Short communication

Protein and energy utilization of rice milling fractions by rats

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Abstract. Brown rice (variety IR32), bran, and polish had higher protein content and lysine content in protein than milled rice. Nitrogen balance in growing rats showed that brown rice had lower true digestibility, but similar biological value and NPU as milled rice. Undermilled rice had similar true digestibility, but higher biological value and NPU than milled rice. Bran and polish had lower true digestibility, but higher biological value than brown and milled rice, but polish had higher NPU than bran and the three other milling fractions. The percentage of digestible energy in the rats was lowest for bran.

Introduction

Chemical analysis suggests that brown rice has a higher content of B vitamins and is more nutritious than milled rice [11, 16]. Brown rice has more protein, minerals, and lipid, and its protein has higher lysine content than milled rice [16]. However, it has higher fiber and phytin P content than milled rice [16].

Comparative protein utilization of all the milling fractions of rice grain in rats has been done by Kik [13] using PER, based on weight gain per amount of protein eaten. He reported PER values of 1.80–1.87 for brown rice and 1.74–1.84 for milled rice at 5%–7% dietary protein level, and 1.92 for rice bran and 1.84 for rice polish at 9% dietary protein level. Eggum and Juliano [6] found a NPU value of 64.2% for IR480-5-9 brown and milled rices, but lower true digestibility and higher biological value for brown-rice protein than for milled-rice protein. Betschart [2] recently reported that brown rice has better protein quality in rats than milled rice. Because of the current interest in high-fiber diets [10], and the inappropriateness of the PER method in measuring utilizable protein [15], the milling fractions of IR32 brown rice were subjected to nitrogen and energy balance studies. These brown, undermilled, and milled rices are also being compared in nitrogen-balance studies in

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preschool children at the Nutritional Evaluation Laboratory, Food and Nutrition Research Institute, Manila, The Philippines.

Materials and Methods

IR32 rough rice was taken from the 1976 crop of the IRRI farm that had been stored at 20°–25° C. Rough rice was dehulled in a Satake SB-2B one-pass pearler and brown rice was sized through a Satake RG-C6A tropics rice grader. Whole brown rice was then undermilled to about 5% weight removal with the SB-2B pearler to obtain bran. Broken grains were removed from one-half of the resulting undermilled rice with the rice grader, and the whole-grain fraction was remilled with the SB-2B pearler for 4% weight removal to obtain polish and milled rice. Contaminant broken milled rice of the bran and polish fractions was removed by sieving successively through 12-, 20-, and 30-mesh sieves.

Representative samples of the five milling fractions were ground for analysis with a UD cyclone mill with a 40-mesh sieve and analyzed for moisture by loss of weight at 130° C for 1 h [1], micro-Kjeldahl protein (N x 6.25) [1], crude fiber [1], neutral detergent or dietary fiber [8], pet. ether extractable crude fat [1], crude ash [1], P [16] and phytin P [9]. Total carbohydrates were assayed by dispersing a 25 mg sample with 6.83 g 26 N (72%) H_2SO_4 for 3 h at 25° C, diluted to 2*N* H_2SO_4 with water and heated for 2.5 h at 100° C [17], and the filtered hydrolyzate treated with phenol-H_2SO_4 reagent [3].

Duplicate samples were defatted with refluxing pet. ether for 48 h and hydrolyzed with 6*N* HCl for 23 h at 110° C in sealed tubes under N_2 and analyzed for amino acids in a Beckman Spinco Model 120C Amino Acid Analyzer with a AA-15 and PA-35 resins [6, 7].

Samples equivalent to 7.5 g N were sent to the National Institute of Animal Science for nitrogen balance by the Thomas–Mitchell method in five Wistar (Wistar-möll) male, growing rats each weighing 65–68 g as described by Eggum [5]. The trial lasted nine days – four days for introductory feeding and a five-day balance period in which pooled feces and pooled urine were analyzed for N. The rats' daily diet had a constant amount of dry matter (10 g) and N (150 mg). Autoclaved potato starch was used to reduce the N content of high-protein samples. Metabolic N and endogeneous N were determined by adding ether-extracted, freeze-dried egg equivalent to 4% protein to the N-free diet of autoclaved potato starch, sucrose, cellulose powder, soybean oil, minerals, and vitamins [5]. Egg protein at this level was completely utilized by rats. Energy value of food and feces was estimated by IKA adiabatic calorimeter. Digestible energy of the diets was calculated by measuring the difference of energy in food and feces according to Miller and Payne [18]. Rat data were subjected to analysis of variance followed by Duncan's [4] multiple range test.

Table 1. Chemical composition of IR32 brown, undermilled, and milled rices, bran, and polish

Property (wet basis)	Brown rice	Under-milled rice	Milled rice	Bran	Polish	LSD (5%)
Wt % of brown rice	100	95	91	5	4	–
Moisture (%)	11.8	11.6	11.7	10.6	10.6	0.6
Crude protein (% N × 6.25)	8.7	8.5	8.3	16.8	13.4	0.2
Lysine (g/16 g N)	3.80	3.64	3.55	5.78	5.04	0.14
Threonine (g/16 g N)	3.77	3.72	3.74	3.53	3.58	n.s.
Cystine + methionine (g/16 g N)	4.35	4.25	4.42	3.92	4.44	n.s.
Tryptophan (g/16 g N)	1.33	1.31	1.30	1.08	0.84	n.s.
Total carbohydrates (% as anhydroglucose)	72.3	76.0	79.2	24.4	33.2	3.4
NFE (by calculation, %)	75.7	77.3	78.7	32.0	43.6	–
Crude fiber (%)	0.7	0.5	0.2	7.8	6.4	0.7
Neutral detergent fiber (%)	2.6	1.8	0.8	20.7	19.1	0.3
Crude fat (%)	2.4	1.5	0.7	27.2	19.8	0.4
Crude ash (%)	0.8	0.6	0.4	5.6	6.2	0.3
Calcium (%)	0.02	0.02	0.02	0.06	0.06	0.01
Magnesium (%)	0.07	0.07	0.03	0.65	0.74	0.01
Phosphorus (%)	0.14	0.14	0.08	1.15	1.34	0.06
Phytin P (%)	0.06	0.04	0.02	0.90	1.10	0.09
Energy value (kcal/g)	3.90	3.86	3.80	4.94	4.45	0.30

Results

Chemical analysis of the IR32 rice milling fractions showed that all nonstarch constituents decreased progressively with degree of milling (Table 1) [16]. This was confirmed by the higher content of nonstarch constituents in rice bran followed by rice polish, except for crude ash and phytin P. Energy values were also higher for these rice byproducts, presumably because of their high fat content. Calcium level was similar for the three rices, but magnesium content was higher for brown and undermilled rices than for milled rice. Total carbohydrates were lower than calculated nitrogen-free extract (NFE) for brown and undermilled rices, bran, and polish, and slightly higher for milled rice. Among the amino acids, lysine, the first limiting essential amino acid in rice protein [11], showed the greatest difference among milling fractions and was also higher in bran and polish than in brown and milled rices.

Nitrogen balance data showed brown-rice protein to be less digestible than milled-rice protein in growing rats (Table 2). The biological value of undermilled-rice protein was higher than that of milled-rice protein. The resulting NPU for brown rice was similar to that of undermilled and milled rices. The corresponding data for rice bran and polish protein showed lower true digestibility, but higher biological value relative to brown and milled rice. Resultant NPU of polish was higher than that of bran and those of the three other rices, and NPU of bran was higher than that of milled rice. Calculated utilizable protein (NPU × protein content/100) was highest for bran, then polish, brown rice and undermilled rice, and then milled rice.

Table 2. Mean nitrogen and energy balance in five growing rats of IR32 brown, undermilled, and milled rices, bran, and polish[a]

Sample	True digestibility (%)	Biological value (%)	NPU (%)	Utilizable protein	Digestible energy	
				(% wet basis)		(kcal/g)
Brown	96.9b	68.9bc	66.7bc	5.8c	94.3b	3.67a
Undermilled rice	97.3ab	69.7b	67.8bc	5.8c	95.5ab	3.69a
Milled rice	98.4a	67.5c	66.4c	5.5d	96.6a	3.67a
Bran	78.8d	86.6a	68.3b	11.3a	67.4d	3.33b
Polish	82.5c	86.3a	71.2a	9.8b	73.3c	3.26b

[a]Means in the same column followed by a common letter are not significantly different at the 5% level by Duncan's [4] multiple range test

The percentage of digestible energy of the milling fractions was highest for milled rice, followed by undermilled rice, brown rice, polish, and bran (Table 2). Corresponding digestible energy (kcal/g) was lower for bran and polish than for brown, undermilled, and milled rice.

Discussion

The poor digestibility of bran and polish protein is in agreement with the lower digestibility of brown-rice protein relative to milled-rice protein (Table 2) [6]. Antinutrition factors in the bran that may have contributed to poorer protein digestibility are high fiber content [5] and phytate [12] (Table 1), trypsin inhibitor [14], and hemagglutinin [19]. The globoid inclusions in aleurone and scutellum protein bodies are phytate salts of potassium and magnesium [20].

The higher biological value of bran and polish protein relative to the residual grain (Table 2) was in keeping with the higher amino acid score based on lysine content of these byproducts (Table 1). Milled-rice protein, which had the lowest lysine content, had the lowest biological value of proteins of the five fractions.

The rat-feeding studies showed a similar NPU for brown, undermilled, and milled IR32 rices (Table 2). Corresponding utilizable protein contents were slightly higher in brown and undermilled rices than in milled rices. The byproducts bran and polish had higher utilizable protein contents than brown, undermilled, and milled rices despite their comparable NPU to the residual grain because of their higher protein contents.

The nitrogen-balance method has the advantage over the PER method of actually obtaining the TD and BV components of NPU and allows the calculation of utilizable protein [15]. Similar NPU or PER values do not always indicate similar TD and BV for the proteins, as was shown in this study of rice milling fractions. In addition, TD alone cannot reliably predict NPU since the digestibility effect is not always random, in view of the preferential digestion of the better quality proteins as a result of cooking [7] and presence of bran pigment [21] and polish (Table 2).

The percentages of digestible energy were again lower in bran and polish than the residual grain, and paralleled relative protein disgestibility values (Table 2). Even with their higher energy values (Table 1), the calculated digestible energy of bran and polish was lower than that of brown, undermilled, and milled rices.

Because of the interrelationship among grain constituents, this study demonstrated the need for actual confirmatory biological testing to determine the utilization of analyzed nutrients, such as protein and energy, in the rice grain. By contrast, previous studies have shown that rice starch is completely utilized by rats [7].

Projection of the biological results in rats to man is complicated by the unique adverse effect of cooking on the digestibility of rice proteins of poor nutritional value [7]. Because of this selective digestibility effect, NPUs of raw and cooked rices are similar in rats.

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