

Proceedings of the
FIFTH NATIONAL SEMINAR ON
RICE RESEARCH AND PRODUCTION
KALA SHAH KAKU
FROM APRIL 25 TO 27, 1985

NUTRITIONAL QUALITY OF RICE GRAIN

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INTRODUCTION

Rice, the ancient staple of the Asian world, which feeds more than half the world's people, was probably one of man's first crops. Rice is nutritionally superior to many other foods that are rich in carbohydrate. The protein content of the grain, although subject to extreme varietal and environmental variability, averages about 7 % in milled rice and 8 % in brown rice. The protein content of rice varieties of world collection ranges from 6-14 %. The quality of rice protein is basically a function of the protein content of the grain. As the protein level is increased, either agronomically or genetically, the degree of protein loss in milling is reduced, indicating that most of the additional protein is not in the bran. Furthermore, the amino acid composition remains relatively stable. (Jennings et al, 1979). It is well known that there is a negative correlation between protein content and grain yield (Clark and Quisenberry, 1929). On the other hand, a positive correlation exists between protein yield and grain yield (Tanaka, 1983). The order of limiting amino acids in cereal grains is lysine and threonine (Khan, 1981). Although rice protein contains higher amounts of the essential amino acids than other cereals, making it higher in nutritive value, one of the important objectives of breeding rice varieties should consist in increasing these amino acids (Tanaka and Sekiguchi, 1966).

In past research, the quality evaluation of cereal grains has emphasized physical properties, rather than nutritional quality characteristics. However, recent years have brought a greater awareness of the need for biological evaluation of cereal proteins. This paper deals with nutritional aspects of cereal grains and factors affecting the protein quality of rice, and its products.

COMPOSITION AND PROTEIN QUALITY OF CEREALS

Chemical composition, efficiency of utilization of protein and digestible energy of wheat, maize, rice, barley, millet and sorghum are given in Table-1.

All cereal grains contain carbohydrate mainly starch as the principle component with the highest value for rice (90.1 %) and the lowest value for sorghum (67.4 %). As in most starches, both of the major components (amylose and amylopectin) occur generally in rice starch. In common rice, amylose amounts to 12-35 % of total starch (Houston and Kohler, 1970). The second highest component of cereal grain is protein. The content in millet is highest (13.4 %) whereas rice contains only 8.9 %. The fat content is relatively low in rice (1.4 %) and highest for maize (5.7 %). Due to low fat content, the cereal grains have a low energy density (approx. 450 kcal/100g) which causes a problem in infant feeding. The crude fibre concentration is low in most cereals and with a very low value in polished rice (0.7 %).

The thiamin and riboflavin contents are low in cereals whereas niacin content is relatively high. The concentration of iron is low especially in rice (3mg/100g) while the zinc contents are similar in all cereals.

It is well established that cereal grains are low in lysine. The concentration of sulphur containing amino acids is quite high with values from 3.6-4.0g/16gN. However, the value for sorghum is below this range (2.8g/16gN). The order of limiting amino acids in rice protein is lysine, threonine and ~~iso~~-leucine (Khan, 1981). The total and digestible lysine content of different cereal grains are given in Table-2. The digestibility of lysine in rice is 99 % which is highest as compared to other cereals.

Assuming that FAO (1973) pattern of 5.5 % lysine in the protein is the ideal level of lysine for the child, we may compare the lysine content of rice protein. On this basis rice protein cannot meet the lysine requirement of a child. However, rice protein can supply all essential amino acids to meet the amino acid requirement of an adult (Table-3).

True protein digestibility (TD) varies between 84.8 % for sorghum to 100.0 % for rice. The relative low digestibility of sorghum can partly be explained by its high crude fibre (4.8 %) and tannin (1.9 %) contents. Both these factors have a negative effect on digestibility of protein and energy (Just et al, 1976; Eggum and Christensen, 1975). Rice has a very low content of both crude fibre and tannin and this might explain the very high digestibility of rice protein and energy as well.

As the biological value (BV) is directly dependent on the concentration of the first limiting amino acid (lysine) the highest BV (71 %) was obtained in rice and the lowest in wheat (55 %). Utilizable protein (UP) is a derived figure ($\% \text{ protein} \times \text{NPU}/100$) and depends on both protein concentration and protein quality (NPU). The UP value for sorghum was lowest due to low NPU of the grain. On the contrary, the relatively low UP in rice was primarily due to low protein content.

It appears from Table 1 that protein quality differs in different cereal grains. The NPU values vary from 50-71 %. In other words, 50-29 % of the ingested nitrogen is excreted in urine and faeces.

FACTORS AFFECTING THE QUALITY OF RICE AND ITS PRODUCTS

The quality of rice is influenced by many factors such as variety, environment, processing and storage.

Effect of Agronomic Conditions

Several semidwarf breeding lines have been developed with higher protein contents than traditionally grown rice. Protein content is significantly influenced by variety and environment (McCall et al, 1953), by crop season or planting date (Cagampang et al, 1966), and by nitrogen fertilization (Juliano et al, 1964). Juliano et al (1964) have shown a difference of some 4 % in protein content of the same rice planted at different seasons. Table-4 indicates that protein content of milled rice was negatively correlated with the lysine content. The correlation co-efficients of protein content with TD, BV and NPU were negative but not significant. NPU for milled rice samples were positively correlated with TD and BV. The utilizable protein showed a corresponding increase with protein content and the correlation was significant. Thus the protein content of rice has the major influence on the nutritional value of this cereal. The effect of nitrogen fertilizer on the quality of rice has been reported by Eggum and Juliano (1975). It was found that an increase in milled rice protein from 8.14-9.90 in IR8 and from 9.90-13.0 in IR 480-5-9 due to N fertilizer application had no significant effect on the lysine content of the protein and had little effect on the TD, BV and NPU of the protein (Table-5).

N-applications normally increase yield and/or protein content of grains and therefore, also the production per area of protein and individual amino acids including lysine. A decrease in the nutritional value of protein, wheather expressed as a reduction in lysine or NPU, will probably always be more than balanced by a larger protein and amino acid production (Eppendorfer,1975).

Effect of Processing

Milling

Milling has a profound effect on rice composition. The compositional differences of rice layers are given in Table 6. The outer layer (bran) contains far more of the essential nutrients than the endosperm (milled rice).

Major proportions of the fat, fibre and ash of the grain are removed with the bran. Protein, which is concentrated between the bran and starchy layers and decreases toward the centre of rice kernel, is fairly well retained in milled rice. The higher concentrations of lysine and threonine in the bran result in better protein quality than milled rice (Juliano, 1972). The major constituent of milled rice is starch and it is most concentrated in the endosperm portion of the kernel. Protein is the second abundant constituent of rice grain and is unique among the cereal proteins because it contains at least 80 % glutelin (alkali soluble protein). Glutelin has the closest amino acid composition to milled rice protein, probably it is the major protein fraction (Table 7).

The nutritional value of rice with respect to vitamins is affected by the content of individual vitamins present and the amount removed or destroyed by milling or processing. Vitamin contents of rice and its by-products are summarized in Table-8 significant losses of essential vitamins occurs in the milling process. Milling therefore, inevitably reduces the protein, B-vitamins and mineral contents of the rice grain, but milling is required for improving the palatability and digestibility of rice.

Cooking

The rice is frequently rinsed or washed before cooking to remove dust and foreign particles and in some cases rinsed after cooking. Baking

is sometimes used and frying or browning in oil is involved in some processes. The parboiling process retains vitamin B contents and may be considered one way of enriching milled rice.

Many of the nutrients are concentrated in the outer zones of the endosperm and are susceptible to removal. It has been estimated that washing and cooking processes remove 10 % of the protein, 50 % of the calcium and phosphorus, 74 % of the iron and 15 % of the calories (Ranganathan et al, 1937). Table 9 shows the effect of cooking and parboiling on the protein quality of rice. The amino acid composition was not affected by cooking. However, cooking reduced digestibility of protein but had no adverse effect on the NPU of rice because a corresponding increase in BV resulted from the cooking. Parboiling before milling resulted in lower TD values (uncooked or cooked rice) as compared to raw rice, but the effect was less than that from cooking.

Vitamin content is probably subject to the most serious reduction. Because the B-vitamins are water soluble, the pre-cook rinse or wash seriously depletes the already low content of thiamine, riboflavin and niacin. According to Swaminathan (1942) a loss of 55 % and 9 % of thiamine in milled and parboiled rice respectively occurs during washing before cooking. However, cooking in excess water that is discarded removes large proportions of the vitamins. Table 10 indicates the losses of thiamine, riboflavin and niacin contents of rice as affected by different methods of cooking. It is evident that losses of B-vitamins are higher in cooked rice if excessive water is removed after boiling. The nutritive importance of not washing before cooking and of using the correct minimum amount of water during cooking is clearly evident. The higher temperatures of frying cause greater thiamine destruction. Frying to a golden brown colour (15 min.) caused some 45-70 % loss (Kennedy and Tsuji, 1952).

The protein quality of some products made from rice is illustrated in Table 11. The lysine content (g/16gN) ranges from 1.6 (rice crunchies) to 6.2 (kheer). Baking of rice bread on flat iron plate at 220-230°C for 7-10 min. had no effect on either TD or BV. However, rice crunchies (breakfast-cereal) had poor protein quality as indicated by low TD and NPU values. The enrichment of breakfast cereals, based on rice, appears justified. The protein quality of kheer was highest due to higher content of lysine. The protein quality of processed products depends on duration and temperature of heat treatment and the presence of moisture and reducing substances (Bender, 1972).

Effect of Storage

Much of traditional rice-growing area of the world lies in the humid tropics, with a climate characterized by high average temperature (around 30°C) and relative humidity (around 85 %). According to De Padua (1974) the post harvest losses from harvesting to milling of rice grain range from 10-30 % in South-east Asia.

Nutritional losses during storage may result from insect or micro-organism attack, rancidification of oil, changes in protein or losses in vitamins. All of these become more rapid as the grain moisture or storage temperature is increased. In Japan, where rice is usually stored as brown rice, the use of refrigerated commercial storage is expanding. The low content of fat in milled white rice makes its deterioration relatively

unimportant nutritionally. Little information is available on changes in the proteins during storage, though some data show a decrease in protein quality after six months storage at 37.5°C (Houston and Kohler, 1970).

The greatest losses during storage probably occur in the B-vitamins content. Table 12 lists average losses of several varieties of rice for warm (attic) and cold (-10°C) storage during $2\frac{1}{2}$ years. The strong protective action of low temperature is to be noted. It is of interest that white (milled) rice loses thiamine more rapidly than the other whole grain forms. In general, the losses due to storage are small as compared to those resulting from improper washing and cooking practices.

Studies of rice grain quality continue to point toward the need for interdisciplinary inputs for effectively improving and evaluating the grain quality. The biochemist, nutritionist and food scientist must work together to better identify this quality characteristic to be bred into rice varieties by the plant breeder.

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Table 1. Chemical Composition (on dry basis) and Biological Data of Six Cereal Grains (McCance and Widdowson 1960, Khan and Eggum 1978).

Grain variety		Wheat	Maize	Rice	Barley	Millet	Sorghum
Protein (Nx6.25)	(%)	12.3	11.4	8.9	12.8	13.4	9.6
Fat	(%)	2.2	5.7	1.4	3.9	5.5	4.5
Available carbohydrate	(%)	81.1	74.0	90.1	64.9	73.7	67.4
Crude fibre	(%)	1.2	2.3	0.7	4.3	1.8	4.8
Ash	(%)	1.6	1.6	1.6	2.2	1.8	3.0
Calories/100g		436	461	432	454	459	447
x Thiamin (mg/100g)		0.52	0.37	0.34	0.12	0.73	0.38
x Riboflavin (mg/100g)		0.12	0.12	0.05	0.05	0.38	0.15
x Niacin (mg/100g)		4.3	2.2	4.7	3.1	2.3	3.9
Fe (mg/100g)		5	4	3	7	8	10
Zn (mg/100g)		3	3	2	3	3	2
Lysine (g/16gN)		2.3	2.5	3.4	3.2	2.7	2.7
Threonine (g/16gN)		2.8	3.2	3.4	2.9	3.2	3.3
Methionine+cystine (g/16gN)		3.6	3.9	4.0	3.8	3.6	2.8
Tannin	(%)	0.5	0.5	0.1	0.8	0.7	1.9
Protein digestibility	(%)	96.0	95.0	100.0	88.0	93.0	84.8
Biological value	(%)	55.0	61.0	71.0	70.0	60.0	59.2
Net protein utilisation	(%)	53.0	58.0	71.0	62.0	56.0	50.0
Utilisable protein	(%)	6.5	6.6	6.3	7.9	7.5	4.8
Digestible energy	(%)	86.4	87.2	96.3	81.0	87.2	79.9

Table 2. Total and digestible lysine in cereal grains (Eggum, 1976)

Lysine source	Total Lysine in D.M. (g/16gN)	Dig. Lysine in D.M. (g/16g N)	Difference (%)
Barley	3.69	2.80	24.11
Oats	4.03	3.21	20.34
Wheat	2.55	2.02	20.80
Rye	3.67	2.40	26.60
Maize	2.73	2.31	15.38
Sorghum	1.83	1.33	27.30
Rice	3.54	3.51	0.85

Table 3. AMINO ACID PROFILE OF REFERENCE PATTERN
AND RICE PROTEIN(g/16gN)

Amino Acid	FAO/WHO Child	Pattern Adult	Rice Protein
Isoleucine	4.0	1.8	4.0
Leucine	7.0	2.5	7.7
Lysine	5.5	2.2	3.4
Phenylalanine	2.4	1.5	4.8
Total sulfur Amino acids	3.5	2.4	4.9
Threonine	4.0	1.3	3.4
Tryptophan	1.0	0.6	1.1
Valine	5.0	0.8	5.4

Table 4. MEAN TRUE DIGESTIBILITY, BIOLOGICAL
 VALUE AND OTHER PROPERTIES OF PROTEIN
 OF RICES DIFFERING IN PROTEIN CONTENT
 (Eggum, 1976)

Protein source	Protein (IN D.M)	TD (%)	BV (%)	NPU (%)	UP (%)	Lysine (g/16gN)
Milled rice						
Intan	6.88	100.1	75.2	75.3	5.18	4.07
IR8	8.50	96.2	73.1	70.3	5.98	3.59
IR8	11.06	95.4	68.4	65.2	7.21	3.50
IR22	11.75	98.5	69.7	68.7	8.07	3.87
IR1103-15-8	13.13	95.9	74.3	71.1	9.34	3.65
IR480-5-9	13.56	94.5	67.9	64.2	8.71	3.34
BPI-76-1	17.06	94.4	70.1	66.2	11.29	3.19

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Table 5. EFFECT OF NITROGEN FERTILIZER APPLICATION ON PROTEIN QUALITY OF MILLED-RICE (EGGUM AND JULIANO, 1975)

Property	IR8		IR480-5-9			I.S.d (5%)
	0	120	0	60	90	
N.fertilizer level (kg/ha)	0	120	0	60	90	-
Protein(%N x 6.25) ^a	8.14	9.90	9.90	11.4	13.0	-
Lysine (g/16gN)	3.57	3.41	3.50	3.38	3.33	n.S
Methionine(g/16gN)	2.86	2.63	2.80	2.59	2.52	0.19
True digestibility(%)	99.2	99.0	99.8	100.0	100.0	1.3
Biological value(%)	69.5	69.2	71.0	68.4	67.7	1.5
Net Protein utilization (%)	68.9	67.8	71.0	68.8	67.8	2.1

a At 12% moisture.

Table 6. Chemical Composition (dry basis) of Brown Rice, Milled Rice and Bran (Resurreccion et al 1979; Singh and Juliano 1977; Cagampang et al 1976)

Constituent	Brown rice (0-100%) ^a	Milled rice (90-100%) ^a	Bran (0-6%) ^a
Starch (% anhydroglucose)	75.9	89.8	9.7
Amylose (%)	30.8	32.7	6.7
Total sugars (% glucose)	1.3	0.4	6.4
Crude fiber (%)	0.8	0.1	9.7
Dietary fiber (%)	1.9	0.7	28.4
Crude fat (%)	3.3	0.6	22.8
Crude protein (%)	8.4	7.7	15.7
Crude ash (%)	1.5	0.56	10.6
Phosphorus (%)	0.27	0.09	1.7
Phytin phosphorus (%)	0.14	0.03	1.1
Iron (mg/100 g)	2.0	0.67	15.7
Zinc (mg/100 g)	2.1	1.3	10.9
Lysine (g/16 g N)	4.1	3.8	5.6
Threonine (g/16gN)	3.7	3.7	4.1
Methionine + cystine (g/16 g N)	4.7	4.9	4.7
Tryptophan (g/16 g N)	1.2	1.2	1.2

^aAbrasive milling fraction of brown rice (% by wt).

Table 7. Levels of Essential Amino Acids of Protein Fractions and Protein of Milled Rice (gm/16.8m N)

Amino Acid	Protein Fraction				Milled Rice Protein, %
	Albumin	Globulin	Prolamin	Glutelin	
Isoleucine	4.05	3.03	4.68	5.27	4.13
Leucine	7.89	6.56	11.3	8.19	8.24
Lysine	4.92	2.56	0.51	3.47	3.80
Methionine	2.54	2.27	0.50	2.61	3.37
Methionine + cystine	5.40	2.27	0.80	4.09	4.97
Phenylalanine	2.97	3.32	6.26	5.42	6.02
Threonine	4.65	4.55	2.86	3.92	4.34
Tryptophan	1.88	1.34	0.94	1.16	1.21
Valine	8.72	6.18	6.97	7.31	7.21

Source: Juliano (1972).

Table 8. Vitamin Contents of Rice and its By-products (mg/100 g)
(Houston and Kohler 1970)

Vitamin	Brown rice	Milled rice	Rice bran	Rice polish	Rice embryo
Thiamin	0.34	0.07	2.26	1.84	6.5
Riboflavin	0.05	0.03	0.25	0.18	0.5
Niacin	4.7	1.6	29.8	28.2	3.3
Pyridoxine	1.03	0.45	2.5	2.0	1.6
Pantothenic acid	1.5	0.75	2.8	3.3	3.0
Folic acid	0.02	0.02	0.15	0.19	0.43
Inositol	119	10	463	454	373
Choline	112	59	170	102	300
Biotin	0.01	0.01	0.06	0.06	0.06

Table 9. Effect of Cooking and Parboiling of Milled Rice on the Amino Acid Composition (g/16 g N) and Nutritional Value of Protein in Growing Rats (Eggum et al 1977)

Protein property	IR480-5-9		IR480-5-9 Parboiled	
	Raw	Cooked	Uncooked	Cooked
Protein (% wet basis)	11.20	11.40	10.40	9.90
Lysine	3.42	3.34	3.60	3.71
Threonine	3.76	3.72	3.73	3.52
Valine	5.95	6.06	6.67	6.56
Methionine	2.33	2.15	2.10	2.08
Isoleucine	4.09	4.11	4.55	4.28
Leucine	8.64	8.16	8.46	8.14
Phenylalanine	5.59	5.28	5.44	5.10
Tryptophan	1.35	1.37	-	-
TD (%)	100.4	87.8	94.7	85.1
BV (%)	66.8	76.6	70.4	80.1
NPU (%)	67.1	67.3	66.7	68.3

Table 10. Loss of Vitamins by Cooking in Excess Water (Kik and Williams 1945)

Type of Rice and Method of Cooking	Thiamine		Riboflavin		Niacin	
	Content ($\mu\text{g/g}$)	Loss (%)	Content ($\mu\text{g/g}$)	Loss (%)	Content ($\mu\text{g/g}$)	Loss (%)
Brown						
Double boiler ^a	4.40	9.0	0.81	6.2	54.0	4.0
Open vessel ^b	4.40	32.2	0.81	26.0	54.0	31.0
"Earle" undermilled						
Double boiler	2.94	1.4	0.38	5.2	50.0	3.0
Open vessel	2.94	42.2	0.38	36.0	50.0	37.7
White						
Double boiler	0.65	1.3	0.27	7.4	20.6	3.4
Open vessel	0.65	54.0	0.27	18.2	20.6	41.0
"Converted" parboiled						
Double boiler	3.02	5.3	0.41	7.3	49.0	2.0
Open vessel	3.02	43.7	0.41	29.4	49.0	37.6

^aOne cup rice and 1-1/2 cups boiling water placed in top of a double boiler.
All water is absorbed and the cooked rice is not rinsed.

^bOne-half cup rice is placed in an open vessel with 8 cups boiling water,
cooked, placed in a colander, and drained.

Table 10. Loss of Vitamins by Cooking in Excess Water (Kik and Williams 1945)

Type of Rice and Method of Cooking	Thiamine		Riboflavin		Niacin	
	Content ($\mu\text{g/g}$)	Loss (%)	Content ($\mu\text{g/g}$)	Loss (%)	Content ($\mu\text{g/g}$)	Loss (%)
Brown						
Double boiler ^a	4.40	9.0	0.81	6.2	54.0	4.0
Open vessel ^b	4.40	32.2	0.81	26.0	54.0	31.0
"Earle" undermilled						
Double boiler	2.94	1.4	0.38	5.2	50.0	3.0
Open vessel	2.94	42.2	0.38	36.0	50.0	37.7
White						
Double boiler	0.65	1.3	0.27	7.4	20.6	3.4
Open vessel	0.65	54.0	0.27	18.2	20.6	41.0
"Converted" parboiled						
Double boiler	3.02	5.3	0.41	7.3	49.0	2.0
Open vessel	3.02	43.7	0.41	29.4	49.0	37.6

^aOne cup rice and 1-1/2 cups boiling water placed in top of a double boiler.
All water is absorbed and the cooked rice is not rinsed.

^bOne-half cup rice is placed in an open vessel with 8 cups boiling water,
cooked, placed in a colander, and drained.

Table 11. PROTEIN QUALITY OF PROCESSED RICE PRODUCTS (Khan & Eggum, 1978,1979)

Products	Rice bread	Rice Krunchies	Kichri	Kheer	Rice (Boiled)	
					Lentil [†]	milk & Sugar [†]
Protein (% N x 6.25)	8.9	8.3	11.4	9.5	11.6	9.2
Limiting Amino acid	Lysine	Lysine	Threonine	Threonine	Threonine	Threonine
Lysine (g/16 gN)	3.4	1.6	5.4	6.2	5.0	5.5
Methionine (g/16 gN)	3.1	2.2	1.7	2.6	1.7	2.6
Threonine (g/16 gN)	3.2	3.2	3.3	3.8	3.5	3.7
True digestibility(%)	100.0	80.0	92.0	96.0	91.0	92.0
Biological value (%)	71.0	53.0	71.0	84.0	65.0	80.0
Net Protein utilization(%)	72.0	42.0	65.0	81.0	59.0	73.0

Table 12. Average Losses of Nutrients in Rice During Storage (2½ years)

Type of Rice	Percentage Loss of Total Content		
	Thiamine	Riboflavin	Niacin
Attic storage			
Rough	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 (-10°C)			
Rough	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

Kik and Williams (1945).