NUTRITIONAL PROPERTIES OF RICE

by

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INTRODUCTION

Nutritive studies on rice are important because rice feeds more than half the world's people. Rice is the staple food in Asia and in some countries in Africa and Latin America. In Many Asian countries, the average individual gets half or more of his total caloric intake from rice (Adair, 1972).

The purpose of this report is to overview the nutritional properties of rice and current technology for improving its nutritional quality for rice-eating populations with the special reference to the Republic of Korea.

It is thought there are two centers of origin of cultivated rice. One center was in southeast Asia, that is in eastern India, Indo-China, and Southern China (Chatterjee, 1951). Another center probably was in Africa (Chatterjee, 1951;Roschevicz,1931).

Among approximately 30 species of genus Oryzae (Sampath, 1962; Sharma and Shastry, 1965), most cultivated rice varieties belong to Oryzae Sativa L. However, a small amount of O. Glaberrima Steud is grown in Africa (Adair,1972). The more than 10,000 varieties of O. Sativa (IRRI, 1964) can be grouped into three subspecies: indica, with slender, somewhat flat grains; japonica, with short roundish grains; and a small class, javanica, with broad, thick grains. The indica group is commonly grown in tropical zones, japonica in temperate zones, and javanica in tropical islands, such as in Indonesia. Within a subgroup there is a second type called glutinous or waxy rice, whose kernels are opaque and chalky and have different cooking characteristics from common rice.

Rice is generally considered to be a tropical crop. It is, however, grown from 43^{o}N latitude to 39^{o}S latitude and at elevation of 8,000 ft or more in India (Houston, and Kohler, 1970). Yields are higher in temperate areas than in the tropics. The best yields are found in the subtropical and warm temperate climates (Adair, 1972).

Of all cereals, rice alone is eaten predominantly as milled whole grain.

It is usually marketed under three grain size types : long grain, over 6 mm long; medium grain, 5 to 6 mm long; and short grain, less than 5 mm long (FAO, 1957).

Various names are given to rice in the husk, rice at different stages of milling and rice treated in various other ways before consumption. By definition (FAO, 1948):

Paddy (rough rice) is rice in the husk after threshing;

Brown rice (husked rice, hulled rice, whole rice) is rice minus its husk, with the germ, pericarp, and aleurone layers intact;

Undermilled rice (lightly milled rice, unpolished rice) is rice from which the husk, germ, pericarp, and the aleurone layers have been partially removed by power machinery;

Milled rice (white rice) is rice with its outer layers (germ, pericarp, and aleurone layer) removed by power machinery;

Polished rice is milled rice treated after milling with polishing powders;

Parboiled rice is obtained by milling paddy which has been steeped in water, steamed, and subsequently dried;

"Raw" rice is rice which is not parboiled;

Rice husks (hulls) are the outermost woody covering of the rice kernels;

Rice bran is the outer layer beneath the husk of the grain with part of the germ;

Rice polishings are inner bran layers, with part of the germ and a small percentage of the starchy endosperm.

White rice is the form consumed by most people. Increase in use of highly milled white rice resulted in the widespread incidence of beriberi in Asia. Over ninety years ago, Admiral Takaki first succeeded in eliminating beriberi from the Japanese navy by partially replacing white rice with barley and wheat. Eijkman and Grijns in Java made it clear that beriberi was a food-deficiency disease and could be prevented by eating brown or undermilled rice instead of white rice (FAO, 1954). White rice is boiled or steamed and eaten with meats, fish and vegetables or as desserts. Only a small percentage of the crop is eaten as brown rice. Over 95% of world production of rice is used for human food (Adair, 1972). The rest is used for seeds and for making wines and sugar (Houston and Kohler, 1970).

Annual per capita consumption of rice varies greatly among different populations. Table 1 sjows the values for various subregions in 1959-1961. The overall average was 72.1 kg per person in 1959-1961, and was projected as 76.3 kg per person in 1970 (USDA Economic Research Service, 1964).

Table 1 - Annual consumption of milled rice per capita in 1959-1961 by subregions, in kilograms (Houston and Kohler, 1970).

	kg		kg
U. S. A.	3.0	North Africa	10.2
Canada	2.8	West Central Africa	21.3
Mexico	6.4	East Africa	31.3
Central America & Caribbean	39.4	Southern Africa	4.5
Brazil	58.8	West Asia	15.9
River Plate	7.8	India	104.6
Other South America	23.5	Other South Asia	152.3
Northern Europe	3.0	Japan	154.3
Southern Europe	10.1	Other East Asia	168.9
Eastern Europe	4.5	Communist	112.0
Soviet Union	3.8	Oceania	3.0

COMPOSITION OF RICE AND ITS MILLING PRODUCTS

The rice grain (rough rice) consists of an edible portion (the rice caryopsis) and its covering structure (the hull or husk). The rice hull constitutes from 18 to 28% of the rough rice weight (Cagampang _et al_. 1966). Fig. 1 shows the structure of the rice grain.

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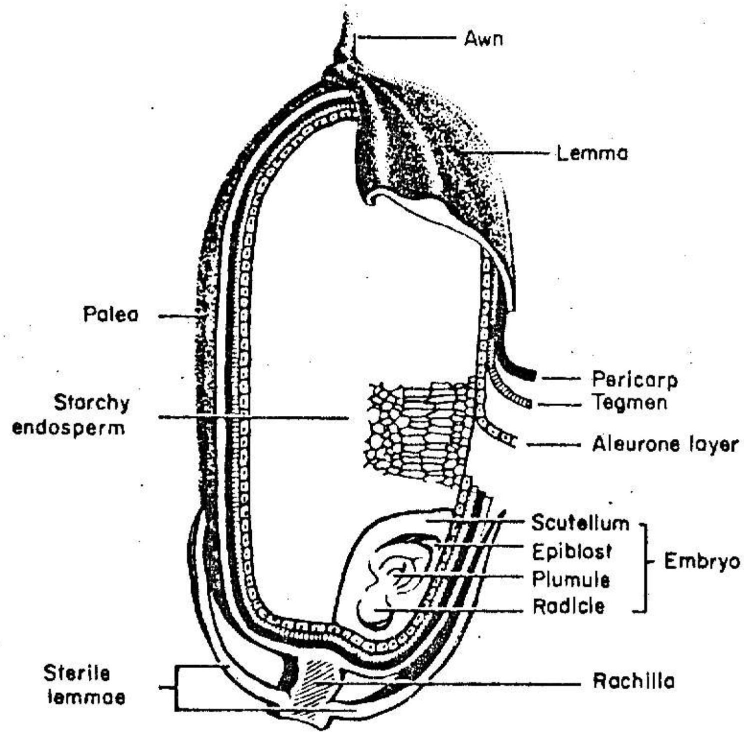

Fig. 1 Structure of the rice grain (Juliano and Aldama, 1937)

Wide variations in composition due to inherent variability of rice and degree of milling as well as differences in analytical techniques have been found. Compositional data have been compiled by Kik and Williams(1945) and McCall et al.(1951), among others. Physico-chemical data on rice have been summarized (Juliano, 1966; Houston and Kohler, 1970). Table 2 presents typical composition of rice and its milling products.

Table 2-Composition of rice and its milling products[a] (Houston and Kohler, 1970)

Description / Components	1	2	3	4	5	6	7	8
Water %	12.0	12.0	13.2	12.0	10.3	9.6	9.7	9.8
Protein %	7.5	6.7	5.6	6.7	7.4	7.5	13.3	12.1
Fat %	1.9	0.4	0.9	0.4	0.3	0.2	15.8	12.8
Ash %	1.2	0.5	0.5	0.5	0.7	0.2	10.4	7.6
Carbohydrate Total %	77.4	80.4	79.8	80.4	81.3	82.5	50.8	57.7
Fiber %	0.9	0.3	0.3	0.3	0.2	0.4	11.5	2.4
Calcium mg/100 g	32	24	36	24	60	5	76	69
Phosphorus mg/100 g	221	94	100	94	200	65	1,386	1,106
Iron mg/100 g	1.6	0.8	2.0	(2.9)	(2.9)	(2.9)	19.4	16.1
Sodium mg/100 g	9	5	10	5	9	1	tr	tr
Potassium mg/100 g	214	92	130	92	150	-	1,495	714
Thiamine mg/100 g	0.34	0.07	0.07	(0.44)	(0.44)	(0.44)	2.26	1.84
Riboflavin mg/100 g	0.05	0.03	0.04	(a)	(a)	(a)	0.25	0.18
Niacin mg/100 g	4.7	1.6	2.0	(3.5)	(3.5)	(3.5)	29.8	28.2

a Values in parentheses for iron, thiamine, and niacin are based on minimum levels of enrichment specified in standards of identity. Those required for riboflavin are presently not in effect.

b
1...Brown.
2...White, fully milled, unenriched, common.
3... " " " , waxy.
4...Enriched, all types.
5...Long-grained, parboiled.
6... " , precooked.
7...Rice bran.
8...Rice polish.

Carbohydrates

Rice carbohydrate consists of starch and small portions of hemicellulose, cellulose and free sugars. Starch is the major constituent of milled rice and makes up 90% of rice solids (Juliano, 1972). As in most starch, the major components of rice starch are amylose and amylopectin, except for waxy rice. Waxy rice has little or no amylose; the amylose content is 0.8% to 1.3% (Juliano, 1972). Generally *indica* varieties have more amylose than do *japonica* varieties.

Hemicellulose content in milled rice is less than that of bran, polish and germ. According to Leonzio (1967), pentosan amounts to 1.42% to 2.08% in brown rice, 0.61% to 1.09% in white rice, 8.59% to 10.9% in bran, and 3.15% to 6.01% in polish.

Leonzio (1967) reported the distribution of cellulose in brown rice as 62% in the bran, 4% in the germ, 7% in the polish and 27% in the white rice.

Sugars are predominantly sucrose, together with small amounts of raffinose, glucose, and fructose (Fukui and Nikuni, 1959). Brown rice contains 0.83% to 1.36% of total sugars and milled rice, 0.37% to 0.53% of total sugars (Williams and Bevenue, 1953).

Proteins

Protein is the second most abundant constituent of rice. The protein content is usually calculated by Kjeldahl nitrogen multiplied by the factor 5.95, based on the nitrogen content of the major protein (glutelin) of 16.8%.

Many references have shown that protein is concentrated in the outer layers of the milled rice kernel and decrease toward the center. The protein content is significantly influenced by cultivar and rainfall (McCall *et al.* 1953), by crop season or planting date (Cagampang *et al.* 1969) and by nitrogen fertilization (Juliano *et al.* 1964). Since no information on such factors was available for most samples analyzed, the average value for protein from numerous references will give only minimal information. Crude protein content for white rice ranges from 5.3% to 13.4% (Grist, 1959; Merrill, 1958;

Juliano et al.,1964; McCall et al.,1953) and for brown rice, from 6.7% to 13.5% (McCall et al.,1951; Juliano, 1964; Limcango-Lopez et al.,1962). True bran varies 15.2% to 19% protein and polish ranges 11.7% to 12.7% (McCall et al.,1951 and 1953).

Protein content can vary by as much as seven per cent in one variety. According to Cagampang et al. (1966),the high-protein cultivar BPI-76 ranges from 9% to 16% protein. With increase in protein content, the difference in protein content between brown rice and white rice decreases. For example, brown rice with 14% protein, on milling gives a white rice with 13.5% protein (Juliano, 1972).

Parboiled milled rice tends to have more protein content, probably because improved grain hardness through parboiling (Raghavendra et al.,1970) facilitates removal of hull and bran requiring less milling than raw rice (Juliano, 1972).

Brohult and Sandergren (1954) found the proportion of types of rice protein comprising the total mixture was different from other cereal proteins. The major protein of rice is glutelin, also called oryzenin, which is alkali soluble. Only small amounts of water soluble proteins can be found. Albumin and globulin are major fraction of the endosperm in both brown and white rice (Cagampang et al., 1966).

The amino acid compositions of brown rice and white rice are presented in Table 3 and Table 4, respectively. The great discrepancies of amino acid composition are due to differences in hydrolysis conditions used by various workers (Houston and Kohler, 1970).

Brown rice tends to have a higher lysine content and a lower glutamic acid content than milled rice. All the milling by-products, bran, germ and polish have higher levels of lysine and lower levels of glutamic acid than milled rice (Juliano, 1972).

Table 3-Amino acid composition of brown rice[a]
(g /16.8 g nitrogen) (Juliano, 1972)

Amino acid	Baldi	Chancel	Garcha & Chopra	IRRI	Vidal & Juliano
Alanine	5.3-6.5	5.5-6.1	6.0-6.2	5.5-6.5	6.2-6.5
Arginine	7.4-9.3	5.8-9.4	8.5-8.8	7.6-9.5	8.8-9.7
Aspartic acid	8.9-9.5	9.0-9.7	9.6-9.8	9.0-10.5	10.6-11.0
Cystine	1.6-2.4	1.9-2.5	1.0-1.3	1.2-2.1	0.5-1.3
Glutamic acid	16.5-19.4	17.9-19.4	21.6-23.4	16.9-19.9	22.1-22.9
Glycine	4.3-4.7	4.6-5.0	4.7-5.3	4.5-5.4	5.2-5.4
Histidine	2.0-2.5	2.5-2.6	2.2-2.7	2.2-2.9	2.7-2.9
Isoleucine	3.4-4.0	4.1-4.4	4.3-4.5	4.1-4.8	3.7-3.8
Leucine	6.5-8.5	8.0-9.0	7.7-8.9	7.9-8.9	8.5-8.8
Lysine	3.2-3.9	3.6-3.9	3.4-3.9	3.5-4.6	3.8-4.2
Methionine	1.5-2.1	1.4-1.9	1.9-2.0	1.9-2.9	1.9-2.4
Phenylalanine	5.1-5.7	5.2-5.7	5.9-6.5	5.3-6.0	5.2-5.6
Proline	4.1-4.6	4.4-4.8	4.5-4.7	4.4-5.5	4.5-4.8
Serine	4.6-5.2	4.9-5.4	5.3-6.0	4.6-5.9	5.9-6.0
Threonine	3.1-3.9	3.5-3.8	3.9-4.3	3.6-4.4	3.8-4.0
Tryptophan	n.d.	n.d.	1.5-1.8	0.9-1.6	1.1-1.6
Tyrosine	3.0-4.4	4.9-5.3	2.7-3.7	4.4-5.4	3.2-3.9
Valine	4.0-6.2	6.0-6.4	6.7-7.5	5.9-7.0	5.4-5.5
Ammonia	6.0-7.9	2.1-2.3	2.6-2.9	2.2-2.8	2.2-2.4
% N recovered	100.8[b]	93[b]	95[b]	93[c]	99.6[b]

[a] By column chromatography.

[b] Values recalculated to 100% N recovery.

[c] Values recalculated to 95% N recovery, tryptophan excluded.

Table 4 Amino acid composition of milled rice[a]

(g /16.8 g nitrogen) Juliano (1972)

Amino acid	Baldi	Bressani et al.	Chancel	Houston et al.	Tecson et al.
Alanine	5.1-6.0	5.7-6.2	5.3-6.5	5.7-6.0	5.8;6.5
Arginine	7.2-8.0	7.9-8.8	8.4-9.5	8.2-9.1	7.5;8.7
Aspartic acid	8.6-9.7	9.5-10.4	8.7-9.5	9.2-9.8	9.9;10.8
Cystine	1.9-2.4	1.4-1.8	2.2-2.5	2.6-2.8	1.5;1.6
Glutamic acid	18.3-19.8	18.3-21.1	17.8-20.6	17.9-19.3	19.7;19.8
Glycine	4.0-4.3	4.5-4.8	4.4-4.8	4.6-4.9	4.2;4.9
Histidine	1.8-2.2	2.5	2.2-2.6	2.2-2.6	2.4;2.4
Isoleucine	3.7-4.2	4.8-5.3	4.0-4.5	4.7-5.1	4.1;5.3
Leucine	7.8-8.8	7.8-9.6	8.3-9.0	8.0-8.9	8.2;8.2
Lysine	2.6-3.3	3.4-4.3	3.4-3.6	3.4-4.0	3.5;3.8
Methionine	1.9-2.2	1.8-3.5	1.2-1.7	2.7-3.3	2.6;3.4
Phenylalanine	4.8-5.6	5.6-6.3	5.2-5.7	5.3-5.7	5.4;6.0
Proline	3.9-4.7	4.7-5.0	4.3-4.7	4.4-4.9	4.6;4.9
Serine	3.6-5.0	5.7-6.9	5.0-5.4	5.1-5.7	6.0;6.1
Threonine	2.8-3.4	3.8-4.1	3.4-3.6	3.6-3.8	3.9;4.3
Tryptophan	n.d.	1.0-1.4	n.d.	n.d.	n.d.
Tyrosine	1.6-4.5	5.0-5.9	4.8-5.6	4.8-5.6	4.9;4.9
Valine	5.6-6.1	6.2-7.3	5.8-6.6	6.2-7.2	7.2;7.3
Ammonia	6.5-7.9	2.3-3.7	2.2-2.4	2.9-3.6	2.7;3.5
% N recovered	102.3[b]	100.6	94	96	101.1

[a] By column chromatography.

[b] Recalculated to 100% N recovery.

The cultivar BPI-76 has a lysine content as much as 0.5% lower than other cultivars at the same protein level (Palmiano et al.,1968), but high lysine cultivars do exist (Juliano,1972). This indicates that varietal differences exist in the levels of some amino acids.

Juliano et al.(1964) demonstrated with a series of 16 rices that crude protein content and percentage of lysine, methionine, and threonine are negatively correlated. They found positive correlations for tyrosine,arginine and leucine. Cagampang et al.(1966) confirmed these trends for lysine and tyrosine in later work.

Taira (1962) and Tecson et al.(1971) reported amino acid composition of the four main protein fractions of brown rice and white rice, respectively. Table 5 shows albumin has the highest lysine content.

Table 5 Comparison of amino acid composition of rice protein fractions (g /16.8 g N) in brown and white rice

	Albumin		Globulin		Prolamin		Glutelin	
Amino Acid	brown	white	brown	white	brown	white	brown	white
Alanine	6.7	8.7	4.9	9.1	8.0	6.6-6.9	5.6	5.0-5.7
Arginine	6.8	8.4	16.9	11.0	2.1	5.3-6.6	7.5	10.2-10.7
Aspartic acid	10.6	10.8	5.6	7.8	10.2	7.9-8.3	7.6	9.8-11.2
Cystine	1.5	2.9	3.8	0.0	0.6	trace-1.0	0.5	1.3-2.1
Glutamic acid	10.3	12.5	18.2	11.8	22.6	20.8-23.3	15.7	16.3-20.2
Glycine	6.7	6.9	6.7	5.9	4.2	2.6-3.8	2.2	4.5-5.2
Histidine	2.6	2.6	1.9	1.6	1.3	0.9-1.5	5.8	2.3-2.5
Isoleucine	6.0	4.1	2.9	3.0	6.6	4.1-6.5		4.5-4.9
Leucine	8.8	7.9	6.4	6.6	16.9	10.6-13.3	9.3	7.2-7.9
Lysine	7.5	4.9	2.8	2.5	0.4	trace-1.1	4.0	3.5-4.0
Methionine	2.6	2.5	1.9	2.3	1.3	trace-0.6	1.9	1.4-2.6
Phenylalanine	5.8	3.0	3.6	3.3	6.4	5.7-6.6	5.6	4.7-6.2
Proline	7.2	6.6	6.5	5.5	11.9	4.0-4.6	5.4	4.2
Serine	5.8	5.2	6.4	5.5	5.6	4.7-6.9	4.8	5.4-6.9
Threonine	6.1	4.6	2.6	2.9	3.1	2.2-3.1	4.1	3.7-4.0
Tryptophan	2.0	1.9	1.3	1.3	1.0	0.9	1.2	1.2
Tyrosine	4.1	3.9	2.9	5.0	4.5	7.7-9.8	3.8	5.1-5.5
Valine	7.5	8.7	5.0	6.3	7.2	5.6-7.0	6.4	6.5-6.9

brown rice data...Taira (1962), microbiological.

white rice data...Tecson et al.(1971), by column chromatography.

Also, there are relatively high concentrations of cystine in globulin, of leucine and proline in prolamin, a very low lysine content in prolamin, and a low cystine content of prolamin and glutelin.

Non-protein nitrogen amounts to about 3% of the total nitrogen of brown rice (Palmiano et al.,1968) and 2% of white rice nitrogen (Kester et al.,1963). Free amino acids accounts for 0.7% by weight of brown rice protein, 0.2% of white rice protein, 1.35% of bran-polish protein, and 4.6% of embryo protein (Tamura and Kenmochi, 1963). The major free amino acids are aspartic acid, glutamic acid, histidine, alanine and ornithine (Cagampang et al.,1971).

Lipids

The major proportion of rice lipids is removed with the polish and the bran containing germ. About 80% of the lipids of brown rice are in the bran and polish and about one-third of this fraction is in the germ (Casas et al., 1963).

Milled or white rice contains only about 0.3-0.7% fat, while brown rice contains 1.5-2.5% total fat. Commercial bran comprises 10.1-23.5% oil (McCall et al., 1951) and polish, 9.1-11.5% (McCall et al.,1951). Rice oil extracted from bran provides a stable, attractive, nutritious cooking oil. The major fatty acids of rice oil are oleic, linoleic, and palmitic acids (Juliano, 1972).

Vitamins

Rice has little or no vitamin A, ascorbic acid or vitamin D. The major proportion of the B-complex vitamins is distributed in the aleurone layers (bran and polish) and germ. Per cent distribution of thiamine, riboflavin, and niacin in brown rice is presented in Table 6.

Table 6-Per cent distribution of thiamine, riboflavin, niacin in brown rice (Juliano, 1972).

vitamin	bran	(germ)	polish	white rice
Thiamine	65	(58)	13	22
Riboflavin	39	(24)	8	53
Niacin	54	(18)	13	33

Thiamine and riboflavin contents vary with variety and place of growth (Kik, 1945), while niacin varies only with variety. The degree of milling significantly influences the contents of thiamine, riboflavin, and niacin and probably other nutrietns which also are concentrated in the germ and aleurone layers (Houston et al.,1964). Therefore, undermilled rice has a higher content of vitamins.

Parboiled milled rice tends to have higher vitamin contents than raw white rice (Revelli, 1968). The lesser degree of milling required for parboiled rice due to its harder grain seems to be the responsible factor, rather than the actual diffusion of vitamins from the aleurone layer and germ to the starchy endosperm (Juliano, 1972).

The relationship between thaimine and protein content is not clearly established yet. Lózsa and Koller (1952) reported protein content and thiamine content are positively correlated, while Guha and Mitra (1963) found no relationship between them.

Minerals

Mineral contents of rice vary considerably with composition of the soil in which rice is grown. The outer layers of the milled kernel have higher contents of ash and minerals than the inner layers. Leonzio (1967) reported the ash distribution is 51% in bran, 10% in germ, 11% in polish, and 28% in milled rice. The distribution of iron, phosphorus, and potassium parallels that of total ash. However, some minerals (e.g., calcium and sodium) show a relatively more even distribution in the grain(Juliano,1972).

Phosphorus accounts for a considerable portion of rice minerals. Relatively large amounts of magnesium and potassium are present in both brown and white rice.

In addition to phosphorus, magnesium, potassium and silicon are major constituents in bran; and potassium and magnesium, in germ and polish (Juliano, 1972). According to Balasubramanian et al.(1962), 55% of the phosphorus of white rice is present as phytin phosphorus, and 20% of iron is ionizable iron. Kik and Williams (1945) reported iron availability in white rice as 62%;in brown rice, 60% ; in bran, 50% ; and in polish,43%.

NUTRITIONAL VALUE OF RICE

The nutiritional value of food should be judged on the basis of nutrient requirements of the user as well as on the quantities of all essential nutrients and calories present. For evaluation, FAO Recommended Dietary Allowances are considered by the writer to be more appropriate for the nutritional status of rice-eating people than NRC RDA. FAO Recommended Dietary Allowances which are lower than NRC RDA which in turn, are lower than the US RDA were developed for people throughout the world and take into consideration on a world-wide basis food supply and transportation as well as the physical status of the people.

Though cereals in general are less adequate nutrients than animal foods, such as meat, milk or eggs, their nutritive worth lies in their high caloric value at low cost. Among cereals, rice is considered to be best in several aspects. Adequacy of essential nutrients of rice will be discussed.

Proteins

Rice is the main source of protein for most rice eaters. Adequacy of protein should be considered in terms of both quantity and quality.

The standard FAO/WHO adult man weighing 65 kg would require 37 g of reference protein per day, at the recommended allowance of 0.57 g/kg (Joint FAP/WHO Expert Committee, 1973).

The reference protein is defined as the protein of 100% net protein utilization (NPU). If this amount (37 g) is converted to the amount of the local proteins in rice-eating countries by adjusting with NPU of local proteins (60%, Joint FAO/WHO Expert Committee, 1973), the recommended dietary allowance of a local protein would be approximately 62 g. If unenriched white rice contains 6.7% protein (Watt and Merrill, 1963) and this is the sole source of protein, consumption of 925 g. of white rice per day would be required to meet the RDA. Rice consumption per person per day in rice-eating countries is about 450 g. (Houston and Kohler, 1970).

Daily consumption of rice will provide about 30 g. of protein(450 x.067). Usually the typical rice diet is supplemented with small portions of pulses, sweet potato, meat or fish and fruits and vegetables. Considering this, total daily intake of protein would be more tham 30 g. According to Food Balance Sheets 1960-1962 (Table 7), total daily protein intakes among rice-eating countries range from 43.8 g to 69.3 g. Daily protein intakes in most rice-eating countries do not meet the FAO requirement of 62 g , except for Japan and Korea. This is partly because of the low protein content of rice.

Although total protein content of rice is lower than that of corn and wheat, which are also staple foods in the world, the quality of rice protein is best among cereals, because of its high biological value (B. V.), chemical score, and net protein utilization (Table 8).

Moreover, rice protein has high disgestibility compared with other cereals. Brown rice has a slightly lower disgestibility (94.7%) than white rice (96%) (Kik, 1957). Cooking improves the digestibility of rice protein (Rosenberg et al.,1959).

However, rice protein, like other cereals, is not an ideally balanced protein. Lysine is the first limiting amino acid, followed by threonine (Rosenberg et al.,1959). It has been demonstrated that supplementing with lysine and threonine raises the biological value of rice protein(Rosenberg et al., 1959; Chen et al.,1967).

Another measure of protein quality is protein efficiency ratio (PER). The PER of rice varies greatly due to the differences in procedures,

Table 7-Countries having rice as main source of proteins (Autret et al., 1968)

		Malaysia[2]	Philipp.[2]	Thailand[2]	Japan[1]	Taiwan[2]	Mauritius[1]	Ceylon[2]	Madacascar[2]	Pakistan[2]	Korea[2]	India[2]
Cal.		2340	1870	2130	2230	2400	2330	2050	2320	1940	2210	1980
Tot. Prot.		52.1	43.8	46.5	69.3	59.2	47.2	44.8	51.9	46.5	64.3	52.2
Prot. Cal.Ratio		8.9	9.4	8.7	12.4	9.9	8.1	8.7	8.9	9.6	11.6	10.5
NPU op Ratio		61	60	61	56	58	61	59	59	58	53	53
ND_p Cal. %		5.5	5.6	5.3	6.9	5.8	4.9	5.1	5.2	5.6	6.1	5.7
Chem. Score	Iso	65	64	64	65	64	63	62	63	62	59	61
	Leu	89	93	89	88	85	90	86	90	88	84	93
	Ly	81	77	73	80	77	77	73	73	71	66	70
	MC	66	66	65	64	63	63	62	62	62	62	58
	Phen	80	77	78	88	77	83	78	78	80	83	85
	Tyro	75	76	73	75	73	75	71	72	76	87	73
	Thre	72	72	70	73	69	70	69	69	69	72	69
	Tryp	77	75	80	79	78	76	75	78	76	81	72
	Val	74	73	76	73	72	72	73	73	71	70	69
Prot. Sources in %	Rice	39	37	61	34	42	38	41	56	37	37	22
	A.P.	30	30	21	23	27	26	19	18	22	9	10
	Other	13B	13M	-	11B	11B	17B	11B	8T	22B	11B	15B
		10L	5L	9L	18L	12L	-	16L	9L	10L	6L 29or	24L 16MS

[1]Food Balance Sheets 1960-62, Rome 1966
[2]Indicative World Plan, provisional results in print

B...Wheat
M...Maize

A.P....Animal products
L...Pulses

MS...Millet and sorghum
or...Barley

T...Roots and tubers

including number and sex of experimental rats, duration of feeding, protein level of rice diet, and vitamin-mineral supplement used by various workers (Juliano, 1972).

Table 8 - Protein quality of cereals

Cereals	B.V.[a]	Chemical Score[a]	NPU[b]
Rice	86	67	63
Corn	72	49	36
Wheat gluten	44	53	49

[a] Guthrie, 1975

[b] Joint FAO/WHO Expert Committee, 1973

The range of PER values for brown rice is 1.73 to 1.93 (Sure and House, 1948; Kik, 1957); for milled rice, 1.38 to 2.56 (Sure and House, 1948; Kik, 1957); for bran, 1.61 to 1.92 (Kik, 1945 and 1956); for germ, 2.59 (Kik, 1954 and 1957); for polish, 1.84 to 1.88 (Kik, 1956 and 1957). PER data cannot be compared directly because of the different protein levels used and the dependence of PER on the protein level of the diet.

Nitrogen balance studies on human subjects by Clark et al. (1971) verified the nutritional value of high protein rice. They found significant improvement in the nitrogen retention of seven adult human subjects fed the same quantity of the BPI-76-1 (14.5% protein) and Blue Bonnet (7.9% protein) milled rice. High protein rice has better nutritional value because of its higher levels of all essential amino acids.

By means of PER and NPU and nitrogen growth index, Bressani et al. (1971) found protein quality tended to decrease slightly with an increase in protein content of white rice. This may be partly due to the increase in the level of poor-quality prolamin with protein content (Juliano, 1972).

Supplementation of rice with milk powder leads to better utilization of total protein, and also it has been reported that calcium improves the biological value of rice proteins (Kik, 1945).

It can be concluded that the protein quantity and quality of rice are lower than those of animal food and rice diets provide less adequate protein than other diets. Figure 2, which shows the protein value of different types of diet in the world, substantiates this conclusion.

Vitamins

The content of individual vitamins present and the amounts lost during milling or processing should be considered in determining the nutritional value of rice vitamins.

The vitamin B complex in brown rice is present in reasonably adequate amounts except for riboflavin. According to Watt and Merrill(1963), in 100 g of brown rice, thiamine is 0.34 mg, riboflavin, 0.05 mg, niacin, 4.7 mg. If daily rice consumption of a rice-eater is 450 g., daily intake of thiamine from brown rice is 1.53 mg; riboflavin, 0.23 mg; niacin, 21.1 mg. The daily dietary allowances recommended by the FAO (Joint FAO/WHO Expert Committee, 1967) for the reference man requiring 3000 Cal are 1.3 mg of thiamine, 1.8 mg of riboflavin, 20.1 mg of niacin equivalents. Daily consumption of brown rice alone would exceed the requirements for thiamine and niacin.

On the other hand, 100 g of white rice contains 0.07 mg of thiamine, 0.03 mg of riboflavin, 1.6 mg of niacin (Watt and Merrill, 1963). The daily intake of thiamine, niacin and riboflavin from white rice among rice-eaters would be 0.32 mg, 0.14 mg, 7.2 mg, respectively. These amounts are far below the RDA. Actually because of increases in white rice consumption, thiamine deficiency is still an important public health problem in rice-eating countries, such as the Philippines, the Republic of Vietnam, Thailand and Burma (Joint FAO/WHO Expert Committee, 1967). Both the cardiac and neuritic types of beriberi are found in adults.

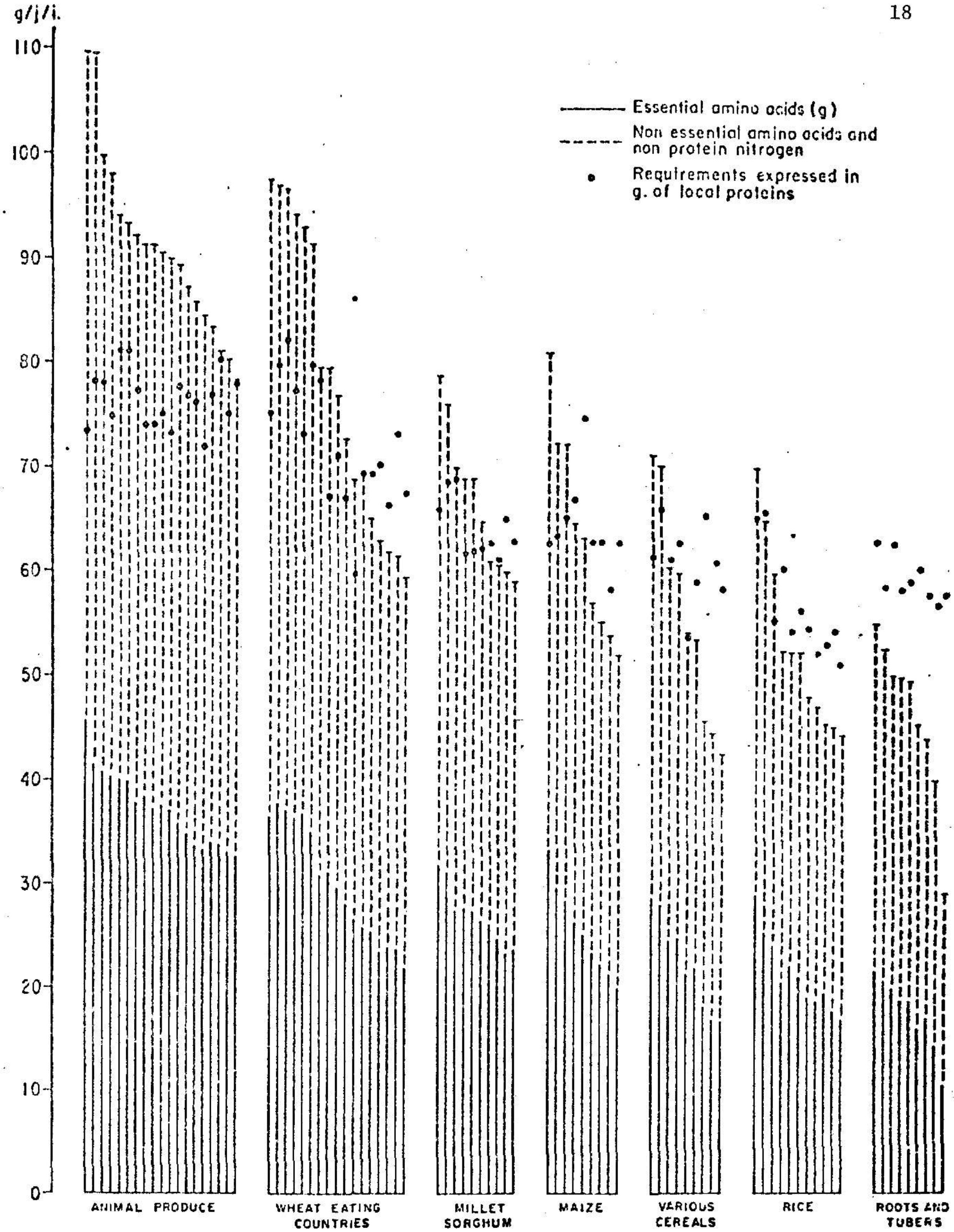

Figure 2 Protein intake and requirements (g) by country, according to type of diet (Autret et al.,1968)

The riboflavin intake is inadequate from both brown and white rice. As a result, clinical manifestations of riboflavin deficiency also occurred in south and east Asia (Joint FAO/WHO Expert Committee,1967).

In spite of the realtively low niacin content in white rice,pellagra resulting from niacin deficiency rarely occurs among rice-eating people (Schaefer, 1965).

Like other cereals, rice has little vitamin A, vitamin C and vitamin B_{12}. But whole rice has a considerable amount of vitamin E. Vitamin A deficiency is common in rice-eating countries, such as Indonesia, the Republic of Vietnam, Ceylon, Pakistan, India and Republic of Korea (Joint FAO/WHO Expert Committee,1967). Especially in the poorest group of the population, considerable numbers of infants and children have shown clinical evidence of vitamin A deficiency of varying degrees of severity. Vitamin A deficiency is often associated with protein-caloric deficiency.

The vitamins removed during milling are found in the polish and bran. According to Juliano (1966), 100 g of bran and polish amy contain respectively up to 2.8 and 5.0 mg of thiamine, 0.4 mg and 0.5 mg of riboflavin and 26 mg and 36.5 mg of niacin. One hundred g of bran and polish will provide more than daily requirements of thiamine and niacin for the Reference Man. Polish produced by undermilling can be used in food, while bran is not suitable for food because of the presence of hull fragments. However, bran also includes the highly nutritious germ, which contains 6-7 mg of thiamine and 5 mg of riboflavin per 100 g. Recovery of these materials is highly desirable.

Minerals

Rice, like other cereals, is deficient in calcium and iron. Considerable portions of these minerals are removed with bran and polish through milling

According to Watt and Merrill (1963), 100 g white rice contains 0.8 mg of iron and 24 mg of calcium. Daily consumption of white rice (450 g) among rice-eaters will supply 3.6 mg of iron and 108 mg of calcium. Brown rice contains 1.6 mg of iron and 32 mg of calcium in 100 g. Daily intake of 450 g of brown rice will provide 7.2 mg of iron and 144 mg of calcium.

Both white and brown rice provide amounts far below adult recommended daily allowances of 9 mg of iron and 400-500 mg of calcium (Joint FAO/WHO Expert Committee, 1962). Enrichment of rice with iron and calcium or supplementation with other food is highly desirable.

Although the dietary intake of iron of the majority of rice-eating people ranges from 10 to 25 mg (Joint FAO/WHO Expert Committee,1970), the prevalence of iron deficiency anemia among rice eaters is about 10% for men, more than 20% for women and 40% for pregnant women. Several surveys indicated prevalence above 50% in children and the extremely high figure of 92% in children under two years of age has been reported (Joint FAO/WHO Expert Committee,1970). On the whole, pregnant women and infants between 6 and 18 months of age appear to be the main groups at risk.

According to the report of Joint FAO/WHO Expert Group(1962), daily intake of some 350 mg or less of calcium is supplied fairly evenly by cereals, pulses, nuts and vegetables in most rice-eating countries. A few countries, Such as Korea and Japan, also have fish for a calcium source. There is, so far, no convincing evidence that calcium intakes below 300 mg or above 1,000 mg a day are harmful when vitamin D status is adequate and there are no other nutritional disorders. The prevalence of calcium deficiency in low calcium-intake populations is not known.

Although the calculated total phosphorus content is adequate, it is not all available. McCall *et al.*(1953) reported 40% is present as phytin phosphorus in white rice. Phytin is not utilized by human beings. The calcium to phosphorus ratio is unfavorable, being about 1 : 10 (brown rice) instead of 1 : 1 or 1.5 which is considered desirable. This again indicates the severe lack of calcium.

Since rice contains low contents of sodium (3-5 mg/100 g) and chloride (6 mg/100 g) (Kik, 1945), it has been used in the Kempner low-sodium diet for hypertension.

Caloric Value

As stated earlier in the report, rice is considered a high energy, low cost food. Carbohydrates, which amount to 80% in white rice and 70% in brown rice, are highly digestible types. Crude fiber which cannot be digested is only about 0.4% in white rice.

A 100 gram portion of white rice provides 363 Cal; brown rice, 360 Cal (Watt and Merrill, 1963). Daily intake of 450 g of white rice would provide 1533.5 Cal which is over 70% of the average daily caloric intake in rice-eating countries (Table 7). The recommended daily allowance is 3000 Cal for the reference man (Joint FAO/WHO Expert Group, 1973). The survey based on Food Balance Sheets 1960-1962 indicates the daily caloric intakes in most rice-eating countries are inadequate (Table 7). The high content of digestible carbohydrate and the low content of fiber in rice are considered important contributing factors of the daily caloric requirement.

NUTRIENT LOSSES AFTER HARVESTING

Nutrient losses occur in the entire rice food chain, from harvesting through home preparation. Minimum losses in handling and increased production of the best quality of rice are necessary to meet the needs of increasing populations. A discussion follows of nutrient losses in rice in each step in the rice chain after harvesting.

During Milling

In commercial milling, which may include polishing, the pericarp, aleurone alyers and germ are largely removed. Proteins, fats, vitamins and minerals are present in greatest quantities in the germ and outer layers, not the endosperm. Therefore, the degree of milling and polishing determines the amounts of nutrients removed. This is particularly true in the case of thiamine which is largely concentrated in the germ and the aleurone alyers. While the loss of thiamine due to milling is the main cause of beriberi among rice-eating populations, the loss of other nutrients is also important. Removal of the pericarp on milling also facilitates the extraction of soluble substances from the aleurone layers during washing.

Kik and Williams (1945) reported that 76.3% of the thiamine, 56.6% of the riboflavin, and 63% of the niacin originally present in brown rice were removed during the milling and polishing process. In addition to vitamin B losses, Kik (1942) reported the average loss of protein was 12.38% on milling and polishing. Also, Platt (1939) reported average loss of protein during milling was 14.9%. Thus, the loss of protein is by no means negligible.

The loss of fat (86%, Platt, 1939) is apparently high but since even brown rice contains but little fat, fat loss has not much significance.

Losses of nutrients in the milling of parboiled rice are not as great. Average loss in parboiled rice was: protein, 4.25%, niacin, 27.55%, biotin, 48.6% and pantothenic acid, 24.55% (Kik, 1951).

To minimize the nutrient loss due to milling, less severe milling can be practiced or the same process of milling can be applied to rice parboiled prior to milling. However, undermilled rice has poor keeping quality, and most rice-producing countries do not have rapid turnover and, moreover, have poor storage conditions. Storage, as well as acceptability, provides a major problem in using undermilled rice.

<u>During Storage</u>

Nutrient losses during storage may result from insect or micro-organism attack, rancidification of oil, changes in proteins or losses in vitamins. All the changes occur rapidly with increase in grain moisture content and temperature.

Undermilled and brown rice are more liable to attack by insects and molds than are white rice and paddy. Milled parboiled rice though more susceptible than paddy, is less easily attacked by insects than white rice and has better keeping quality. Thus, the storage of rice in the form of paddy is theoretically preferable (FAO, 1948).

Although, considerable losses in fat and fat soluble vitamins and vitamin C occur during storage in the presence of air, their original low levels in rice make the losses relatively insignificant.

Protein in rice may become less available during long term storage; that is, molecular structure may change so that the body is less able to utilize this protein. Amino acids may be lost when the rice is stored at room temperature (Anon.,1974).

Probably the greatest losses during storage occur in the B-vitamin content. Thiamine content of rice (including paddy, brown, undermilled and white) may be reduced by 8 to 15% during storage for 9 months at a temperature of 84°F (Kik, 1945). Average losses in several types of rice for attic (warm) and cold (-10°C) storage during two and a half years have been reported by Kik and Williams (1945)(see Table 9). Cold storage for two and a half years did not cause any significant loss of vitamins in rice. This indicates low temperature of storage is very important. Prolonged storage of rice under poor conditions, such as high temperature and moisture, affects cooking quality, probably as a result of changes in the starch fractions. Generally speaking, the losses due to storage are small compared to those resulting from improper milling and washing and cooking practices.

Table 9 Average losses of nutrients in rice during storage

	Percentage loss of total content		
Type of rice	Thiamine	Riboflavin	Niacin
Attic storage			
Rough (paddy)	19.87	6.34	4.12
Brown	25.40	4.20	3.87
White	29.40	5.44	3.77
Bran	50.37	16.35	15.20
Polish	45.30	18.00	14.60
Cold storage			
Rough (Paddy)	1.81	1.98	1.10
Brown	1.21	3.84	1.95
White	0.74	1.61	1.20
Bran	0.40	1.73	1.25
Polish	0.16	1.75	1.61

During Washing and Cooking

In most rice-eating countries, rice is usually washed before cooking to remove dust and foreign particles. Washing involves hand rubbing of the kernels in more than two volumes of tap water, at least three times. Stones are removed during this treatment by a specially devised ladle. In some cases, rice is rinsed after cooking. Sometimes rice is soaked before cooking to improve acceptability, especially of stale rice.

The nutrient losses on washing or rinsing occur mainly in the water soluble, vitamin B group. The amount of loss depends on the degree of milling and the amount of washing.

Swaminathan (1941) found that raw rice samples lost an average of 60% [illegible] niacin on the first washing, and the second and third washings did not remove much more. This indicates that less intensive washing at first is very important.

Brown rice is less impoverished by washing than white rice because of the protective pericarp. The losses of thiamine, riboflavin and niacin of brown and white rice during washing are compared: The figures are 21.1 and 43% for thiamine, 7.7 and 25.9% for riboflavin, 13.0 and 23.0% for niacin.

Parboiled rice is less seriously affected by washing than ordinary rice. Losses of thiamine may be reduced some five-fold by parboiling (Swaminathan, 1941).

Enriched rice,which is regulated to be rinse resistant (USFDA, 1958) is less impoverished by washing than white rice. The washing loss of thiamine has been reported from 28% to 63% in white rice and 8 to 9% in enriched rice (Aalsmeer et al., 1954).

Rice is usually prepared by boiling or steaming. Since the water is absorbed into the rice in steaming, the loss of extracted or soluble nutrients is not significant. On the other hand, since the cooking water is usually discarded after boiling, larger proportions of water soluble vitamins are removed. Most rice-eating populations in the Far East, such as Korea, Japan, Taiwan, use a steaming method. However, a comprehensive survey of rice washing and cooking practices in various regions of India, done in 1969 for the Food and Nutrition Division of the U.S. Agency for International Development, New Delhi, India, showed that 80 to 90% of the rice consumed in India was cooked in excess water which was subsequently discarded, and only 10 to 20% was cooked by steaming (Mansinghal Association, 1969).

All types (white, brown, parboiled) of rice lose an average of 4.29% of thiamine in steaming, while 46.85% of thiamine is lost in boiling. The average losses of riboflavin and niacin in steaming were 6.74% and 3.35%, respectively. These values were 43.0% for riboflavin and 44.8% for niacin when a boiling method is used (Kik, 1945).

Malakar and Banerjee (1959) determined losses of thiamine, riboflavin, niacin, calcium, phosphorus, iron, and nitrogen from Indian rice after a single washing followed by cooking in different volumes of water. When the rice was cooked in eight volumes of water and rinsed once, approximately half of the water soluble vitamins and a third of the minerals were lost.

Frying rice at high temperatures also causes considerable thiamine loss. Frying to a golden brown (15 minutes) destroyed 45-70% of thiamine (Kennedy and Tsuji, 1952).

Other nutrients besides vitamins can be lost by improper washing and cooking practices, because many nutrients are concentrated in the outer layers of the endosperm. The washing of white rice in the Japanese way, which is a relatively intensive washing method, resulted in a loss of 16% protein, 20% carbohydrate, 43% fat, 73% inorganic substances, and 100% thiamine (Proc. 6th Pacific Science Congress, 1939). It has been reported (Ranganathan, 1937) that washing and cooking methods common in some parts of India removed 10% of the protein, 50% calcium and phosphorus, 74% iron and 15% of the calories.

Generally, washing before or rinsing after cooking causes much more nutrient loss than cooking (Table 10). Therefore, minimum washing by supplying clean and well packaged rice and a proper cooking method using a minimum amount of water (steaming) are very important to prevent considerable nutrient losses.

Table 10-Losses of thiamine in washing and cooking raw white rice and parboiled rice (Swaminathan, 1942)

Sample Number	Thiamine content (µg/g)	Loss in washing (%)	Loss from washed rice in steaming, %
Raw white 1	1.0	60	25
Raw white 2	1.2	50	33
Average	1.1	55	30
Parboiled milled 1	1.9	10	25
Parboiled milled 2	2.4	8	25
Average	2.2	9	25

NUTRITIONAL IMPROVEMENT OF RICE AND RICE DIETS

The existence of many nutritional problems among rice-eating people indicates that the typical rice diet is inadequate and needs to be improved. To improve the nutritive value of rice, some positive approaches such as parboiling, enrichment, and supplementation are needed in addition to minimizing nutrient losses by proper milling and washing and cooking.

Parboiling

Parboiling is an ancient method of processing of paddy which originated in India. Parboiled rice is used mainly in India, Ceylon and British Guiana and the places (e.g., British Malaya) where immigrant Indian coolie labor has demanded or preferred it.

The process of parboiling consists essentially of soaking rough rice in water (either cold, warm, or hot), draining off the water, steaming the rice and drying it. Then it undergoes mill processing just like other raw rice.

Parboiling treatment provides several nutritional advantages. Parboiling toughens the grain, therefore reducing the amount of breakage in milling. Also, milled parboiled rice is less liable to insect attack and has better keeping quality. Parboiled rice retains more nutrients than white rice (see Table 11 and Figure 3).

Table 11-Vitamin content of milled Parboiled and White rices (Kik, 1945)(ug/g)

Variety	Thiamine		Riboflavin		Niacin	
	Parboiled	White	Parboiled	White	Parboiled	White
Nira	1.35	0.59	0.47	0.30	49.0	20.6
Caloro	1.61	0.84	0.33	0.26	45.2	18.5

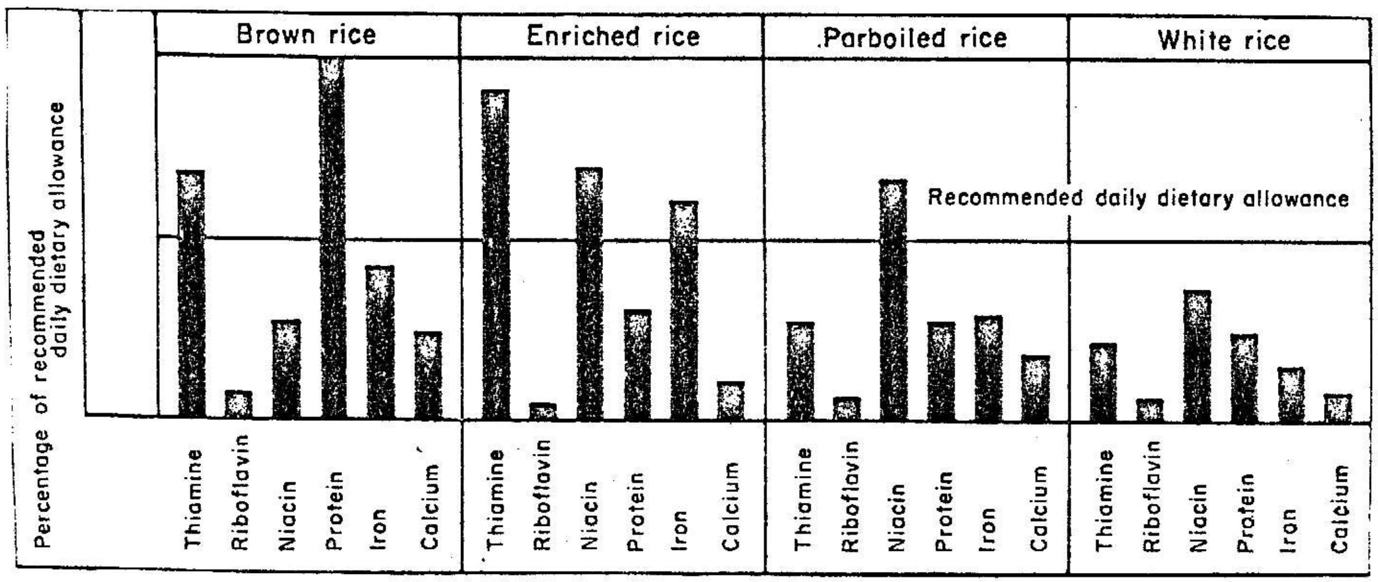

Figure 3 Content in vitamins, proteins and mineral salts of parboiled rice compared with other types of rice (Gariboldi, 1974)

It is thought this is mainly because the grain, hardened through parboiling, allows a less severe milling process rather than because the vitamins present in aleurone layers and germ diffuse into the starch endosperm (Juliano, 1972). Nicholls (1947) found that part of germ (scutellum) which contains from 40 to 50% of the available thiamine remains in the milled parboiled kernel. Hinton (1948) showed that the parboiling treatment leads to the redistribution of thiamine in the grain, with the result that the endosperm is significantly enriched. Contrary to Juliano, Hinton thinks that the redistribution is mainly because a small amount of water condensed on its surface enters into the grain as the starch gelatinizes, carrying thiamine from the germ and aleurone.

As stated earlier, another advantage is that the water soluble vitamin content of parboiled rice is less affected by washing. Swaminathan (1942) demonstrated that whereas raw white rice loses about 85% of its thiamine in washing and cooking, the loss from parboiled rice is only about 34 percent. The explanation may be that the protective pericarp remains on the grain due to the lesser degree of milling required and that penetration of the water soluble vitamins into the endosperm during parboiling makes them less accessible to water used in washing (Grist, 1959).

On the other hand, there are some disadvantages in parboiling. It has no standardized process and the quality of the end product is very variable. Milled parboiled rice is usually less attractive in appearance than raw rice milled to a high degree of whiteness, and it has a different taste (FAO, 1948).

Some of these disadvantages could be improved by conversion. Rice "conversion" originated in England (Kik, 1945). Essentially it is technically perfected and modernized parboiling, protected by patents. In general, in the conversion process, the soaking is more carefully standardized than in ordinary parboiling. Rice conversion can produce an attractive, highly milled product with the nutritive properties of parboiled rice. However, it has some disadvantages; i.e., it is more expensive than ordianry parboiling because more complicated machinery is needed and the process is covered by patents.

Although consumption of parboiled rice is recommended because of its high nutritive value, acceptability seems a major problem, especially to rice eaters who are unfamiliar with it. According to a study by El-Dash (1975), who investigated the effect of pretreatment (soaking or boiling) and steaming steps of parboiling on flavor elements and consumer acceptability, the aroma and taste are independent of the soaking and steaming step; texture improves significantly with parboiling, especially in the steaming step; and the color of parboiled rice seems to be influenced more by variety than by parboiling itself.

Enrichment and Fortification

Enrichment and fortification have official definition in FDA regulations (Wodicka, 1974). Enrichment is addition to a food or class of foods, as a matter of public policy, of incremental amounts of nutrients already present. Restoration is replacement of nutrients lost in processing. Fortification is addition, to achieve sound nutritional design, of nutrients not originally present in appreciable amounts. The difference between enrichment and fortification is that enrichment is connected with standards of identity that have been legally promulgated, and fortification includes all addition of nutrients, including those for enrichment.

The goal of rice enrichment is to give the final product a nutrient content which is considered desirable on public health grounds. According to the Standard of Identity of US FDA (1958), enriched rice should contain (minimum and maximum in mg/lb) thiamine 2.0-4.0, riboflavin 1.2-2.4, niacin 16.0-32.0, and iron 13.0-26.0. Addition of vitamin D (212-850 USP units/lb) and calcium (425-638 mg/lb) is optional. Because of causing yellow spots in cooked rice, addition of riboflavin is stayed. In case minimum level is applied directly, the label should state as follows:"to retain vitamins do not rinse before or drain after cooking." Also, enriched rice should be rinse resistant and should retain not less than 85% of vitamins and minerals after rinsing.

Early in 1972, a new standard of identity was proposed (NAS-NRC,1974) showing the same single levels of the required and optional ingredients. Vitamin D was dropped as an optional ingredient and riboflavin remained stayed. However, even by 1976 the proposed levels were not adopted. The 1958 and 1972 levels are presented in Table 12.

Table 12-Original (1958) and Proposed (1972) levels of nutrients in enriched rice (Brooke, 1972)

	Original	Proposed
Thiamine,mg/lb	2.0-4.0	2.9
Riboflavin,mg/lb	1.2-2.4	1.8
Niacin, mg/lb	16-32	24
Iron, mg/lb	13-26	40
Calcium, mg/lb	500-1,000	960
Vitamin D, USP Units/lb	250-1,000	...

The enrichment of rice is technically more difficult to achieve than the enrichment of other cereal products, because rice is eaten in the form of uncrushed grain; moreover rice is usually washed before being cooked. Enrichment processes have been developed for producing rice premix kernels which will meet the rinsing requirements of US FDA (85% retention). The most widely used method is that of Hofmann-LaRoche (Furter and Lauter, 1949). A portion of the rice is heavily fortified with thiamine, niacin, and iron. An edible protecitve coating consisting of stearic acid, zein, and abietic acid in alcoholic solution is first sprayed on the rice which is then sprayed with ferric pyrophosphate and finally dusted with talc to complete the coating. The fortified rice is mixed 1:200 with regular white rice to produce the final enriched product.

Flavor and cooking quality are not affected by the enrichment process. Household washing and cooking show relatively low vitamin loss, as Kik(1945) has reported.

The Bataan experiment in Philippines in 1948-50 (Aalsmeer et al.,1954) and the nutritional survey of the Chinese National Army (Tai,1965) demonstrated the benefits of enriched rice. Both established the effectiveness of enriched rice in reducing mortality from beriberi in a rice-eating population.

Another enrichment process has been developed to produce powdered premix. This is added to white rice at about 0.5 to 1 part per 1,600 parts of rice. The powder adheres sufficiently when the mixture is tumbled to endure ordianry handling. This enriched product must have the warning label stating not to rinse so that vitamins are retained(Houston and Kohler,1970).

Japanese workers have developed a different premix technique using thiamine derivatives which are more or less insolbule in water yet, have biological activity equivalent to thiamine hydrochloride (Brooke,1972). Kawasaki (1961) recommended benzoyl thiamine disulfide as the most useful compound for enrichment of rice because it is almost insoluble in water, is easily soluble in dilute acetic acid, and has acceptable biological properties.

In spite of nutritional advantages, the use of enriched rice is not common among rice-eating countries because of economic and political problems (Aalsmeer, 1954). The use of enriched rice in Japan, the Philippines, and the Republic of China seems quite successful, although they don't have legislation for enforcing the use of enriched rice (Tai, 1965). In Japan, enriched rice is more popular than undermilled rice because of the poor palatability and relatively limited nutrients in the unsupplemented rice. It is estimated that about one-third of the Japanese population consumes enriched rice (Brooke,1972).

Fortification with lysine and threonine to improve the protein quality of rice has shown marked supplementary effect; however, no single amino acid, e.g., limiting amino acid lysine at 0.8%, increased growth of weanling rats over the 90% basal rice diet at 5.3 to 6.7% protein (Pecora and Hundley,1951). Waddell (1953) pointed out that if the amounts of single amino acids added were excessive, unbalanced mixtures would result. Chen et al.,(1967)confirmed the effectiveness of a lysine and threonine supplement to a rice diet in increasing nitrogen retention when the diet had a high level of total nitrogen (12 gram per day). Tara and Bains (1971) demonstrated that if rice is cooked in just sufficient water, added lysine and threonine would be well retained.

Supplementation

Nutritional deficiency diseases are common in rice-eating countries. Typical rice diets contain excessive proportions of rice and are lacking in the vitamin B group, vitamin A, iron, calcium and protein. The major problem is a lack of high quality protein. The foods which provide these deficient nutrients and which also can be produced locally should be used in greater quantities as supplements; for example, pulses, vegetables, fish, and poultry.

Partial replacement of rice with other cereals helps the situation of short supply of rice as well as improving rice diet. Although it has limited value, because cereals generally are deficient in the same amino acids, supplementation of white rice with other whole-grain cereals is nutritionally advantageous. It will increase the intake of certain minerals and vitamins, especially thiamine, and protein level. For example, yellow corn would also supply vitamin A. Saxena and co-workers (1966) reported that rats on a rice and legume diet supplemented with rice polishings had increased retention of nitrogen, calcium and phosphorus over control rats on the unsupplemented diet. This is because polish has more B vitamins and essential amino acids. Later Wakefield and Rowland (1973) confirmed the possible use of rice polish as a source of protein. They also found that a combination of rice polish and fish protein concentrate had high biological value.

Combination of rice and legumes or pulses are frequently eaten by rice-eating people. Legumes have relatively high protein and lysine contents but are poor in methionine and cystine. Thus, in combination, rice and legumes compensate each other. Legumes also provide calcium and iron to rice diet.

The 2.02 PER of undermilled rice was raised to 2.09-2.18 with various pulses (Houston and Kohler, 1970). Also PER values showed a rice-red gram-amaranth combination was as effective as skim milk.

In east Asia the soybean is a familiar and important food. soybeans and peanuts are in protein than are other legumes. Also, soybeans have a more complete amino acid composition than do other legumes (Houston and Kohler, 1970).

Narayanaswamy (1974) reported that a blend of 70% wheat, 15% soybean, and 15% peanut flour improved rat growth rate significantly and the optimal supplementary value of such a protein blend to poor rice and ragi diets was 22.6%.

Relatively plentiful, vegetables are a very important supplemen in the typical rice diet; fruits are less plentiful, therefore, used less. Vegetables are part of the daily diet, although fruits are rarely consumed. Fruits and vegetables are the principal source of ascorbic acid. Potatoes and sweet potatoes, red pepper and citrus fruits and acerola fruit are good sources of ascorbic acid.

The use of sprouted pulses as vegetable salads is common in rice-eating countries. These provide ascorbic acid as well as protein. Vitamin A is provided by yellow or leafy green vegetables, calcium,also,is supplied by green leafy vegetables. However, spinach contains large amounts of oxalic acid which tend to make the calcium partially insoluble and less available (Basu, 1946).

Although nutritional benefits from meat, eggs, poultry, fish and milk as supplements to rice diets are well known, they are not available in adequate amounts to many people of the world. These animal protein foods improve protein quality in rice diets by furnishing large proportions of essential amino acids; providing vitamin B_{12} which exists only in animal foods; and providing fat which is usually low in rice diets.

Eggs, chicken, milk and fish are good sources of vitamin A. Fish flour and small fish eaten with bones furnish calcium. Raw fish and fermented fish (Vimokesant, 1975), commonly eaten in Asian countries, may contain anti-thiamine factor, a thiamine-destroying enzyme. Benefits from food yeasts were reported by Sure (1950). Dried yeast contain about 50% crude protein (N x 6.25), and about 80% of this is true protein of good biological value. However, the essential amino acids, methionine, in yeast protein, is not utilized by human beings (FAO, 1948). Dried yeast furnishes the vitamin B group : thiamine, riboflavin, niacin, and pantothenic acid. A small daily supplement of 7 to 15 grams of food yeast supplies sufficient additional protein and vitamins (FAO, 1948). Deficiency of riboflavin in a rice diet is difficult to correct. Milk is among the richest source of this nutrient,but in most of the rice-eating regions little or no milk from domestic animals is available. Green leafy vegetables and pulses contain riboflavin, but they have to be eaten in alrge amounts to meet the recommended daily allowances.

According to world food survey (FAO, 1954; 1957, Jansen and Howe, 1964) protein quantity and quality deficiency calls for special attention, particularly in infant and children. Deficiencies of both protein and calories result in marasmus; deficiency of only protein results in kwashiorkor. Calorie intakes per capita shown in Far East data (Jansen and Howe, 1964, and Table 8) sre uniformly lower than the requirements. Since rice, which is in short supply, is the major source of calories,supplying adequate food calories is probably the world's greatest need.

In planning national food production policies, careful attention should be given to ways and means of increasing the production of such basic foods as rice and others which are of special value from the standpoint of nutrition.

CURRENT STATUS IN THE REPUBLIC OF KOREA

To illustrate the status of a rice-eating country, the dietary pattern, nutritional status, recommended dietary allowances, and nutrition education of Korea are introduced herewith.

General Description of Korea

The Korean peninsula stretches almost directly south from Manchuria, and is about 500 miles long. Korea is a chain of hills. The major portion of the country is mountainous, only 20% of the land being flat. Korea, thus, has one of the roughest topographies in the world. However, the land is characterized by low hills which lack steepness and for the most part are spread out horizontally.

The Confucian family system was fundamental to the older Korean society, whereby respect and deference were given to elders. Korean families may be getting smaller and more widely scattered, but the old loyalty to the clan and its patriarch is not fading, simply taking new forms.

Since Korea is a mountainous land, only 22% of the total area is under cultivation. However, more than half of the nation's total population is engaged in farming or fishing. The food supply in Korea depends largely on rice and barley. Rice production is an especially important part of the food supply and depends on seasonal weather conditions. Irrigated paddy fields account for 40 percent of the total paddy fields.

Dietary Pattern

The cultural dietary pattern of Korea consists of a main dish (rice) and secondary dishes (vegetables, meat, fish and soybeans and soybean products). As in many other rice-eating countries, Koreans eat large amounts of steamed white rice (average daily intake, 500 g) and small amounts of "kimchi," (the traditional pickled cabbage) and vegetable soup at almost every meal. Sometimes meat, cooked with other vegetables, and fish and seafood can be eaten together with the above-mentioned foods.

They have large varieties of fish and sea weeds because the country is a peninsula. They are important sources of protein, calcium and iodine in the Korean diet. The small sardine which can be eaten with bone is fairly good source of calcium. For example, 100 g of dried small sardine provides 1860 mg of calcium (Korean FAO Association, 1975). One 15 g serving would provide 300 mg of calcium. Compared to other items in the Korean food supply, these small sardines are easily available. Dried tangle, a sea weed usually prepared as a soup, provides iodine. Because of this, there are few goiter patients, in spite of no iodized salt.

Traditionally, not much milk is drunk. These days Koreans are encouraged to drink milk, particularly infants and children. The government is encouraging the establishment of dairy farms. The meat group, such as beef, pork, chicken, egg, is rarely eaten because of limited availability. Although Koreans may have independent meat dishes, they usually cook meat with vegetables as a stew type dish.

They have a relatively large variety of vegetables and consume more vegetables than the other food groups. In the farming villages, sun dried vegetables are available during winter months.

The consumption of fruits is relatively low. Apple is one of the most abundant fruits in Korea.

Barley and legumes are second to rice in importance, in the cereal group. Currently, the Government encourages the Korean people to eat combined cereal dishes (e.g., combination of 70% rice and 30% barley or legumes), and wheat flour-based dishes such as noodles and bread, because of the short rice supply as well as their nutritional advantage. Thus, rice consumption will be decreased gradually.

Favorite seasonings in the Korean diet are soy sauce, chopped scallion, garlic powder, sesame oil and red pepper and red pepper paste.

Table 13 presents daily food consumption per capita (Korean FAO Association of U.N., 1975), based on numerous nutritonal surveys.

Because it is the main side dish in a Korean meal, kimchi merits further consideration. No Korean meal can be served without kimchi. The estimated daily consumption of kimchi per person is between 200 and 300 g. Kimchi is made from chinese cabbage flavored with red pepper and other spices, chopped scallion, onion, garlic and ginger. In most cases, fishery products such as oysters, salted shrimps, and pickled fish are added with the seasonings.

The nutrient content of 100 g of kimchi is as follows : Calories, 19 Cal; water, 88.4%; protein, 2.0g; fat, 0.6g; carbohydrate, 1.3g; ash 0.5g ; calcium, 28 mg ; beta-carotene, 295.2 mg ; thiamine, 0.03 mg ; riboflavin, 0.06 mg ; niacin, 2.1 mg ; ascorbic acid, 12 mg (Korean FAO Association of UN, 1975). Kimchi represents an ingenious, preserved food for supplying vegetables, particularly during the winter months when no fresh green vegetables are available. There is sufficient scientific evidence indicating that its vitamins are fairly well preserved (Lee, 1968).

Table 13-Food consumption in different villages (per capita per day)
(Korean FAO Association of UN, 1975)

village / intake / Food group	farming villages		fishing villages		mountainous village		city		averages	
	g	%	g	%	g	%	g	%	g	%
Cereals	547	48.2	470	44.6	616	54.5	601	47.8	558.5	48.9
Legumes	69	6.1	66	6.3	80	7.1	75	6.0	72.5	6.3
Vegetables	113	9.9	125	11.9	87	7.7	83	6.6	102.0	8.9
Kimchi	317	27.8	312	29.7	222	19.6	187	14.9	259.5	22.8
Meats	15	1.3	3	0.3	8	0.7	89	7.1	28.8	2.5
Fish	63	5.6	55	5.2	21	1.9	67	5.3	51.5	4.5
Sea Weeds	3	0.3	6	0.6	3	0.3	24	1.9	9.0	0.8
Potatoes	3	0.3	9	0.9	55	4.9	13	1.0	20.0	1.8
Milk & Milk products	-	-	-	-	-	-	66	5.3	16.5	1.4
Seasonings	2	0.2	4	0.4	8	0.7	9	0.7	5.3	0.5
Wines	-	-	-	-	27	2.4	-	-	6.8	0.6
Fruits	-	-	-	-	-	-	29	2.3	7.3	0.6
Eggs	3	0.3	1	0.1	2	0.2	14	1.1	5.0	0.4
Total	1,135	100	1,051	100	1,129	100	1,257	100	1,1427	100

Nutritional Status

Since little information about the nutritional status of the civilian population is available, the status of Korean Armed Forces will be discussed mainly. Generally, the Armed Forces are better fed than the civilian population.

Korean Armed Forces food consists basically of rice (576 g) and barley(252 g) and soup at the three meals each day. Milled rice (70% milling rate) which contains 2.3-2.8 µg thiamine/g is issued for the Armed Forces (Lee, 1968).

Average nutrient intake is presented in Table 14. According to this 1957 dietary assessment of Korean Armed Forces done by ICNND (1957), the critical nutrients were riboflavin and vitamin A.

Table 14-Mean individual nutrient intakes per man per day of Korean Armed Forces (ICNND, 1957)

Total calories	3,814
Protein, g	127
Protein % of calories	13.3
Fat, g	43
Fat % of calories	10.2
Carbohydrate, g	730
Carbohydrate % of calories	76.5
Calcium, mg	780
Iron, mg	34
Salt	20.1
Vitamin A, IU	1,218
Thiamine, mg/1,000 calories	.55
Riboflavin, mg/1,000 calories	.26
Niacin,	21.1
Vitamin C, mg	55

ICNND also conducted a biochemical assessment which is summarized in Table 15. Thiamine was measured by urinary excretion levels per gram of creatinine. Excreting less than 65 µg of thiamine per gram of creatinine is considered as below acceptable. Riboflavin was evaluated on the basis of those individuals excreting less than 80 µg per gram of creatinine. Incidence of riboflavin deficiency was greatly reduced due to supplementation by food products which had a higher riboflavin content compared to the previous studies conducted in 1953 (Schaefer, 1965). Niacin was measured by the excretion of urinary N'-methylnicotinamide of less than 1.6 mg per gram of creatinine. Vitamin A was assessed on the basis of those individuals having less than 20 µg of vitamin A per 100 ml of serum. Vitamin C level was not acceptable if less than 0.2 mg per 100 ml of serum. Generally, the incidence of vitamin C deficiency is higher in the military than in the civilian population (Schaefer, 1965).

Although the nutrient intake data (Table 14) indicated an adequate dietary content of iron, over 25% of the military personnel examined had hemoglobin concentrations of less than 12 g per 100 ml blood in the biochemical assessment.

Table 15-Results of biochemical assessment of Korean Armed Forces(ICNND,1957)

	% prevalence below "acceptable"
Urinary thiamine excretions	5
Urinary riboflavin excretions	16
Urinary N'-methylnicotinamide	0
Serum vitamin A level	18
Serum vitamin C level	1

Criteria for "below acceptable"

Urinary excretion
- Thiamine 65 µg / g creatinine
- Riboflavin 80 µg / g creatinine
- Niacin (as N'-methyl-nicotinamide) 1.6 mg/ g creatinine

Blood serum
- vitamin A 20 ug / 100 ml
- vitamin C 0.2 mg / 100 ml

Unfortunately, other hematologic parameters are missing, so that it is hard to classify the anemia observed. More information is needed to give an understanding of the cause of anemia in Korea (Darby, 1965).

Anthropometric measurements reported by Drs. H.S.Kim and H.Y.Ryo, May, 1966, were made to assess physical condition and body strength on entering the Recruit Training Center and after six weeks' training. The results are shown in Table 16 (Lee, 1968). These results indicate an average increase of 1.5 kg in body weight and a little improvement in grenade distance throwing.

Table 16-Average physical measurements of recruits and body strength (Lee, 1968)

	On arrival	At the end of the 6th week
Height, cm	166.2 ± 3.1	----
Weight, kg	57.0 ± 4.2	58.5 ± 3.7
Chest circumference, cm	87.8 ± 3.6	87.4 ± 4.0
Gripping, kg	38.5 ± 5.1	38.4 ± 5.3
Pulling, kg	118.3 ± 7.3	119.2 ± 7.0
Grenade distance throwing,m	32.6 ± 5.3	35.5 ± 5.7

A nutritional survey (dietary and clinical survey) of civilians in farming villages conducted in July, 1962, showed the following : animal protein ratio to the total protein intake was only 5.2%; riboflavin intake was only 0.7 mg per person/day; prevalence of angular lesions was 22.7% and cheilosis, 27%; and unfilled tooth cavities was 28.2% (Chai and Chang, 1965). Both the ICNND survey and the farm village survey reveal the facts that riboflavin, vitamin A and iron deficiency are common in Koreans.

Recommended Dietary Allowances for the Korean People

The Food and Nutrition Expert Committee of FAO Korean Association established the RDA for Korean people in 1962 for the first time. In the calculations of the allowances, the method of FAO was used, applying Korean physical status, basic metabolism data, Korean dietary habits. In 1967, RDA's were revised and it was planned to revise them every five years; however, the second revision was done in 1975. Table 17 presents

Table 17-Recommended daily dietary allowances for Korean (Revised 1975) Reference man:60kg* woman :52kg**

	Age (yrs)	Weight (kg)	Height (cm)	Energy (Kcal)	Protein (g)	Vitamin A (IU)	-carotene (IU)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid,mg	Vit.D. (IU)	Calcium (g)	Iron (mg)
Infants	0.0-0.5	6	60	700	-	1,400	4,200	0.4	0.4	6	35	400	0.4	10
	0.5-1.0	9	72	1,000	2.4g/kg	1,400	4,200	0.5	0.6	8	35	400	0.5	15
Children	1-3	11	82	1,100	35	1,500	4,500	0.6	0.7	8	40	400	0.5	15
	4-6	17	105	1,500	45	1,700	5,100	0.8	0.9	10	40	400	0.5	10
	7-9	25	123	2,000	55	1,900	5,700	1.0	1.2	13	40	400	0.5	10
Males	10-12	32	138	2,300	65	2,100	6,300	1.2	1.4	15	40	400	0.7	15
	13-15	44	155	2,500	80	2,300	6,900	1.3	1.5	17	60	400	0.7	15
	16-19	56	166	2,900	85	2,500	7,500	1.5	1.7	19	60	400	0.7	18
	*20-49	60	168	2,700	80	2,000	6,000	1.4	1.6	18	60	-	0.5	10
	50-65	60	166	2,400	75	2,000	6,000	1.2	1.4	16	60	-	0.7	10
	66 +	59	165	2,100	75	2,000	6,000	1.1	1.3	14	60	-	0.7	10
Females	10-12	33	139	2,100	65	2,000	6,000	1.1	1.3	14	40	400	0.7	10
	13-15	44	152	2,300	75	2,000	6,000	1.2	1.4	15	60	400	0.7	18
	16-19	52	156	2,200	75	2,000	6,000	1.1	1.3	15	60	400	0.7	18
	**20-49	52	157	2,000	70	2,000	6,000	1.0	1.2	13	50	-	0.5	18
	50-65	51	155	1,800	65	2,000	6,000	1.0	1.1	13	50	-	0.7	10
	66 +	50	154	1,600	65	2,000	6,000	1.0	1.0	13	50	-	0.7	10
Pregnant				+300	+25	2,400	7,200	+0.3	+0.3	+2	65	400	1.2	18
Lactating				+500	+30	3,500	10,500	+0.3	+0.5	+4	85	400	1.2	18

the RDA for Korean people (Korean FAO Association, 1975). Also recommended were daily intakes of five basic food groups (1.meat group, including poultry, fish, egg, and legumes; 2.fruit and vegetable group; 3.cereal and potato group; 4.milk and milk products and small fish eaten with bones; and 5.fats) to meet the nutritional requirements. Table 18 shows the suggested daily amounts of the five basic food groups for the reference adult man (Korean FAO Association, 1975). The Expert Committee also suggested that percent of calories from carbohydrate be around 70% and one-third of recommended daily protein intake come from high quality protein. They recommended the combination of 130 g of rice and 40 g of other cereal for one serving for an adult man.

Table 18-Recommended daily intake of 5 basic food groups based on RDA of Korean reference man (age 20-49 weight 60 kg) (Korean FAO Association, 1975)

Food group	amount, g	number of servings
1.Meat		
meat, fish, poultry and egg	140	more than 2
legumes (soy bean curd)	15(70)	1
2.Fruit and vegetable		more than 4
dark green and yellow vegetable	150	
other vegetables	250	
fruits	100	
3.Cereal and potato		more than 3
cereals	500	
potatoes	150	
4.Milk and milk products and small fish eaten with bones		more than 1
milk and milk products	180	
small fish with bones	15	
5.Fat		——
oil, butter	30	

Nutritional Education

The Korean Nutrition Division under the Survey and Training Department in the Korean National Institute of Health is in charge of nutrition education. Nutrition education is begun in the home economics class of junior high school. Since 1962 when only two college nutrition departments existed, an increasing number of college nutrition departments have been established throughout the country. The graduates of these college curricula will be given the title "nutritionist" by the government. The license for nutritionists was legally established, based on the "Food Sanitation Law" issued in January, 1962 (Chai and Chang, 1965).

The Korean National Institute of Health has nutrition courses for public health and nurse training. This covers the general principles and practical knowledge of nutrition. Trainees are working at health centers located throughout the country. Also maternal and child health centers teach mothers some nutrition education whenever they supply them with powdered milk to improve maternal and child health.

FURTHER RESEARCH AND CONCLUSION

The goal of long range study in cooperation with the plant breeders is to raise the protein content of rice. Increases in the protein content of rice can be achieved with presently available information and technology. It is known that the protein content of rice varies not only with variety but also with fertilization, environment and cultural conditions. Increase in protein content is possible through fertilization and breeding.

Developing rice that has a larger proportion of lysine is also a goal of future research. If, in fact, a high lysine cultivar exists in rice, we should find it and breed it (Juliano, 1972).

Acceptability, digestibility and keeping quality of brown rice are still unsolved problems. These need to be improved to increase consumption of brown rice.

To increase utilization of parboiled rice which provides more vitamins and minerals than does white rice, acceptability, color, flavor, and odor of the parboiled rice should be improved for the people who prefer white rice.

Color problems due to riboflavin still exist in current enrichment processes. Practical means to include riboflavin in enriched rice should be sought urgently. Riboflavin deficiency in a rice eating population is difficult to correct even with supplementation, due to the limited availability of milk.

Finally, utilization of the protein and the other nutrients in rice bran and polish is highly desirable. This will require development of milling techniques or improved classification procedures, or both.

Evaluation of nutritional adequacy of rice, based on nutritional requirements of users and essential nutrients, indicated that rice is inadequate in protein content, protein quality, vitamin A, thiamine, riboflavin, iron and calcium. Also these inadequacies are evidenced by the nutritional status of rice-eating people.

Numerous studies have shown considerable nutrient losses in the entire food delivery chain. To improve the rice diet and nutrition of rice-eating people : First, nutrient losses should be minimized through undermilling, less severe washing, and cooking with steam. Second, the nutritional quality of rice and therefore the rice diet should be improved through enrichment or parboiling or supplementation. The above suggestions should be accompanied by nutrition education of the public and by a positive government nutrition policy.

REFERENCES

Aalsmeer, W.C., Mitra, K., and Obando, N. 1954. Rice enrichment in the Philippines. FAO Nutritional Studies No.12 Rome.

Adair, C.R. 1972. Production and utilization of rice. Rice Chemistry and Technology, ed. D.F. Houston, Am. Assn. Cereal Chem.,St. Paul,Minn.

Anonymous. 1974. Scientific status summary of the Institute of Food Technologists' Expert Panel on Food Safety and Nutrition and the Committee on Public Information-The effects of food processing on nutritional values. Food Technol. 28(10):77.

Autret, M., Périssé, J., Sizaret, F., and Cresta, M. 1968. Protein value of different types of diet in the world; Their appropriate supplementation. FAO Nutrition Newsletter. 6(4):1.

Balasubramanian, S.C., Narasinga Rao, B.S.,Ranamurthy, P.S.V.,and Shanalikar, I.S. 1962. Investigation of Indian foodstuffs for some major and minor nutrients. Indian J. Med. Res. 50:779.

Baldi, G. 1969. Studi sulle proteine del riso. Riso. 18:3 Cited by Juliano (1972).

Basu, K.P. 1946. Studies on protein, fat and mineral metabolism in Indians. Special REport No. 15, Indian Research Fund Association.

Bressani, R., Elias, L.G., and Juliano, B.O. 1971. Evaluation of the protein quality of milled rices differing in protein content. J. Agr. Food Chem. 19:1028.

Brouhult, S. and Sandergren, E. 1954. The Proteins, eds. H. Neurath and K. Bailey, Academic Press, New York.

Brooke, C.L. 1972. Rice enrichment. Rice Chemistry and Technology, ed. D.F. Houston, Am. Assn. Cereal Chem. St. Paul. Minn.

Cagampang, G.B., Cruz, L.J.,Espiritu, S.G.,Santiago, R.G.,and Juliano, B.O. 1966. Studies on the extraction and composition of rice proteins. Cereal Chem. 43:145.

Cagampang, G.B., Cruz, L.J., and Juliano, B.O. 1971. Free amino acids in the bleeding sap and developing grain of the rice plant. Cereal Chem. 48:533.

Casas, A., Barber, S., and Castillo, P. 1963. Factors de calidad de arroz.x. Distribucion de grasa en el endospermo. Rev. Argoquim Tecnol. Alimentos 3:241. Cited by Juliano (1972).

Chai, R. S. and Chang, K.H. 1965. Progress report-Korea. Second Far East Symposium on Nutrition. U.S. Govt. Print. Off., Washington, D.C.

Chancel, J.G. 1962. Le riz de camargue. Pharm. D. Thesis, Fac. Med. Pharm. Marseilles. Cited by Juliano (1972).

Chatterjee, D. 1951. Note on the origin and distribution of wild and cultivated rices. Indian J. Genet. Plant Breeding. 11:18.

Chen, S.C.S., Fox, H.M. and Kies, C. 1967. Nitrogenous factors affecting the adequacy of rice to meet the protein requirements of human adults. J. Nutr. 92:429.

Clark, H.E., Howe, J.M., and Lee, C.J. 1971. Nitrogen retention of adult human subjects who consumed a high-protein rice. Am. J. Clin. Nutr. 24:324.

Darby, W.J. 1965. The nutritional anemias. Second Far East Symposium on Nutrition. U.S. Govt. Print. Off., Washington, D.C.

El-Dash, A. 1975. The effect of parboiling on the consumer acceptance of rice. Cereal Foods World. 20:101.

FAO. 1948. Rice and rice diets. FAO Nutritional Studies. No.1, FAO, Washington, D.C.

FAO. 1954. Rice and rice diets. FAO Nutritional Studies No.1, revised. Rome.

FAO. 1957. Rice trade glossary. Rome.

Fukui, T. and Nikuni, Z. 1959. Changes in sugar content during the germination of rice seeds. Application of ion-exchange chromatography. Nippon Nogeikagaku Kaishi 33:72. Cited by Juliano (1972).

Furter, M.F. and Lauter, W.M. 1949. Fortifying grain products. U.S. Patent 2, 475, 133.

Gariboldi, F. 1974. Rice Parboiling. FAO. Rome.

Grist, D.H. 1959. Rice, John Wiley & Sons, Inc., New York, 3rd Ed.

Guha, B.C. and Mitra, B.R. 1963. Studies on the consistency of thiamine and protein contents of pure-bred strains of rice. Ann. Biochem. Exptl. Med. (Calcutta). 23:69.

Guthrie, H.A. 1975. Introductory Nutrition, 3rd ed. The Mosby Co.,St.Louis.

Hinton, J.J.C. 1948. Parboiling treatment of rice. Nature, 162:913.

Houston, D.F.,Mohammad, A., Wasserman, T.,and Kester,E.B. 1964. High-protein rice flours. Cereal Chem. 41:514.

Houston, D.F.,Allis, M.F., and Kohler, G.O. 1969. Amino acid composition of rice and rice by-products. Cereal Chem. 46:527.

Houston, D.F. and Kohler, G.D. 1970. Nutritional properties of rice. National Academy of Sciences, Washington, D.C.

Interdepartmental Committee on Nutrition for National Defense.(ICNND). 1957. Korea:Nutrition Survey of the Armed Forces. National Institute of Health, Bethesda, Md.

International Rice Research Institute. 1964. Annual Report 1963. Los Banõs, Laguna, Philippines.

International Rice Research Institute. 1970. Annual Report 1969. Los Banõs, Laguna, Philippines.

Jansen, G.R. and Howe, E.E. 1964. World problems in protein nutrition. Am. J. Clin. Nutr. 15:262.

Joint FAO/WHO Expert Committee. 1962. Calcium requirements. FAO Nutrition Meeting Report Series No. 30. FAO and WHO,Geneva.

Joint FAO/WHO Expert Committee. 1967. Requirements of vitamin A, thiamine, riboflavin and niacin. FAO, Rome.

Joint FAO/WHO Expert Committee. 1970. Requirements of ascorbic acid, vitamin D, vitamin B_{12}, folate and iron. FAO, Rome.

Joint FAO/WHO Ad Hoc Expert Committee. 1973. Energy and protein requirements. FAO, Rome.

Juliano, B.O., Bautista, G.M.,Lugacy, J.C., and Reyes, A.C. 1964. Studies on the physico-chemical properties of rice. J. Agr. Food Chem. 12:131.

Juliano, B.O. 1966. Physico-chemical data on the rice grain. Intern. Rice Res. Inst. Tech. Bull. 6:150.

Juliano, B.O. 1972. The rice caryopsis and its composition. Rice Chemistry and Technology. ed. D.F.Houston, Am. Assn. Cereal Chem. St. Paul,Minn.

Juliano, J.B. and Aldama, M.J. 1937. Morphology of Oryzae Sativa L. Philippine Agriculturist, 26:1.

Kawasaki, C. 1961. Modified thiamine derivatives.Paper presented at Tenth Pacific Sci. Congr. Univ. of Hawaii, Philippines, Aug-Sept.

Kennedy, B. and Tsuji, F. 1952. Thiamine retention in brown rice. J. Am. Diet. Assn. 28:1144.

Kester, E.B.,Lukens, H.C.,Ferrel, R.E.,Mohammad, A., and Iinfrock,D.C.1963. Influence of maturity on properties of western rices. Cereal Chem. 40:323.

Kik, M.C. 1942. Nutritive studies of rice and its by-products. Ark. Agr. Exp. Station Bull. No. 416, Fayetteville, Arkansas.

Kik, M.C. 1945. Effect of milling, processing, washing, cooking and storage on thiamine, riboflavin and niacin in rice. Ark. Agr. Exp. Station Bull. No. 458, Fayetteville,Arkansas.

Kik, M.C. and Williams, R.R. 1945. The nutritional improvement of white rice. Natl. Res. Council Bull. No. 112. National Research Council, National Academy of Sciences, Washington,D.C.

Kik, M.C. 1951. Nutritive studies of rice. Ark. Agr. Exp. Station Bull. No. 508, Fayetteville, Arkansas.

Kik, M.C. 1954. Nutritive value of rice germ. J. Agr. Food Chem. 2:1179.

Kik, M.C. 1956. Nutrients in rice bran and rice polish quality with amino acids. J. Agr. Food Chem. 4:170.

Kik, M.C. 1957. The nutritional value of rice and its by-products. Ark. Agr. Exp. Station Bull. No. 589, Fayetteville, Arkansas.

Korean FAO Association of the United Nations. 1975. Korean food composition table. In Korean Recommended Dietary Allowances, 2nd ed. Korean FAO Association, Seoul, Korea.

Lee, M.H. 1968. Current status of garrison and combat feeding. Third Far East Symposium on Nutrition.(Manila, Feb. 1967), U.S. Govt. Print. Off., Washington, D.C.

Leonzio, M. 1967. Contenuto di pentosani nel riso e nei suoi principali sttoprodott. Riso, 16:313. Cited by Juliano (1972).

Limcango-Lopez, P.D., Acharasco, F.S., and Castillo, F.S. 1962. The chemical composition of rice and corn by-products:1.Proximate composition and minerals. Philippine Agriculturist 46:324.

Lózsa, A. and Koller, K. 1952. Die Bestimmung des Vitamin B_1 Gehalts und des biologischen Wertes der Eiweissfraktionen der verschiedenen ungarischen Reissorten. Acta PhySiol. Acad. Sci. Hung. 3 (suppl.1):19. Cited by Juliano (1972).

Malakar, M.C. and Banerjee, S.N. 1959. Effect of cooking rice with different volumes of water on the loss of nutrients and digestibility of rice in vitro. Food Res. 24(6):751.

Mansinghal Associates. 1968. A project report for identifying the regions of India suitable for introduction of fortified rice. vol.1, Profile of rice- an all India view;vol.2, Area surveys and alaysis. Mansinghal Associates, New Delhi, India.

McCall, E.R., Hoffpauir, C.L., and Skau, D.B. 1951. The chemical composition of rice. A literaure review. U.S.Dept. Agr. Bur. Agr. Ind. Chem. Mimeo. Circ. AIC-312; 49.

McCall, E.R., Jurgens, J.F.,Hoffpauir, C.L., Pons, W.A.,Stark,S.M.,Cucullu, A.F., Heinzelman, D.C.,Cirino,V.O., and Murray, M.D. 1953. Composition of rice. Influence of variety and environment on physical and chemical composition. J. Agr. Food Chem. 1:988.

Merrill, D.F. 1958. Composition of cereal grains and forages. National Academy of Science-National Research Council Publication 585, Washington, D.C.

Mitsuda, H. 1962. Paper presented at 1st International Congress of Food Science and Technology, Sept. London. Cited by Brooke (1972).

Narayanaswamy, D. 1974. Supplementary value of protein enriched cereal foods containing varying amounts of protein to poor rice and ragi diets. The Indian J. Nutr. and Dietet. 11:72.

National Academy of Sciences-National Research Council. 1961. Progress in meeting protein needs of infants and preschool children. NAS-NRC Publication 843, Washington,D.C.

National Academy of Sciences-National Research Council,1974. Proposed fortification policy for cereal-grain products. NAS-NRC, Washington,D.C.

Nicholls, L. 1947. Treatment of milled raw and parboiled rice. Nature,160:298.

Palmiano, E.,Almazan, A.M., and Juliano, B.O. 1968. Physico-chemical properties of protein of developing and mature rice grain. Cereal Chem. 45:1.

Pecora, L.J. and Hundley, J.M. 1951. Nutritional improvement of white polished rice by the addition of lysine and threonine. J. Nutr. 44:101.

Platt, B.S. 1939. Nutrition in the colonial empire. 1st rep. pt. 1.

Proc. 6th Pacific Science Congress, San Francisco. 1939. p.265, 271,279,287, 313. Cited by FAO (1948).

Raghavendra, R.S.N. and Juliano, B.O. 1970. Effect of parboiling on some physico-chemical properties of rice. J. Agr. Food Chem. 18:289.

Ranganathan, S., Sundarajan, A.R., and Swaminathan, M. 1937. Survey of the nutritive value of Indian foodstuffs. Part. 1. The chemical composition of 200 common foods. Indian J. Med. Res. 24:689.

Revelli, M. 1968. Studio sperimentale sul contenuto in vitamin del gruppo "B" ed in ferro, del riso e dei suoi derivati alimenturi. Minerva Di etol. 8:70. Cited by Juliano (1972).

Roschevicz, R.J. 1931. A contribution to the knowledge of rice. Bull. Appl. Bot., Genet. and Plant Breeding. 27(4):1.

Rosenberg, H.R., Culik, R., and Eckert, R.E. 1959. Lysine and threonine supplementation of rice. J. Nutr. 69:217.

Sampath, S. 1962. The genus Oryzae : its taxonomy and species interrelationships. Oryzae, 1(1):1. Cited by Adair (1972).

Saxena, K.L., Chakraborti, C.H., and Nath, M.C. 1966. Effect of rice polishing concentrate on the nitrogen, calcium, and phosphorus metabolism of Albino rats kept on rice and jowar diets. Indian J. Nutr. Diet. 3(4):121.

Schaefer, A.E. 1965. Biochemical and dietary assessments in eight far east countries by the ICNND. Second Far East Symposium on Nutrition (Taipei, May 1964). U.S. Govt. Print. Offi., Washington, D.C.

Sharma, S.D. and Shastry, S.V.S. 1965. Taxonomic studies in genus Oryzae L. 111. O. rufipogon Griff. sensu stricto and O. nivara Sharma et Shastry nom. nov. Indian J. Genet. Plant Breeding. 25:157.

Sure, B. and House, F. 1948. The relative biological values of protein in cereal grains. J. Nutr. 36:595.

Sure, B. 1950. Nutritional improvement of cereal grains with small amounts of foods of high protein content. Ark. Agr. Exp. Station Bull. No.493, Fayetteville, Arkansas.

Swaminathan, M. 1941. The effect of washing and cooking on the nicotinic acid content of raw and parboiled rice. Indian Med. Res. Mem. 29:183.

Swaminathan, M. 1942. Effect of washing and cooking on vitamin B_1 content of raw and parboiled milled rice. Indian J. Med. Res. 30:409.

Tai, Y. C. 1965. Nutrition surveys and rice enrichment in the armed forces, Republic of China. Second Far East Symposium on Nutrition. U.S. Govt. Print. Off.,Washington, D.C.

Taira, H. 1962. Botan. Mag. (Tokyo), 75:242, Cited by Houston (1970).

Tamura, S. and Kenmochi, K. 1963. Studies on amino acid content of rice. 111. Distribution of amino acid in rice grain. Nippon Nogeikagaku Kaishi, 37:753. Cited by Juliano (1972).

Tara, K. A. and Bains, G.S. 1971. Effect of cooking rice on the stability of lysine and threonine in a model system. The Indian J. Nutr. Dietet. 8:186.

Tecson, E.M.S.,Esmama, B.V.,Lontok, L.P., and Juliano, B.O. 1971. Studies on the extraction and composition of rice endosperm glutelin and prolamin. Cereal Chem. 48:168.

U. S. Department of Agriculture, Economic Research Service. 1964. World food budget, 1970. Foreign Agr. Economic Report No. 19. Washington, D.C.

U. S. Food and Drug Administration. Federal Register. 21:10412, 1956; 22:6887, 1957;23:1170, 1958.

Vidal, A.J. and Juliano, B.O. 1967. Composition of waxy and nonwaxy rice. Cereal Chem. 44:86.

Vimokesant, S. L. 1975. Effects of betel nut and fermented fish on the thiamine status of northeastern Thais. Am. J. Clin. Nutr. 28:1458.

Waddell, J. 1953. The amino acid supplementation of cereal diets. Processed Plant Protein Foodstuffs, ed. A. A. Altschul, Jr. Academic Press, New York.

Wakefield, L.M. and Rowland, R. 1973. Protein quality of rice polish and combination with peanut flour, fish protein concentrate, and lysine. Cereal Chem. 50:428.

Watt, B.K. and Merrill, A.L. 1963. Composition of Foods. Agr. Handbook No.8, USDA, Washington, D.C.

Williams, K.T. and Bevenue, A. 1953. A note on the sugars in rice. Cereal Chem. 30:267.

Williams, V.R.,Wu, W.T.,Tsai,H.Y., and Bates, H.G. 1958. Varietal differences in amylose content of rice starch. J. Agr. Food Chem. 6:47.

Wodicka, V.O. 1974. U. S. regulation on enriched and fortified cereal products. Cereal Foods World. 19:381.

NUTRITIONAL PROPERTIES OF RICE

by

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AN ABSTRACT OF A MASTER'S REPORT

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Abstract

Many people throughout the world are dependent on rice as the staple food of their diet. The purpose of this report is to overview the nutritional properties of rice as rice-eating populations use it, and to highlight ways to improve nutritional status, with special considerations being given to the Republic of Korea.

The nutrient content of rice, nutritional adequacy based on the nutritional requirements of users and essential nutrients, and nutrient losses during milling, storage, washing and cooking were discussed. Rice is inadequate in protein content and quality, vitamin A, thiamine, riboflavin, iron, calcium. These inadequacies are also evidenced by respective nutritional deficiencies of rice-eating people.

To improve rice and rice diets and to further nutrition of rice-eating people, minimizing nutrient losses during handling should be emphasized by proper milling, storage, washing and cooking. Positive approaches, such as parboiling, enrichment, supplementation are also highly desirable. For best results, nutrition education of the public and a positive nutrition policy of the government should be accompanied by the above suggestions.