICE IN STORAGE

Deterioration of rice in storage is a subject of very great importance. A reading of the literature gives one a strong impression that rice is more subject to deterioration than wheat. To what extent this is true, to what extent it reflects intrinsic properties of the two grains, and to what extent differences in the usual conditions of storage and use of the two grains are responsible, are questions to which no definitive answer can be supplied at present. One should remember that rice is adapted to cultivation only in areas of abundant water and, since any staple food tends to be eaten most in the areas where it is produced, the regions in which rice is stored tend to be much warmer and more moist than those where wheat is prevailingly stored. It is quite possible that this fact alone accounts for the apparently greater perishability of rice.

Grain spoilage must be considered from three standpoints: (a) attack by insects, especially weevils, (b) rancidification, and (c) loss of specific nutrients, notably thiamine. The first two of these deteriorative factors apply particularly to brown or undermilled rice. All of them apply to rough rice to a lesser extent, since the presence of the hulls affords a considerable measure of protection. They apply least to highly milled rice because its nutritional inadequacy in certain respects makes it unattractive for insects and its low fat content reduces tendency to rancidity.

The literature on the effects of storage of grains is largely lacking in material of quantitative character. The most elaborate studies of the storage of rice are those of Kondo and Okamura.[30] They examined rice that had been stored under various conditions for periods as long as 30 years, testing for physical characters of the starch, germinating power, enzyme content, flavor of the cooked product, and vitamin B content. The last estimation involved feeding experiments with fowls. Principal conclusions were that, with a moisture content below 12 percent, rice may be stored in hermetically sealed containers for many years with little deterioration. In straw bags deterioration is serious after two years storage. The authors advocate storage in the hulled condition (to reduce volume) in dry sealed concrete silos. Under these

[30] Kondo, M., and Okamura, T. Storage of rice. Ber. Ohara Institus landwirt. Forschungen 5: 395, 407, 413 (1932); 7: 471, 483 (1937).

conditions, storage up to 5 years resulted in little deterioration. These papers do not treat of insect attack in detail.

Insect Attack

The total damage by insects to stored grain in the United States has been estimated at $300,000,000 annually. This is due principally to weevils and beetles which deposit their eggs in the outer bran layers of the grain, whence they develop. Vast amounts of wheat are damaged by this means and control of weevils in flour mills and warehouses is a problem of great importance. White flour is very little subject to attack, but flours which retain more or less of the bran coats and germs rapidly become infested, especially in warm weather. The weevils and their eggs may be removed from fine ground flour by resifting it.

A similar though somewhat less serious problem exists in rice mills in this country. Rice is usually stored for long periods only as rough rice or as fully milled rice. The former is much, though not completely, protected by the hulls, the latter by absence of the full complement of nutritional factors required for growth of the insect. Many modern rice mills practice some system of fumigation against insects; this, however, is applied principally to finished goods in carton package form. It is especially necessary in preparing brown rice for the retail market. Methyl bromide, hydrocyanic acid, and carbon disulfide are chiefly used. Rice bran and polish attract weevils quickly, but these products are rarely stored in rice mills for long.

Reference is encountered in the European literature to the use of non-silicious, non-toxic mineral dusts, for example, rock phosphate, for preventing infestation. The dusts are mixed with grain during storage and are said to destroy insects already present as well as to prevent further infestation by causing a film of the dust to coat the insects' body surfaces. The dusts are removed mechanically before converting the grain to finished form for human use. New and more effective dusts for this purpose have recently been mentioned.[31] We have not, however, encountered this practice in the rice mills of the United States.

Rancidity

Rice deteriorates in odor and flavor with long storage, largely because of development of rancidity in the contained fats. Rancid odors which may become very foul are most prominent in rice bran and polish if these are kept for a long time and provided weevils do not first consume them. Unhulled rice is greatly, though not completely, protected by the enclosing hulls. White rice, being very low in fat, develops noticeable rancidity only after very long storage under unfavorable conditions. The rancidity problem is therefore largely associated with brown rice, undermilled rice, and the various types of parboiled rices. In all these instances it is a problem of first im-

[31] Kitchener, J. A., Alexander, P., and Briscoe, H. V. A. Method of protecting cereals and other stored foodstuffs against insect pests. Chemistry and Industry 62: 32 (1943); Wigglesworth, V. B. Action of inert dusts on insects. Nature 153: 493 (1944).

portance, since the grain may be rendered quite inedible, or at least unsaleable, after long storage.

Rancidity [32] in grain is regarded as due primarily to changes by atmospheric oxidation of the fat present. These changes affect predominantly the unsaturated fatty acids by attack at the double bonds with intermediate formation of oxides or peroxides, which then split to form aldehydes and fatty acids of shorter chain length. A considerable number of modifications of the fundamental theory of rancidification have been proposed and it is probable that a number of reactions occur simultaneously in the deterioration of fatty foods. These questions remain controversial even in the case of isolated fats and oils and are even more uncertain in the case of grain. There is reason to think that rancidification is autocatalytic, rising slowly at first and then much more rapidly. Enzymic liberation of free fatty acids may play a role in the rancidification of rice, but it is not the dominant one, since rice that has been steamed is still quite capable of becoming rancid. Another possible, though less probable, factor is the action of microorganisms. Rancidification is hastened by exposure to light. It is slowed by storage at low temperature, is little affected or is even favorably affected by humidity, but can be greatly retarded by limiting the supply of oxygen through hermetic sealing or storage in inert gases.

Practical preventive measures against rancidity are not numerous. Shipment and storage of rice in unhulled form is recommended by many authorities and is practiced generally by the trade both in the United States and in the Orient. Another effective expedient is prompt milling to a white rice stage, but this involves familiar serious losses of nutrient values. It is difficult to judge from the literature the seriousness of rancidity in the case of parboiled rice used so extensively in India. There is reason to suspect that the users of parboiled rice are less sensitive to rancid odors than users of raw rice. The proposals of Kondo and Okamura [30] regarding storage of rice in dry sealed silos may have value for bulk storage, but such storage would be unsuitable for the purpose of constant daily withdrawals for sale or use. Packing in small retail air-tight containers, especially in inert gases, would be effective, but these methods like those of cold storage are far too expensive to be applied to staple supplies of rice for great masses of populations.

Losses of Nutrients in Storage of Rice

Several investigators have reported on the effect of storage on the nutritive qualities of grain products other than rice. The effect of storage on protein in corn has been reported [33] and it was found that ground corn and whole shelled corn in a storage period of 2 years showed a decrease in the solubility of proteins, a partial breakdown of the proteins, indicated by a decrease in true protein content, and a decrease in digestibility. The extent of the

[32] Lea, C. H. Rancidity in edible fats. Great Britain Dept. of Scientific and Industrial Research, Special Report No. 46 (1938).

[33] Jones, D. Breese, Divine, J. P., and Gersdorff, Chas. E. F. The effect of storage of corn on the chemical properties of its proteins and on its growth-promoting value. Cereal Chemistry 19: 819 (1942).

changes was influenced by temperature, type of container, duration of storage, and the nature of the material stored. Samples stored at 76° F. were affected more than those stored at 30° F., and those in bags more than those in sealed glass jars. Changes in the ground corn were greater than those in the whole shelled corn. Significant decreases in feeding values were also found.

The effect of storage on thiamine content and on development of rancidity in wheat germ has been reported.[34] Wheat germ samples with moisture content varying between 8.0 and 26.5 percent were stored in air in sealed tins. The storage temperatures used were −40°, −15°, 0°, 15°, 30°, 60°, and 75° F., and the storage time was six months. Proteins were believed to be the chief factor involved in wheat germ spoilage. Very little loss in thiamine occurred even when the wheat germ had become inedible because of rancidity and protein spoilage.

In research on storage of rice, it was found that the starches are affected. These studies were concerned with cooking qualities and digestibility of stored as compared with unstored rice. The results showed that the cooking quality was improved in samples stored in air-tight containers or under anaerobic conditions. Well-stored rice grains swell on cooking to about 4 times the original volume, while the unstored grains swell to scarcely twice the original volume. Well-stored rice seems also to be more digestible. The results are partly explained on the basis of changes undergone by the starch during storage.[35] The studies of Kondo and Okamura [30] previously mentioned are also pertinent in this connection.

The effect of storage on thiamine in rice has been studied by Cailleau and coworkers.[36] The samples were stored at approximately 68° F. in a dark cupboard in a ground floor laboratory, where the temperature varied but little. The rice samples were kept in muslin or very heavy paper sacks. The bran samples were kept in screw-top glass jars. It was found that, after six months storage at 68° F. under good conditions, brown rice lost from 0 to 30 percent of thiamine. Rice bran and rice polish lost 16 to 28 percent of thiamine during 6 months storage, and 50 to 67 percent after 24 months of storage. Parboiled brown and parboiled undermilled rice did not appear to lose thiamine during storage of 6 months and 3 months respectively.

A recent publication by Anheuser Busch, Inc., under date of January 22, 1945, shows surprisingly high losses of thiamine during six months storage of beans, peas, and unhulled rice, compared with wheat in whole grain form, in spite of low moisture content. On the other hand, we have data from Hoffmann-La Roche [37] showing negligible losses of thiamine in brown and converted rices during storage for 19 months at room temperature or for 500 hours at 45° C. The conflicting evidence in the literature may well be due in part to the difficulties of complete extraction for assay purposes.

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[34] Pearce, J. A. Effect of storage on the thiamine content and on development of rancidity in wheat germ. Canadian Jour. of Research C, 21: 57 (1943).

[35] Screenivasan, A. Investigation on rice. Current Science 6: 615 (1938).

[36] Cailleau, R., Kidder, L. E., and Morgan, A. F. The thiamine content of raw and parboiled-rices. Cereal Chemistry 22: 50 (1945).

[37] Private Communication. Siemers, G. F. Feb. 20, 1945.

TABLE 16

STABILITY OF THIAMINE IN RICE IN STORAGE

Products	Supreme Blue Rose 551[a]					Supreme Blue Rose 606[a]				
	Before	After		Loss		Before	After		Loss	
		Ground kernels	Whole kernels	Ground kernels	Whole kernels		Ground kernels	Whole kernels	Ground kernels	Whole kernels
	μg/g	μg/g	μg/g	percent	percent	μg/g	μg/g	μg/g	percent	percent
rough	3.60	2.82	2.86	21.70	20.55	3.00	2.36	2.42	21.13	18.13
brown	4.00	3.06	3.20	23.50	20.00	3.88	2.45	2.82	36.60	27.32
white	0.74	0.44	0.48	40.54	35.13	0.55	0.35	0.37	36.36	32.72
bran	33.00	20.82		36.91		33.60	11.15		65.77	
polish (brush)	27.90	15.23		48.72		26.70	13.41		50.00	
	Early Prolific 569[a]					Early Prolific 663[a]				
rough	3.43	2.75	2.86	19.82	16.32	3.00	2.33	2.41	22.33	19.66
brown	4.18	2.98	3.04	28.71	27.94	3.30	2.37	2.45	28.20	25.76
white	0.65	0.40	0.45	38.46	30.77	0.58	0.40	0.43	31.03	26.00
bran	32.20	18.82		41.55		23.90	12.25		48.74	
polish (brush)	21.30	14.55		31.70		20.00	7.55		61.22	
	Fortuna[a]					Lady Wright[b]				
rough	3.20	2.38	2.41	25.62	24.70	3.00		2.94		2.00
brown	3.24	2.33	2.40	28.21	26.00	3.50		3.45		1.42
white	0.84	0.62	0.65	26.20	22.62	0.65		0.64		1.53
bran	21.50	8.90		58.61		26.60	26.50		0.38	
polish (brush)	15.00	9.77		34.87		19.40	19.37		0.15	
	Improved Blue Rose[b]									
rough	3.07		3.02		1.62					
brown	3.00		2.97		1.00					
white	0.85		0.82		0.35					
bran	20.80	20.71		0.43						
polish (brush)	16.40	16.37		0.18						

[a] Samples (ground and whole kernels) were stored in the dark for 2½ years in dark brown bottles in the attic of the building.
[b] Samples were placed in cold storage (—10° C) for 2½ years.

The effect of storage on thiamine, riboflavin, and niacin in rice has been studied in the laboratory of the Arkansas Agricultural Experiment Station. In 1941, samples of rice and its by-products of three varieties, Supreme Blue Rose lot 551 and lot 606, Early Prolific lot 559 and lot 663, and Fortuna, were stored at room temperature in dark brown bottles in boxes in the attic of the building. Similar samples of two varieties, Lady Wright and Improved Blue Rose, were simultaneously placed in a freezer-storage locker (temperature —10° C.). All these samples were obtained from one mill. Details of the effect of storage on thiamine in these rice samples after 2½ years are given in Table 16, and the average thiamine, riboflavin, and niacin losses in the samples (whole and ground kernels) of three varieties stored in the attic are given in Table 17. The samples of bran and polish molded considerably, which may account for the high losses.

TABLE 17

AVERAGE LOSSES OF NUTRIENTS IN RICE DURING ATTIC STORAGE

	Whole kernels Loss (percent)			Ground kernels Loss (percent)		
	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin
Rough	19.87	6.34	4.12	22.10	8.75	5.76
Brown	25.40	4.20	3.87	29.00	7.57	6.80
White	29.40	5.44	3.77	34.50	6.40	5.71
Bran	50.37	16.35	15.20			
Polish	45.30	18.00	14.60			

No significant losses of thiamine or niacin and only slight losses of riboflavin occurred during cold storage. The average percentage losses for thiamine, riboflavin, and niacin in the samples (whole kernels) kept at —10° C. are given in Table 18.

TABLE 18

AVERAGE LOSSES OF NUTRIENTS IN RICE IN COLD STORAGE

	Loss (percent)		
	Thiamine	Riboflavin	Niacin
Rough	1.81	1.98	1.10
Brown	1.21	3.84	1.95
White	0.94	1.61	1.20
Bran	0.40	1.73	1.25
Polish	0.16	1.75	1.61

Rice samples in various stages of milling were also obtained from different mills and stored in bottles during the summer of 1944 at room temperature (average 84° F.). They were samples of whole kernels of the varieties Lady Wright, Caloro, Rexoro, Blue Rose, and Zenith, and stored in glass containers in the light in the laboratory. Ground kernels, samples of the same varieties, were stored in paper bags in the dark in a closed metal container. All these samples were tested after three and after nine months for thiamine, riboflavin, and niacin. Data on stability of thiamine in samples (whole kernels and ground) of 5 varieties stored at room temperature, (range 68° F.-100° F. average 84° F.), are given in detail in Table 19. The average percentage losses are given in Table 20. Losses up to 7 percent were found after 3 months storage, and up to 15 percent in ground kernels and 13 percent in whole kernels after 9 months storage. The losses were slightly lower for whole kernels than for ground kernels.

TABLE 19

STABILITY OF THIAMINE IN RICE IN STORAGE[a]

Type and variety	Before Storage	After Three Months Ground µg/g	After Three Months Ground Loss, %	After Nine Months Ground µg/g	After Nine Months Ground Loss, %	After Nine Months Whole Kernels µg/g	After Nine Months Whole Kernels Loss, %
Lady Wright							
rough	3.64	3.45	5.22	3.31	9.06	3.60	1.10
brown	3.55	3.40	4.22	3.21	9.60	3.38	5.00
unpolished	2.18	1.92	8.80	1.81	17.00	1.94	11.00
milled	1.27	1.17	8.00	1.03	18.80	1.09	14.17
Caloro							
rough	3.27	3.10	5.20	2.85	12.84	3.21	1.22
brown	3.36	3.10	8.00	3.09	8.04	2.91	13.40
unpolished	2.27	2.19	3.50	2.00	11.90	2.12	7.00
milled	1.55	1.45	6.45	1.35	12.90	1.39	10.32
Rexoro							
rough	3.25	3.00	7.70	3.00	7.70	2.96	9.00
brown	3.26	3.12	4.30	2.91	10.73	2.71	17.00
unpolished	1.30	1.27	2.30	1.09	16.15	1.11	14.60
milled	.93	.85	8.60	.80	14.00	.80	14.00
Blue Rose							
rough	3.09	2.95	4.53	2.54	17.80	2.70	12.62
brown	3.79	3.63	4.22	3.16	17.00	3.26	14.00
unpolished	1.36	1.30	4.41	1.20	11.80	1.27	6.62
milled	.82	.78	4.88	.71	13.41	.73	10.97
Zenith							
rough	3.82	3.69	3.40	3.20	16.23	3.16	17.28
brown	3.09	3.00	3.00	2.60	15.85	2.85	7.76
unpolished	1.09	1.00	8.20	.91	16.51	1.05	3.67
milled	.73	.65	9.00	.60	17.67	.61	16.52

[a] Samples of whole kernels were stored in the light at room temperature in glass containers in the laboratory. Samples of ground rice were stored in the dark in paper bags in a container in the laboratory.

TABLE 20

AVERAGE LOSSES OF THIAMINE IN RICE IN STORAGE

	After 3 months Loss (percent)	After 9 months Loss (percent) Ground kernels	After 9 months Loss (percent) Whole kernels
Rough	5.01	12.73	8.24
Brown	4.75	11.28	11.43
Undermilled	5.40	14.67	7.18
Milled	7.38	15.35	13.19

In the foregoing experiments, the conditions of storage were at least as favorable as would be encountered in commercial practice, and in general they were more favorable. Further experiments are in progress under conditions more closely approximating commercial storage and these will be reported in a later publication. (See Appendix page 76). However, it is to be anticipated that they will reveal losses somewhat larger rather than smaller than those reported above.

The average period of commercial storage of rice in the United States may be taken as about 5 months, although obviously the storage period will vary extremely, depending on the distance the rice has to be shipped, the demand for rice at the time of milling, and many other similar factors. However, it becomes evident from the foregoing study that from a nutritional standpoint stability in storage presents a major problem in the rice industry. All evidence tends to indicate that wheat, whether in whole grain, whole wheat flour, or refined flour form, is considerably more stable than rice. In the Oriental tropics the problem of deterioration of rice by all these causes is doubly important because of climatic conditions and the difficulties of technical control. The aversion of Oriental rice millers to undermilled rice because of storage difficulties cannot be dismissed as mere prejudice.

PARBOILING OF RICE

Reference has already been made (page 30) to the use of parboiled rice by the larger part of the rice-eating population of India. Only in the Northern Circars along the coast from above Madras to the boundary of Orissa is rice used in the raw state and it is this area that produces nearly all the forthright beriberi of India, according to Aykroyd and his collaborators.[12] Parboiled rice is also used exclusively in Ceylon and British Guiana and locally in many places where immigrant Indian coolie labor has demanded or preferred it. This is especially true in British Malaya, where in certain provinces the larger part of the output of mills is parboiled. The Indian demand is also responsible for the parboiling of 12 to 15 percent of the rice annually exported from Burma. Parboiled rice is therefore a commercial product of major importance. No specific figures appear to be available, but it seems quite possible that parboiling is applied to a fifth or even more of the world's annual rice crop. Parboiled paddy is offered for sale in large volume in the markets of many cities of eastern India, where it is purchased for home milling.

The parboiling process is an ancient tradition. Presumably its original purpose was to facilitate the removal of the hulls. The grains are swollen by soaking in water and subsequently dried, usually in the sun. Often steaming follows the soaking. The hulls are loosened in either case so that they are removed more readily by pounding. It was only subsequently discovered by observations on the incidence of beriberi, which have been reviewed by Vedder,[19] that there is a nutritional advantage in the parboiling of rice. This advantage was ascribed by Vedder and others before him to greater retention of the bran after parboiling, since the bran is toughened thereby and is less readily removed. The nutritional merit of parboiling was later more fully explained by Aykroyd and others as described below.

The parboiling process is by no means highly standardized.[38] It may consist of merely soaking in cold water for several days in a concrete tank and subsequently spreading out on packed earth or a concrete floor and drying in the sun. In more systematic commercial operations, steam is blown through the paddy after steeping until the husk slightly dehisces. In this operation the surface starch is partly gelatinized. Often the steeping is carried out in hot water for 24 hours or less. Charlton recommends that water at 180° F. flow onto and through the paddy till a temperature of at least 140° F. is attained at the coolest point in the tank. Two steel boiling tanks and a battery of six concrete steeping tanks, all tanks having a capacity of 1000 gallons each, are indicated as appropriate. By this means, the steeping process is shortened to not over 36 hours and, even more important, the generation of foul odors due to bacterial action is avoided. It would appear that hot steeping might greatly improve or at least modify the flavor of the finished grain.

Another version of the parboiling process is used in Malaya, principally for consumption by Indian immigrant laborers. No steeping is involved. The paddy is merely heated in steel cylinders by steam under pressure of 20 pounds per square inch for 10 minutes and then quickly dried and milled as usual. This method is practiced particularly in government mills.[39] Few data are available on the nutritive merit of rice so steamed. "Steaming" of rice is understood to be under commercial-scale trial in Chungking under government encouragement, but no particulars of the process are presently available. In our limited experience, steaming of rice appears almost as effective as steeping and steaming for conserving the nutrients.

The flavor and other characteristics of parboiled rice are unquestionably strongly preferred by the Indians who are accustomed to it, as evidenced by the demand for it by expatriates in Malaya and the islands of the Pacific. It seems equally certain that it is heartily disliked by people who have long used raw milled rice. To the untutored Westerner, the flavors of the cooked products do not appear to differ conspicuously. The odor of the parboiled product, however, is noticeable in the raw state, especially if the rice has been kept in a closed container for some months. It appears as a rancidity to which raw milled rice of an equal apparent degree of decortication is less subject. Attempts to introduce parboiled rice in China have met with disfavor. It is, however, quite possible that proper choice of methods and the exercise of suitable controls in parboiling and subsequent storage may mitigate the distaste for it and make it commercially acceptable. This can only be determined by persistent long-term commercial market trials.

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[38] Charlton, J. Prevention of nuisances caused by the parboiling of paddy. Bulletin 46, Agricultural Research Institute, Pusa, Calcutta, 1923.

[39] Jack, H. W. Rice in Malaya. Bulletin 35, Dept. of Agric. Federated Malay States, 1923. Page 31.

Nutrients in Parboiled Rice

Aykroyd[40] showed that parboiled rice retains a considerable proportion of its thiamine and phosphorus content even when highly milled, and suggested that some of the vitamins contained in the germ and pericarp diffuse into the grain during the process of soaking and steaming. Subrahmanyan and co-workers (1938)[41] made a study of the effect of milling on the chemical composition and commercial qualities of raw and parboiled rices. They concluded that, with the same degree of milling, parboiled rice is usually richer in nitrogen and phosphorus than raw rice, and part of the nitrogen and of the phosphorus originally present in the germ is transferred to the endosperm. Parboiled rice has a higher ash content than raw rice milled to the same extent, while smaller losses of nitrogen or of phosphorus occur in parboiled rice than in raw rice on repeated washing in connection with cooking.

TABLE 21

THIAMINE, RIBOFLAVIN, AND NIACIN IN MILLED PARBOILED AND MILLED RAW RICE

Variety	Thiamine milled parboiled µg/g	Thiamine milled raw µg/g	Riboflavin milled parboiled µg/g	Riboflavin milled raw µg/g	Niacin milled parboiled µg/g	Niacin milled raw µg/g
Nira	1.35	....	0.47	....	49.00	....
Nira	....	0.59	....	0.30	....	20.6
Caloro	1.61	....	0.33	....	45.20	....
Caloro	....	0.65	....	0.28	....	18.5
Indian	1.74	....	0.30	....	45.00	....

Parboiling also improves the milling quality of rice varieties. Aykroyd and co-workers (1940)[12] found that parboiled rice, even when highly milled, retains most of the thiamine and nicotinic acid originally present in the unmilled grain and only about 50 percent of the vitamins are lost during washing and cooking. They highly recommend the use of parboiled rice.

Screenivasan[42] offers the following explanation of the fact that parboiled rice is more nutritious than raw rice: During the process of parboiling, the endosperm of the grain swells and imbeds some of the bran constituents so that they are generally preserved in the kernel even after milling. Further, commercial parboiled rice in India is prepared only from coarse rice varieties that have thicker bran layers than ordinary fine varieties, and they do not mill so well. Finally, commercial parboiled rice is usually undermilled; the parboiling makes the outside of the grain tough and therefore it is less easy to polish parboiled rice.

[40] Aykroyd, W. R. The effect of parboiling and milling on the anti-neuritic vitamin (B_1) and phosphate content of rice . J. of Hygiene 32: 184 (1932).

[41] Subrahmanyan, V.; Screenivasan, A.; and Das Gupta, P. Studies on Quality in Rice. I. Effect of milling on the chemical composition and commercial qualities of raw and parboiled rices. Indian Jour. of Agricultural Sciences 8:459 (1938).

[42] Screenivasan, A. Food value of rice. Indian Medical Journal. Vol. 32, No. 12, 1938.

Most of the foregoing studies were performed without the benefit of the more modern analytical methods now available and were concerned primarily with the conservation of thiamine. The matter has been re-examined experimentally by one of the present authors (M. C. Kik) with results of a confirmatory character.

In Table 21 data are presented on thiamine, riboflavin, and niacin content in samples of rice parboiled in the laboratory and milled * in a miniature McGill mill, compared with samples of the same rice similarly milled without parboiling. This table shows that the milled parboiled rice has retained more of three important vitamins than the milled raw rice.

This confirms the observation of previous investigators that milled parboiled rice has higher nutritive value, not only with respect to thiamine but also as regards niacin. The advantage with regard to riboflavin is slight.

RICE CONVERSION †

There have been several attempts to modernize and improve the traditional rice parboiling process. Much the most extensive experience has been acquired by those who are identified with the so-called rice conversion process. This process originated in England and was considerably developed there by its senior inventor, Mr. Erich G. Huzenlaub. An organization called Rice Conversion Ltd. was formed to exploit the process through affiliations with firms having extensive interests and contacts in the Oriental rice trade. Negotiations were undertaken to introduce the process extensively in the Orient, but these were interrupted and postponed by the onset of World War II. The United States rights, however, were conveyed to a firm organized in Houston, Texas, of which Mr. Gordon L. Harwell is the primary technical director. This firm, originally James and Harwell, now Mars and Harwell, set up a plant in Houston about 1941 for the development and exploitation of the process. Operations at first were on a laboratory scale, but presently expanded into commercial scale operations in a plant which was gradually evolved for the purpose. This plant has been shipping converted rice in carload lots for two years past and has accordingly provided significant commercial experience.

Recently a larger plant has been erected at Houston with Defense Plant Corporation funds at a reputed cost of $625,000. It is expected that this plant will be in operation before summer of 1945 and will be capable of handling 1400 barrels of rice per day at the outset and twice that quantity ultimately. This plant will add substantially to the total milling capacity of Texas. The product is being taken exclusively by military authorities and is presumably being shipped, along with a large amount of raw milled rice, into Oriental areas where military operations are in progress.

A somewhat kindred process devised by M. Yonan-Malek is now receiving attention looking to a similar development in California. Very much less

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* Through courtesy of Dr. C. R. Adair, Associate Agronomist, Stuttgart, Arkansas.

† With the cooperation of Dr. C. W. Ofelt, Carnation Company, Milwaukee, Wis. Formerly technologist, Mars & Harwell Company, Manufacturers of Converted Rice, Houston, Texas.

extensive operations of this process have so far been carried out. At the outset a prime objective in its development was the production of canned cooked rice, but the process appears potentially adapted to the production of milled rice of a parboiled type.

A reading of the patents on these two processes does not readily reveal a clear distinction between them. We are unable to point out clear-cut and obvious evidence of fundamental invention over some of the traditional processes in use in the Orient, nor have these questions been adjudicated by the courts so far as the present writers are aware. Our interest in the processes is confined to the fact that their existence has led to large scale exploitation of parboiling with reasonable technological controls, especially in the case of rice conversion. The sale of such rice in the United States and in the Orient must do much to evaluate its commercial acceptability and competitive feasibility.

The rice conversion process [43] is essentially a modernized parboiling method. Rough rice or paddy is cleaned by being passed over a separator to remove fine dirt, large stones, and straw. It is then passed through another separator which removes the whole and broken hulled rice as well as any remaining fine dirt. Finally, it is subjected to aspiration to remove as much of the chaff and extremely light paddy as possible. Formerly this was followed by a further separation through flotation of the remaining light-weight rice and hulls containing only partly developed kernels. This was accomplished by introducing the rice into a trough of turbulent water, where the light-weight kernels rose to the top to be floated off while the heavier grain was removed from the bottom of the trough by an inclined screw conveyor. At present only dry mechanical processes are used for cleaning.

The cleaned paddy is introduced into a large vessel which is then evacuated (to 25″ or more) for a period of at least ten minutes. Hot water (75-85° C.) to an amount about one-third greater than the weight of paddy is then introduced under a pressure of 80 to 100 lbs./sq. inch and the rice is steeped under these conditions, with recirculation of the water, for a period ranging from 120 to 165 minutes. The times and temperatures required for steeping are said to depend upon the variety of rice being processed, moisture content, the length of time it has been in storage, and the color desired in the final product.

The steeping water is drained off and the steeped paddy is introduced into a large cylindrical, rotating, steam-heated vessel, which is then partially evacuated and the paddy heated for a short time. At this point dry direct steam is introduced and the paddy is heated in this manner for a few minutes. The steam is then blown off and a vacuum of 28″ to 29″ applied. The product

[43] Patents:

British No. 519,926, 4/10/40, to Erich Gustav Huzenlaub and John Heron Rogers.
British No. 522,353, 6/17/40, to Erich Gustav Huzenlaub and John Heron Rogers.
U.S. P.O. No. 2,239,608, 4/22/41, to Erich Gustav Huzenlaub, et al.
U.S. P.O. No. 2,268,486, 12/20/41, to E. G. Huzenlaub.
U.S. P.O. No. 2,287,737, 6/23/42, to Erich Gustav Huzenlaub and John Heron Rogers.

A descriptive pamphlet may be obtained from Rice Conversion, Ltd., 14-19 Leadenhall St., London, E. C. 3.

is dried under vacuum in the rotating steam-jacketed vessel until a moisture content of slightly less than 15 percent is attained. Final drying is done at atmospheric pressure. Recent work indicates that it is possible to dry the product throughout at atmospheric pressure without damage to its milling properties, provided the grain temperatures attained never exceed 145° C.

The hot, dry "converted" paddy is placed in bins and cooled by passing air through it and allowing it to remain in the bin for at least eight hours before milling. This "tempering" period is necessary in order that a state of moisture equilibrium throughout the berry may be attained.

The converted rice is milled in the usual way. The paddy is passed through shellers, then through Engelberg "hullers," and finally is cleaned up on a pearling cone. Suitable aspirations are performed between operations. Smaller amounts of bran and polish are obtained than from milling of unconverted rice, which suggests that converted rice is undermilled although this is not evident from its appearance.

The finished product is not coated and is of a yellowish color. Examination of the smooth, vitreous, translucent grain under a microscope, with polarized light, indicates that the starch of the outer part is gelatinized. The grain cooks to a product which appears practically as white as any cooked rice. Comparison in the cooked state with rice that has been highly milled without parboiling reveals only a barely discernible yellow cast. There is said to be a low percentage of breakage during the milling and the kernels are more resistant to insect infestation, which is favorable for long-distance transportation and for storage.[44]

Laboratory Tests of Rice Conversion

Rice conversion has so many potentialities that the process was deemed worthy of a systematic investigation. This work was begun in the laboratory in the fall of 1941 and later extended to plant operations through the courtesy of Mars and Harwell Company. In Table 22 are presented data of preliminary laboratory experiments with rough rice treated according to the principles of rice conversion. The following procedure was used: A 60-gram sample of rough rice was milled raw and analyzed for thiamine, riboflavin, and niacin. Eleven other 60-gram samples of the same batch of rice were "converted" separately with slight variations in temperature, pressure, and duration of treatment. After conversion, these samples were milled to the same degree of milling as the raw milled sample, and all were analyzed for thiamine, riboflavin, and niacin. This was repeated with another batch of rough rice of which two samples were "converted" and milled while a third was milled to the same degree without conversion. Both results indicate that the "converted" samples are much higher in thiamine, riboflavin, and niacin than are the raw samples. Treatment at 60 pounds pressure at a temperature of 70° C. for two hours gave satisfactory results.[44a]

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[44] Kik, M. C. The story of rice conversion. The Rice Journal. (March and April 1942)
[44a] Kik, M. C., and Van Landingham, F. B. The influence of processing on the thiamine, riboflavin, and niacin content of rice. Cereal Chemistry 20: 569-572.

The processing was done with the aid of an iron chamber which could be used as either a vacuum or a pressure chamber. A compressed air tank furnished up to 60 lbs. pressure, and steam was obtained from the heating plant. The vacuum chamber was connected with the pressure tank and, through another connection, with a motor vacuum pump. A distillation apparatus with receiving flask placed between the vacuum chamber and the pump collected the moisture that was drawn from the material placed inside the chamber. Through another inlet, hot water could be introduced into a small vessel containing the sample of rough rice placed within the chamber. After the processing, the rice was vacuum dried, following which it was dried overnight in the laboratory with an electric fan. The milling * was done with the aid of a McGill miller for small samples. This mill was equipped with a constant pressure device (consisting merely of a series of weights placed on the pressure cup) so as to make it possible to mill the samples in a uniform manner and to the same degree.

TABLE 22

THIAMINE, RIBOFLAVIN, AND NIACIN IN RAW AND CONVERTED MILLED RICE. (Laboratory)*

Laboratory Sample	Thiamine		Riboflavin		Niacin	
	raw µg/g	converted µg/g	raw µg/g	converted µg/g	raw µg/g	converted µg/g
0	.82		.285		24.3	
1		2.42		.380		44.0
2		2.90		.456		52.0
3		2.32		.390		48.8
4		2.14		.364		45.3
5		2.23		.356		46.9
6		1.99		....		43.1
7		2.16		....		....
8		2.90		.401		51.2
9		2.47		.401		43.5
10		1.90		.349		33.9
11		2.29		.400		48.9
18	.53	....	.317	....	15.1	....
16		2.46		.520		46.8
17		2.73		.500		39.5

* Credit is due Dr. C. R. Adair, Assoc. Agronomist, U. S. Dept. of Agriculture, Bureau of Plant Industry, Rice Branch Experiment Station, Stuttgart, Ark., for his valuable assistance in milling some of these samples.

Studies of Commercial Conversion

The foregoing laboratory studies of rice conversion were extended to plant operations by the cooperation of Mars and Harwell Company. Their plant at Houston, Texas, was visited four times during 1942-1944 and all details of the process were disclosed to us. In addition, numerous samples were sup-

* Credit is due Dr. C. R. Adair, Associate Agronomist, Stuttgart, Ark., for the milling of some of these samples.

plied us of identical batches of rice in the converted and unconverted states. The converted samples obtained during 1942 came from the pilot plant. Later, after the operation of the manufacturing plant was inaugurated in September 1942, we secured samples from that source. We are greatly indebted to the management and especially to Mr. Gordon L. Harwell, General Manager, and to the inventor of the process, Mr. Erich G. Huzenlaub, for all this assistance.

Table 23 gives the nutrient contents of the various mill products of two lots of Rexoro rice obtained from the pilot plant in 1942. Tabe 24 shows similar data on four lots of rice obtained from the manufacturing plant in 1943. These data show that the finished converted rice has much higher retention of these vitamins than unconverted rice. The content of these vitamins in bran and hulls from converted rice is lower than in those from unconverted rice. This shows that the higher retention in the endosperm is at the expense of the outer layers of the kernel.

Table 25 presents data on the thiamine, riboflavin, and niacin content in the rough and milled states of 25 samples of converted rice from the manufacturing plant. All these samples were from the same lot and variety, Rexoro, except batch numbers 543, 544, 581, and 540, which were of the Nira variety. On the average the thiamine, riboflavin, and niacin contents per unit weight of the converted rices were 92, 71, and 77 percent respectively of the corresponding contents of the rough rices. "Retention" is given on this basis in Table 25. However, the net conservation of these nutrients was less, as a result of the fact that the hulls making up 20 percent of the rough rice and the bran making up about 10 percent of the rough rice both contained appreciable amounts of these nutrients which were discarded. By the use of Table 24 one can calculate approximately the discards which must have been involved. Correcting for these we can say that about 70 percent of the thiamine, 50 percent of the riboflavin, and 60 percent of the niacin present in the rough rice is conserved in the converted rice. Compared with commercial brown rice, converted rice may be said to contain about 85 percent as much thiamine and niacin and about 70 percent as much riboflavin. This is clearly a creditable performance.

Effect of Conversion on Milling Quality

The milling quality of 13 samples, of two varieties, of which 8 were Rexoro and 5 Nira, (converted and unconverted) was determined by means of the Smith shelling device. This is officially used by the U. S. Department of Agriculture [45] in determining grades of rough rice (paddy) for the Southern Rice Industry in the United States. The method is as follows:

Accurately weighed (50 gram) samples of rough rice are given a definite number of strokes of equal force and friction with a weighted block upon a prescribed curved surface. The surfaces of these two frictional elements are covered with leather and when wear occurs they are renewed to provide a constant type of surface to avoid error in the machine's result.

[45] U. S. Department of Agriculture, Circular No. 48, October 1928.

TABLE 23

COMPARISON OF THIAMINE, RIBOFLAVIN, AND NIACIN IN MILLED RICE,* CONVERTED VERSUS RAW (1942)

Products	Variety and mill lot											
	Rexoro lot C						Rexoro lot D					
	Thiamine		Riboflavin		Niacin		Thiamine		Riboflavin		Niacin	
	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw
	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g
Rough	3.40	3.40	.55	.55	54.12	54.12	3.12	3.12	.54	.53	54.12	53.72
White milled	2.50	.50	.38	.19	32.17	16.40	2.70	.40	.33	.15	44.95	20.15
Brokens and chips	2.64	.86	.35	.15	40.70	16.07	2.60	.90	.39	.22	39.71	20.12
Bran	6.82	21.05	1.90	2.79	233.52	269.21	7.72	20.15	1.01	2.41	177.12	231.52
Hulls	1.81	2.41	.47	.62	27.92	48.52	1.18	2.42	.66	.81	28.62	39.42

* Samples obtained from pilot plant through the courtesy of the James and Harwell Company (now Mars and Harwell Company), manufacturers of Converted Rice Houston, Texas.

TABLE 24

DISTRIBUTION OF THIAMINE, RIBOFLAVIN, AND NIACIN IN PRODUCTS OF COMMERCIAL MILLING OF CONVERTED RICE* (1943)

Products	Nira 301			Rexoro 303			Rexoro 304			Rexoro 305		
	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin
	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g
Paddy or rough rice	3.82	.67	57.43	2.90	.63	52.14	2.81	.70	60.00	3.67	.57	55.8
From milling process:												
Whole brown rice	3.64	.56	57.12	3.00	.57	53.91	2.88	.57	55.21	3.58	.55	50.4
First break huller rice	3.40	.48	46.26	2.90	.44	44.91	2.66	.43	46.09	3.39	.40	43.0
Second break huller rice	3.20	.43	45.21	2.80	.42	42.82	2.53	.41	44.18	3.21	.37	41.0
Third break huller rice	3.18	.40	42.07	2.58	.41	40.13	2.50	.40	42.01	3.20	.35	40.0
Screenings	3.61	.52	46.01	2.81	.51	43.91	2.56	.47	49.21	3.41	.47	47.9
Rice by-products:												
Hulls	1.90	.64	36.51	1.92	.60	30.66	2.22	.70	36.20	2.00	.56	34.0
First break bran	4.70	1.52	203.11	6.80	2.34	154.92	7.00	1.59	176.71	7.30	2.05	197.12
Second break bran	3.86	1.40	170.05	6.33	2.09	151.71	6.09	1.52	161.43	7.00	1.52	185.72
Third break bran	3.64	1.33	163.92	5.62	1.90	140.62	5.86	1.41	152.51	6.36	1.41	180.69

Variety and mill lot: Nira 301, Rexoro 303, Rexoro 304, Rexoro 305.

* Samples obtained from manufacturing plant through the courtesy of the James and Harwell Company (now Mars and Harwell Company) manufacturers of Converted Rice, Houston, Texas.

TABLE 25

PERCENTAGE RETENTION OF THIAMINE, RIBOFLAVIN, AND NIACIN IN CONVERTED RICE[a] BEFORE AND AFTER MILLING

Batch number	Type of rice	Thiamine		Riboflavin		Niacin	
		μg/g	Retention[b] percent	μg/g	Retention[b] percent	μg/g	Retention[b] percent
714	rough	3.20		.51		53.14	
714	milled	2.86	89.69	.38	74.51	42.80	80.54
713	rough	3.20		.51		58.10	
713	milled	3.00	93.75	.46	90.19	44.30	76.24
551	rough	3.00		.73		55.40	
551	milled	2.80	93.33	.50	68.49	45.71	80.70
543	rough	3.80		.56		60.51	
543	milled	3.40	89.47	.46	82.14	44.53	73.59
566	rough	3.00		.66		60.02	
566	milled	2.86	95.33	.51	77.27	42.11	70.00
544	rough	3.70		.52		54.24	
544	milled	3.50	94.60	.38	73.08	42.57	78.48
581	rough	3.82		.56		60.03	
581	milled	3.50	91.62	.41	73.40	49.78	82.92
540	rough	3.62		.61		56.63	
540	milled	3.25	89.77	.38	63.20	41.21	72.77
556	rough	2.87		.51		59.46	
556	milled	2.75	95.82	.41	80.40	47.14	79.28
565	rough	2.89		.61		51.32	
565	milled	2.70	94.07	.38	62.30	49.51	96.47
564	rough	3.25		.53		56.56	
564	milled	3.06	94.15	.41	77.36	47.46	83.91
711	rough	3.00		.63		59.00	
711	milled	2.71	90.33	.38	60.32	42.75	72.46
704	rough	3.10		.76		60.92	
704	milled	3.00	96.77	.51	76.10	49.75	81.66
710	rough	3.40		.70		56.41	
710	milled	3.20	94.11	.53	75.71	43.29	76.74
708	rough	3.24		.78		59.24	
708	milled	3.00	92.60	.46	58.97	42.18	71.21
707	rough	3.45		.71		60.00	
707	milled	3.09	89.53	.51	71.83	48.12	80.20

TABLE 25—Continued

Batch number	Type of rice	Thiamine		Riboflavin		Niacin	
		μg/g	Retention[b] percent	μg/g	Retention[b] percent	μg/g	Retention[b] percent
709	rough..........	3.13		.66		52.50	
709	milled.........	3.00	95.84	.43	65.15	42.27	80.51
712	rough..........	3.30		.46		56.64	
712	milled.........	3.08	93.33	.28	60.87	40.41	71.34
706	rough..........	3.00		.76		60.91	
706	milled.........	2.86	95.33	.38	50.00	49.25	80.85
700	rough..........	3.25		.61		62.50	
700	milled.........	2.91	89.53	.46	75.41	46.14	73.82
699	rough..........	3.25		.61		66.32	
699	milled.........	2.97	91.38	.43	70.50	44.18	66.61
705	rough..........	3.20		.71		65.42	
705	milled.........	2.89	90.31	.48	67.60	50.70	77.50
703	rough..........	3.25		.61		65.00	
703	milled.........	3.00	92.30	.51	83.60	48.30	74.31
702	rough..........	3.37		.61		62.42	
702	milled.........	3.00	90.00	.33	54.10	44.95	72.01
701	rough..........	3.00		.51		54.32	
701	milled.........	2.80	93.33	.40	78.43	47.07	86.55
Average		{ 3.25 { 3.00	92.25[b]	{ 0.61 { 0.43	70.82[b]	{ 58.70 { 45.50	77.62[b]

[a] Obtained through the courtesy of the James and Harwell Company, (now Mars and Harwell) manufacturers of Converted Rice, Houston, Texas.
[b] The meaning of retention is explained on page 67.
All samples are Rexoro, except batch numbers 543, 544, 581, and 540, which are Nira.

The machine automatically stops at the end of the operation (after about 4 minutes); the sample is then removed, whole kernels and broken kernels are separated and counted, and the percent of brokens, whole grains, and total recovery determined.

These data are interpreted into mill results by official conversion factors. The results are given in Table 26 and it was found that the average percent of broken kernels for the 13 samples of converted rice was 3.5 percent compared to 19.5 percent for the samples of raw rice, or by varieties: Rexoro broken kernels, raw 17.4 percent, converted 3.5 percent; Nira broken kernels, raw 23 percent, converted 3.5 percent. The reduced breakage in the converted rice is most probably due to toughening of the grain by the heat treatment or steaming. Our results clearly tend to substantiate the claims of the proponents of rice conversion that the extra costs of converting the rice will be largely offset in extensive commercial practice by the greater yield of head rice in the milled state and are consistent with the findings of Jones and

TABLE 26

EFFECT OF CONVERSION ON BREAKAGE IN SHELLING

Batch number	Variety	Treatment	Whole kernels	Broken kernels	Yield head rice	Total Yield
			percent	percent	pounds	pounds
304	Rexoro..........	raw.........	61.0	13.5	82.4	108.0
304	Rexoro..........	converted....	72.5	4.0	97.8	110.0
301	Nira............	raw.........	47.0	21.5	69.5	103.0
301	Nira............	converted....	71.0	2.5	95.8	107.0
303	Rexoro..........	raw.........	60.5	15.0	81.6	108.0
303	Rexoro..........	converted....	73.0	4.5	98.5	111.0
305	Rexoro..........	raw.........	61.5	12.0	83.0	107.0
305	Rexoro..........	converted....	70.5	4.0	95.1	108.0
543	Nira............	raw.........	58.5	19.0	80.1	111.6
543	Nira............	converted....	72.0	3.5	97.2	108.7
544	Nira............	raw.........	47.5	29.5	70.3	111.6
544	Nira............	converted....	72.5	5.0	97.8	111.6
540	Nira............	raw.........	54.0	22.0	76.1	110.2
540	Nira............	converted....	73.0	3.5	98.5	110.2
581	Nira............	raw.........	54.5	22.0	76.8	110.2
581	Nira............	converted....	75.5	3.0	101.9	113.1
566	Rexoro..........	raw.........	43.0	35.0	65.3	113.1
566	Rexoro..........	converted....	74.5	3.0	100.5	111.6
699	Rexoro..........	raw.........	63.5	15.0	85.7	113.1
699	Rexoro..........	converted....	75.5	3.0	101.9	113.1
706	Rexoro..........	raw.........	67.0	13.0	90.4	116.0
706	Rexoro..........	converted....	76.0	3.5	102.6	114.5
704	Rexoro..........	raw.........	64.5	16.5	87.0	117.4
704	Rexoro..........	converted....	75.5	3.5	101.9	114.5
702	Rexoro..........	raw.........	59.0	19.0	80.2	113.1
702	Rexoro..........	converted....	77.0	3.0	103.9	116.0

Taylor regarding parboiled rice.[46] Broken grains always sell at a large discount and breakage is therefore an economic factor of first importance to the miller.

[46] Jones, J. W., and Taylor, J. W. Effect of parboiling rough rice on milling quality. U. S. Dept. of Agric. Circular 340, February 1935.

Malek Process

In this process [47] rough rice or paddy is soaked in water at a temperature of approximately 100°F. for a period of four to six hours, steamed for about 15 minutes at 15 pounds pressure, dried, and milled. The milled parboiled rice may be packed in bulk for home cooking. However, the inventor proposed to can it in vacuum sealed tins and sell it as canned Malek cooked rice. The inventor, Yonan-Malek, is a Persian American.

As the process is not in commercial operation, only two samples have been available to us. On analysis, the following values (expressed as micrograms per gram) were obtained in the milled, parboiled rice:

Thiamine	2.00 μg
Riboflavin	0.40 μg
Niacin	44.0 μg

Lower values were obtained in the canned Malek cooked rice, indicating losses due to faulty handling during cooking:

Thiamine	0.60 μg
Riboflavin	0.30 μg
Niacin	30.0 μg

Through the kindness of Major Virgil O. Wodicka and First Lieutenant Robert R. Mickus of the Quartermaster Corps Subsistence Research and Development Laboratory, Chicago, we are able to present the gist of their views with regard to converted and Malekized rice. From their standpoint, the greater tendency of these processed rices to remain as discrete grains in the cooked state is a great advantage, especially in canned combinations of meat and rice for army rations. Major Wodicka and Lt. Mickus also confirm the greater resistance of the translucent grains to attack by weevils. If the grains are in part chalky rather than translucent in appearance the chalky parts are preferentially attacked by weevils. This condition is much more prevalent in the samples of Malekized rice so far examined. More extended tests of liability to weevil attack are in progress. In agreement with our analyses, the Quartermaster's experience is that the content of water-soluble nutrients in processed rice is materially higher than in white rice but somewhat less than in brown rice.

ARTIFICIAL ENRICHMENT OF RICE

The artificial enrichment of rice has not been considered officially by the Food and Nutrition Board of the National Research Council, nor has the Federal Security Agency proposed hearings on this subject. Indeed, the total amount of experimentation on the artificial enrichment of rice so far made public is scarcely sufficient to permit such consideration. However, looking forward to the time when this topic may come up for discussion in the United States, and also in view of the great need for some systematic attack

[47] U. S. Patent 2,334,665, Nov. 16, 1943, and U. S. Patent 2,334,666, Nov. 16, 1943, to Milton Yonan-Malek.

upon the beriberi problem in the Orient, it is appropriate to consider the possibility of this form of remedy for the deficiencies of white rice.

In areas where rice is a staple food, it would appear to be consistent with the general policy of the Food and Nutrition Board, as set forth in its resolution of October 1, 1941, to consider artificial enrichment of rice if such local action should prove to be feasible. The problem of artificial enrichment of rice is, however, much more difficult than the artificial enrichment of flour, in view of the necessity of impregnating the entire grain with the nutrients to avoid their loss during rinsing preparatory to cooking. Some rice superficially fortified by a spray of vitamin solution on the surfaces of the grains has appeared on the market but cannot be considered as effectively enriched.

Two methods of internal enrichment of rice have been reported. They are based on the addition of nutrients to any desired level called for by public health consideration, e. g. that found in the natural product, brown rice. In both methods the enrichment is performed in two steps by (a) producing a fortified premix, and (b) diluting the premix with ordinary white rice in a subsequent process.

The production of the premix by the first method [48] "consists in impregnating white rice kernels with a concentrated solution of the vitamins and/or minerals selected for the enrichment, followed by coating of the fortified rice grains with film-forming edible substances. This coat protects the vitamins against deterioration and prevents substantial losses of vitamins during the customary washing prior to cooking.

"The blending of premix with white rice in the rice mills results in the final market form of enriched rice. Neither the premix nor the enriched rice differs in appearance from ordinary polished white rice if thiamine, niacin, and iron in the form of pyrophosphate are used for the fortification, whereas addition of riboflavin of course changes the color of the premix sufficiently to make it visible in the blend.

"A fortification of the premix rice with 1 mg. of thiamine and 13 mg. of niacin per gram and the use of 1 part of premix to 200 of white rice yields a final product with the vitamin content of high quality brown rice. Enriched rice prepared on this basis contains 5 mg. thiamine and 65 mg. niacin per kg. (2.27 mg. thiamine, 29.5 mg. niacin per lb.). The cost of the two vitamins, the coating ingredients, the manufacturing of the premix, and the blending for this degree of fortification is estimated not to exceed 0.25¢ per kg. or 0.114¢ per lb. enriched rice.

"It has been determined that the premix is homogeneously distributed throughout the finished enriched rice. Usual household washing of enriched rice prior to cooking will not remove more than 3 to 5 percent of the incorporated vitamins. Flavor and cooking quality are not affected by this fortification procedure."

It is claimed that storage of premix rice for one year at room temperature did not affect the potency of the thiamine and niacin incorporated. During

[48] Developed by Hoffmann-La Roche, Inc., Nutley, N. J. Credit is due Dr. M. F. Furter, Director, Pharmaceutical and Control Dept., for this personal communication. (Patent applications pending.)

Lend-Lease tests, storage for 3 weeks at 45° C., a loss of 3 percent of thiamine and no loss of niacin was found.

The second method [49] of artificial enrichment involves impregnating the white rice grains with a water solution of vitamins (thiamine, niacin, and a highly soluble salt, primary sodium phosphate). The rice is dried and coated with a thin collodion membrane. The vitamins are now protected from rinsing losses but are available to the body in the cooked product, since the film is removed by the hot water. The rice is prepared with a high vitamin concentration and then diluted with unenriched white rice 1 : 100. The rinsing losses are reduced.

The author states: "The principle of the method is the use of a vitamin solution of sufficiently high osmotic pressure to counteract the imbition pressure of the rice grain so that the solution is absorbed slowly and uniformly by the rice grain. In this way we prevent checking and cracking of the grains of rice.

"The membrane applied is of such a nature as to be a dialysing membrane so that normal washing with water will not destroy the protection, while during the cooking of the rice the swelling of the grains, due to diffusion of water through the membrane, ruptures and destroys the coating and allows the vitamins to diffuse into the water. This allows for more uniform distribution of the vitamins during the cooking operation."

Samples of rice prepared by these methods were received and tested in our laboratory. The results of these tests are given below:

TABLE 27

EFFECT OF COOKING ON THE NUTRIENT CONTENT OF ARTIFICIALLY ENRICHED RICE

Sample	Thiamine μg/g	Loss Percent	Niacin μg/g	Loss Percent	Riboflavin μg/g	Loss Percent
Hoffmann-La Roche						
before cooking	5.44		44.15		2.60	
washed three times [a]	5.01	7.90	40.13	9.10	2.51	3.45
cooked in double boiler [b]	5.27	3.12	43.35	1.81	2.53	2.68
cooked in open vessel [c]	4.66	14.33	36.25	17.90	2.31	11.15
Fieger						
before cooking	4.72		46.00			
washed three times [a]	4.08	13.50	39.50	14.1	.....	.....
cooked in double boiler [b]	4.41	6.40	44.00	4.3	.....	.....
cooked in open vessel [c]	2.40	49.10	29.30	36.30	.....	.....

[a] One cupful of rice is covered with one cupful of water, stirred, and the supernatant liquid discarded. This is repeated twice.

[b] One cupful of rice and three half cups of boiling water are placed in the top of a double boiler cooker. All the water is absorbed in the cooked rice, which is not rinsed afterwards.

[c] One cupful of rice is placed in an open vessel with 10 cupfuls of boiling water, cooked, placed in a colander and drained.

These data show that in the Fieger sample with this type of washing about 14 percent of the vitamins are lost; if the rice is cooked in a large volume of

[49] Developed by Dr. E. A. Fieger, Head, Department of Agricultural and Biochemistry, Louisiana State University, Baton Rouge, La. Credit is due Dr. Fieger for this personal communication.

water which is discarded the loss is 49 percent. Considerably smaller losses were found in the Hoffmann-La Roche sample.

However, one cannot afford to pay too high a price for the protective coating lest it exceed the cost of the vitamins which it saves. One might consider 1 milligram thiamine per day per capita a reasonable minimum provision for an Asiatic rice supply if utmost economy were necessary. This would correspond roughly to 1 milligram per pound of rice where the rice consumption is high (365 pounds per capita). At the present price in the United States, the cost of thiamine for such fortification would be less than 1.6 cents per 100 pounds of rice, or 5.84 cents per capita per annum. Of the Hoffmann-La Roche cost figure of 0.114 cent per pound above quoted, about half represents the cost of the vitamins; the remainder covers coating ingredients, premix preparation, etc. For the Orient, these accessory costs must be reduced to a minimum. In the enrichment of flour in the United States (a simpler process) accessory costs amount to 40 to 50 percent of the basic ingredient costs. It would seem that eradication of beriberi in the Orient by the use of synthetic thiamine will at best cost 10 cents per capita per annum. This, however, would be a small price to pay for the benefit to be gained.

An economic advantage of such artificial enrichment over any form of parboiling is that only 1 to 2 percent of the rice requires special processing. Where weather conditions permit prompt and satisfactory sun drying of parboiled rice, this should not be costly. However, when artificial drying must be resorted to, either constantly or intermittently with changes of weather, drying costs may equal or exceed the cost of fortifying ingredients. On the other hand, if parboiling saves a large amount of breakage and if under Oriental conditions such breakage results in serious loss of saleability, the advantages may lie with parboiling. The perils of inadequate or improper drying under tropical conditions also need careful evaluation.

RÉSUMÉ

A critical review of the possibilities for the nutritional improvement of milled white rice indicates that such improvement is important for only limited segments of population in the United States, specifically in the Carolinas, Florida, Georgia, and particularly southern Louisiana. It is also important in Puerto Rico.

In the Orient,[50] improvement of white rice is of vital importance for Japan, Southeastern China, Malaya, Siam, Burma, the Netherlands East Indies, and parts of British India. While other serious nutritional faults are prevalent in these areas, the eradication of beriberi alone would be of great value to public health and this appears possible by proper treatment of white rice without awaiting the advent of grossly higher standards of living.

The custom of cooking rice in an excess of water and discarding this water prevails with perhaps half of the population of the Orient. This practice

[50] As we go to press an article appears discussing many aspects of the subject, especially in Hawaii. Miller, C. D., Jour. Amer. Dietetic Assn. 21: 345 (1945).

has disastrous consequences nutritionally, well nigh comparable with those of the milling of rice to whiteness. No measure other than re-education in cooking methods will supply an adequate remedy for this defect. In areas where this practice is absent or of limited occurrence, it appears possible to consider practicable measures against beriberi.

The possible corrective measures include (1) undermilling of rice, (2) widened use of some form of parboiled rice, (3) artificial enrichment of white rice, and possibly (4) the incorporation of vitamins in the salt supply. Of these , the first is handicapped by the great difficulty of controlling the degree of undermilling and of preventing deterioration in storage. The second is limited principally by a popular distaste for parboiled rice, which, however, does not exist among millions of Asiatics who have long been accustomed to it. The artificial enrichment of rice would perhaps encounter the least popular opposition, since the flavor and appearance of the grain are unaltered. It would also be the most economical as only 1 to 2 percent of the rice would have to be specially processed. It will probably be necessary to produce the necessary vitamins in at least the larger Asiatic countries to avoid unpopular drains on their foreign exchange. Prevention of beriberi by addition of thiamine to salt may be feasible in countries where salt distribution is under rigorous government control. Otherwise there would be far too great an incentive for illicit traffic in unfortified salt, which would be much cheaper than the legitimate fortified article. Further work is needed to render thiamine fully stable in salt. The basic annual cost of eradicating beriberi in the Orient is not greatly in excess of 10 cents per capita.

APPENDIX

At the time of going to press, data are available for loss of thiamine in rice after three months of storage in cotton bags exposed to the air at temperature of 71°-76° F. They are as follows:

TABLE 28

EFFECT OF STORAGE ON THIAMINE IN RICE

Variety and Type of Rice	Thiamine μg/g	Thiamine After 3 Months μg/g	Loss Percent
Fortuna			
Rough	3.07	2.98	2.93
Brown	....	....	.....
First break	1.34	1.26	6.00
Second break	1.20	1.08	10.00
White	1.00	0.88	12.00
Zenith			
Rough	3.06	3.03	1.00
Brown	3.31	3.11	6.00
First break	1.34	1.14	14.80
Second break	1.25	1.08	13.60
White	0.77	0.70	9.00
Nira			
Rough	3.70	3.60	2.70
Brown	4.10	3.93	4.14
First break	2.25	2.04	9.33
Second break	1.59	1.42	10.70
White	1.00	0.92	8.00
Prelude			
Rough	3.56	3.48	2.25
Brown	3.84	3.66	4.68
First break	1.40	1.26	10.00
Second break	1.12	1.02	7.14
White	0.84	0.80	4.76

The National Research Council

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The Council was esablished at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.