Protein Quality of Rice Polish and Combinations with Peanut Flour, Fish Protein Concentrate, and Lysine[1]

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ABSTRACT

Assessment of proteins by cumulative weight gain, protein efficency ratio (PER), biological value (BV), and digestibility coefficient (DC) indicated rice polish as an effective means of increasing BV and PER in animal feeding experiments. DC indicates possible use of rice polish as a source of protein in India's diet. Rice polish and a protein concentrate had highest BV in this study. Rice polish unused in India may have market potential alone or blended with fish flour as a protein source.

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In a developing country like India with its exploding population, freedom from hunger will be difficult to attain. Inadequate food leads to malnutrition; associated with malnutrition are poverty, ignorance, and disease. A large proportion of the hungry population suffers primarily from protein deficiency. Consumption of protein-rich foods is vital for children's growth and development; low intake of protein during preschool years can result in mental and physical retardation. Protein deficiency is widespread among children in India and Indonesia (1).

Food scientists have developed low-cost protein foods suitable for infants and children based on such locally available, protein-rich materials as soybeans, legumes, oilseed meals from peanut and cottonseed, and fish protein concentrate. Little attention has been given to by-products wasted by the milling industry, mainly rice bran and rice polish. Rough rice yields 8% bran and 2% polish (2). It is estimated that about 2 million tons of rice bran and 500,000 lb. of rice polish are produced annually in India.

Rice polish is a good source of protein, fat, minerals, and B vitamins (3). It contains 12 to 14% protein, and its protein contains high proportions of albumins and globulins, which give it a higher potential nutritional value than that of milled rice (2).

Chakrabarti (3) has summarized the nutritive qualities of a fiber-free concentrate prepared from rice bran, called rice polishings concentrate (RPC). Digestibility, biological value (BV), and protein efficiency ratio (PER) of Indian pulses increased when supplemented with RPC (4). Rats on a choline-deficient diet accumulated in their livers large amounts of lipids which were not observed when RPC was added (5). RPC prevented development of cholesterol fatty livers, which are induced by a high-cholesterol diet (6).

Availability of iron in RPC was determined by regenerating hemoglobin levels in rats made anemic with phenylhydrazine. RPC regenerated hemoglobin in anemic rats better than ferric ammonium citrate did (3). When poor, vegetarian diets, based on rice and jowar, were supplemented with RPC (7), growth and hemoglobin and red blood cell counts increased. Retention of nitrogen, calcium, and phosphorus by rats on rice and jowar diets increased when their diets were supplemented with RPC (8). Those favorable nutritional qualities prompted us to compare (by biological assay) the protein quality of rice polish alone and in combinations with peanut flour, fish protein concentrate, and lysine with casein.

MATERIALS AND METHODS

Growth and metabolic experiments were used to evaluate protein quality. Criteria derived from growth experiments were cumulative weight gain and PER and liver protein. In the nitrogen balance experiment, BV and digestibility coefficients (DC) were used to measure protein quality.

Growth Experiment

Six diets and a control (casein) were formulated after Campbell (9), as shown in Table I. The protein of all diets was maintained at 10%. The diets listed in Table I were as follows: 1, casein; 2, rice polish (RP); 3, rice polish plus peanut flour (RP+P); 4, rice polish plus fish protein concentrate (RP+F); 5, rice polish plus lysine (RP+L); 6, rice polish plus peanut flour plus lysine (RP+P+L); 7, 4% egg albumin (EA). Ingredients for the diets used in the growth and nitrogen balance

TABLE I. COMPOSITION OF DIETS, PERCENTAGES

Ingredients	Diets[a]						
	1 Casein	2 RP	3 RP+P	4 RP+F	5 RP+L	6 RP+P+L	7 EA
Casein (purified, high nitrogen)	10.0	...	...	...	...	...	...
Rice polish	...	74.6	44.8	44.8	74.6	44.8	...
Peanut flour	...	...	6.8	...	...	...	...
Fish protein concentrate	...	...	...	5.0	...	...	...
Corn starch	70.0	5.4	28.4	30.2	5.4	28.4	76.0
Corn oil	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Nonnutritive cellulose	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Salts, USP XIV	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Vitamin mixture	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L-Lysine HCl	...	...	...	...	0.187	0.262	...
Egg albumin	...	...	...	...	...	...	4.0

[a]RP=rice polish; RP+P=rice polish + peanut flour; RP+F=rice protein + fish protein concentrate; RP+L=rice polish + lysine; RP+P+L=rice polish + peanut flour + lysine; and EA=egg albumin.

experiments were weighed and mixed in a Hobart mixer, and stored in a freezer. The amino acid content of the diets and the minimum amino acid requirements of the rat are given in Table II.

A completely randomized design was used. Sixty male weanling albino rats of the Sprague-Dawley strain, 22 days old, and weighing from 46 to 55 g. were used in the growth experiment. Ten, selected randomly, were assigned to each diet. The rats were housed individually in metal screen-bottom cages, in a room maintained at 26° to 28°C. Feed and water were provided ad libitum for 4 weeks. Body weight and feed intake were recorded weekly.

At the end of the 4-week growth period, each rat was anesthetized with chloroform, the abdominal and thoracic cavities were opened, and the entire liver removed quickly, blotted with filter paper, wrapped in aluminum foil, and stored in a freezer at −10°C. until it was analyzed for nitrogen. Each liver was thawed, weighed, and minced with scissors. Duplicate 1-g. samples were taken for nitrogen determination by the macro-Kjeldahl method (10).

Nitrogen Balance

The technique of Mitchell (11) was used to determine the BV of protein. To correct for endogenous losses, endogenous urinary and fecal nitrogens were determined. The rats were kept on a 4% egg-albumin diet.

Sixty male albino rats of the Sprague-Dawley strain, 5 weeks old and weighing from 93 to 103 g., were used in a random design. Ten, selected randomly, were assigned to each of the same six diets used in the growth experiment. The rats were housed individually in metabolic cages in a room maintained at 26° to 28°C. Feed and water were given ad libitum. Body weight and feed intake were recorded at the beginning and end of each collection period.

The metabolic period was 10 days, followed by 3 days of adjustment and 7 days for the collection period. Daily urine samples were taken for the nitrogen

TABLE II. AMINO ACID CONTENTS (PERCENTAGES) OF THE SIX DIETS AND MINIMUM REQUIREMENTS FOR THE RAT

Amino Acid	Minimum Requirement for the Rat[a]	Diets					
		1 Casein[b]	2 RP[c]	3 RP+P[c]	4 RP+F[c]	5 RP+L	6 RP+P+L
Lysine	0.90	0.80	0.47	0.41	0.62	0.62	0.62
Histidine	0.30	0.30	0.29	0.26	0.24	0.29	0.26
Arginine	0.20	0.41	0.85	0.98	0.77	0.85	0.98
Threonine	0.50	0.43	0.37	0.33	0.42	0.37	0.33
Valine	0.70	0.74	0.55	0.51	0.56	0.55	0.51
Total sulfur amino acids	0.60	0.32	0.24	0.18	0.23	0.24	0.18
Isoleucine	0.50	0.66	0.32	0.33	0.37	0.32	0.33
Leucine	0.80	1.00	0.67	0.68	0.72	0.67	0.68
Total aromatic amino acids	0.90	0.83	0.58	0.59	0.55	0.58	0.59

[a]Nutrient requirements of domestic animals (No. 10, 1962, NAS, NRC Publ. 900a).
[b]Amino acid composition taken from Nutrition and Diet Therapy by S. R. Williams, 1969, p. 614.
[c]Analysis for protein and amino acid composition determined at Department of Grain Science and Industry, Kansas State University.

determination by the macro-Kjeldahl method (10). To ensure sharp separation of feces, carmine was used as a marker. One gram of carmine was mixed with 100 g. of food, and the rats were fed this mixture at the beginning and end of each collection period. The week's total collection of dried feces sample was recorded, and the sample was ground in a Wiley laboratory mill with a 40-mesh screen. Duplicate 1-g. samples were analyzed for nitrogen by the macro-Kjeldahl method (10).

RESULTS AND DISCUSSION

Cumulative Weight Gain

Cumulative weight gains of rats fed the six diets are presented in Table III. Rats fed RP+F gained more ($P < 0.05$) than those receiving any other diet, whereas those fed RP+L gained more ($P < 0.05$) than those fed casein, RP+P, or RP+P+L. Gains between rats fed RP and RP+L did not differ significantly.

TABLE III. MEAN CUMULATIVE WEIGHT GAIN OF RATS FED ONE OF SIX INDICATED DIETS

Diet	Cumulative Weight Gain g.	Protein Intake g.	PER
4. Rice polish + fish protein concentrate	131.9	44.05	2.99
5. Rice polish + lysine	107.4	40.44	2.65
2. Rice polish	100.5	40.32	2.49
3. Rice polish + peanut flour	97.5	41.41	2.35
1. Casein	95.6	33.64	2.84
6. Rice polish + peanut flour + lysine	91.4	37.76	2.42

Protein Efficiency Ratio

RP+F gave the highest PER; other diets in descending order were casein, RP+L, RP, RP+P+L, and RP+P. The PER for RP+F was higher ($P < 0.05$) than that for casein, which was higher ($P < 0.05$) than those of the remaining four diets. The PERs for the six diets differed significantly from each other, except those for RP+P+L, and RP+P+L and RP+P. Weight gain and PER correlated moderately and positively ($r=0.53$).

Liver Protein

Total liver protein (wet weights) at the end of the 4-week growth period are presented in Table IV. Rats fed RP+F had the most liver protein, followed by rats fed RP+L. Liver protein contents of rats fed those two diets did not differ significantly. Rats fed RP had significantly higher liver protein contents than those fed casein, RP+P, or RP+P+L. Liver protein contents of rats fed the last three diets were essentially the same.

TABLE IV. MEAN TOTAL LIVER PROTEIN OF RATS FED ONE OF SIX INDICATED DIETS

Diet	Nitrogen per g. Liver mg.	Wet Weight of Liver mg.	Total Liver Protein g.
4. Rice polish + fish protein concentrate	29.46	7.18	1.322
6. Rice polish + peanut flour + lysine	29.02	5.74	1.034
2. Rice polish	28.77	6.53	1.174
1. Casein	28.57	5.92	1.055
5. Rice polish + lysine	28.44	7.15	1.267
3. Rice polish + peanut flour	28.34	5.96	1.054

Biological Value and Digestibility Coefficient

The BVs and DCs obtained for the six diets are shown in Table V. Casein had the highest BV followed in order by RP+F, RP, RP+L, RP+P+L, and RP+P. The differences among the means were significant for all the diets except those between RP and RP+L, and RP+L and RP+P+L.

Casein had the highest DC while RP and RP+L tied for the lowest. Differences among a) RP+P, and b) RP+F, c) RP+P, and d) RP+P+L were not significant.

Feeding rats rice polish alone resulted in nonsignificantly greater weight gain and

TABLE V. BIOLOGICAL VALUES AND DIGESTIBILITY COEFFICIENTS OF THE SIX DIETS

Diet	BV %	DC %
1. Casein	89.88	96.59
4. Rice polish + fish protein concentrate	82.72	81.25
2. Rice polish	77.52	74.88
5. Rice polish + lysine	76.03	74.65
6. Rice polish + peanut flour + lysine	73.37	83.01
3. Rice polish + peanut flour	68.22	82.31

greater liver protein content than feeding casein alone. PER, BV, and DC were lower for the rice polish diet than for the casein diet. Saxena et al. (7) reported increased weight gains from 12.5% rice polishings concentrate to a rice diet (65.6 to 42.7 g.). The PER we obtained using rice polish was higher than the 1.84 reported by Kik (12) from using 9.0% polishings, but out BV differed little from Kik's 78.9 with an 8% protein diet.

Amino acid contents of RP and RP+F showed that neither diet meets the protein requirement specified for rats (Table II). RP was more deficient than RP+F, particularly in lysine, threonine, isoleucine, and leucine. Fish protein concentrate helped raise levels of those amino acids, so lysine then nearly equalled that in egg protein. The fish protein concentrate probably accounted for increases in all the protein criteria of RP+F over RP alone. Our results were similar to those of Sure (13) whose PER increased from 1.54 to 2.50 when 1% fish protein concentrate was added to rice in a 5% protein diet.

Peanut flour improved only DC in protein quality, while decreasing the protein quality of RP. Some amino acid values were lower for RP+P than for RP alone, the greatest difference being for total sulfur, containing amino acids, followed by lysine, threonine, and valine. That amino acids are more deficient in RP+P than in RP alone probably accounts somewhat for the lower protein quality of the RP+P diet. Carpenter and DeMuelenaere (14) have reported that peanut flour is about the least well balanced in amino acid composition of the common protein-rice foods.

Considering amino acid requirements of the rat, lysine is the first limiting amino acid in RP, so we added lysine to RP and to RP+P to bring their lysine levels equal to that in RP+F. Results we obtained were not consistent among criteria we used to evaluate protein quality.

Adding lysine to RP did not significantly improve weight gain or BV, but significantly improved ($P < 0.05$) the PER and liver protein.

Adding lysine to RP+P did not significantly improve weight gain, PER, or liver protein, but significantly improved BV, indicating some contributory effect from lysine. A supplementary value of lysine in cereal products has been reported (15,16). However, Pecora and Hundley (17) have made it clear that lysine, threonine, or any other amino acid added individually to a rice diet yielded better growth than rice alone. When rice was supplemented with all the deficient amino acids simultaneously, growth improved considerably more than when it was supplemented with lysine and threonine only.

We assume that we did not get maximal response from adding lysine because we lacked other limiting amino acids for optimum balance.

The casein diet had the highest DC, the RP diet, the lowest DC, probably because fiber content is high in rice polish. Although DC was not fully reflected in food intake, food intake tended to increase or decrease with decrease or increase in DC. Rats fed the casein diet, with the highest DC, ate the least food. A palatability factor might be involved; rats on RP+F ate the most, though DC was not lowest for that diet. Munro et al. (18) observed that fish protein concentrate increased food intake.

Rats fed the casein diet grew more slowly than those fed any of the other diets, perhaps because they ate less than those on any of the other six diets. Casein diet may not have been palatable to rats or its high DC could have reduced consumption.

CONCLUSIONS

Our data show that protein quality of rice polish can be improved by adding fish protein concentrate. As judged from cumulative weight gain, PER, and total liver protein, RP+F was the best of the six diets we studied. It also had the highest BV of the tested diets. Adding lysine to RP or to RP+P improved protein quality somewhat, but not consistently. RP+P had the lowest values for all protein-evaluation criteria except DC.

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