THE EFFECT OF THE DEGREE OF POLISHING OF RICE ON NITROGEN AND MINERAL METABOLISM IN HUMAN SUBJECTS[1]

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ABSTRACT

Negative calcium balances were recorded in human subjects when brown (unpolished) rice or rice polished to remove 2.9% of the brown rice was fed as the cereal portion in a poor vegetarian diet. Under similar conditions, rice polished to remove 4.1 or 6.3% of the brown rice produced slight positive calcium balances. In spite of its higher protein and phosphorus content, the brown rice did not produce higher nitrogen or phosphorus balances than the polished rice samples.

Rice polished to remove 4.1% of the brown rice represented a *via media* stage of polishing with 1.7 γ per g. of thiamine and could be recommended for consumption by rice eaters. The exclusive consumption of brown rice in diets containing marginal or submarginal amounts of calcium is not to be recommended as it may produce negative calcium balances.

It is well known that the polishing of rice leads to extensive loss of minerals and B-group vitamins and, hence, intake of undermilled rice is recommended on nutritional grounds. For reasons of economy also, completely unpolished rice is often given in the diet. Against these apparent advantages, brown rice or undermilled rice has poor storage and cooking qualities and contains large amounts of phytic acid which interferes with the utilization of dietary calcium. The latter aspect is all the more disturbing, since rice contains far less calcium than wheat (12) and is the staple diet for a large section of the people in many countries. People of the low-income groups in these countries consume very little milk and derive very little of their calcium requirements from any other source. This is particularly true of the "poor South-Indian rice diet" of India (2).

In rat experiments, brown rice had a higher growth-promoting capacity than polished rice (17). The biological value of the protein was also relatively higher for the brown rice (11). Human metabolism experiments, however, have shown that brown rice produces lower nitrogen and mineral balances than polished rice (4,5). This difference in response of the human being and the rat and the fact that rice forms over 75% of the diet of the low-income groups in India led to a reinvestigation of the problem by this laboratory, with a view to arriving at an optimal degree of polishing for rice which would not

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deplete thiamine below a safe level (about 1.5–1.8 γ per g.) and would not affect adversely mineral and nitrogen balances in human subjects. The problem is analogous to the effect of the degree of extraction of wheat flour on the nutritive value of bread, which has been investigated in great detail (19).

Metabolism studies on children which formed a part of these investigations on rice were completed first and have already been reported (10). Results of studies on adults using samples of rice milled to known degrees of polishing are reported here.

Materials and Methods

Healthy human adults from the laboratory served as experimental subjects for the study. The details of height and weight are given in Table I.

A long, fine-grained variety of rice (Bangar Sanna Co-11), shelled in a commercial sheller, was polished in a cone polisher to remove 2.9, 4.1, and 6.3% of the brown rice. The chemical composition of samples is given in Table II. These samples, hereafter referred to as 2.9-, 4.1-,

TABLE I

Age, Height, and Weight of the Experimental Subjects

Subject No.	Age	Height	Weight
	years	*meters*	*kg*
1	30	1.62	45.4
2	30	1.60	50.9
3	26	1.62	50.0
4	32	1.68	49.1
5	28	1.60	52.7
6	26	1.54	45.4
7	24	1.58	55.0

TABLE II

Chemical Composition and Other Characteristics of Rice Polished to Different Degrees

	6.3%-Polished Rice	4.1%-Polished Rice	2.9%-Polished Rice	Brown Rice
Chemical composition				
Nitrogen, mg%	936.0	963.0	987.0	1,014.0
Calcium, mg%	8.9	9.3	11.1	12.4
Total phosphorus, mg%	215.0	245.0	296.0	365.0
Phytin phosphorus (as % of total phosphorus) mg%	38.6	52.2	56.1	60.3
Crude fiber, %	0.20	0.22	0.50	0.80
Thiamine, γ/g	1.1	1.7	2.1	3.2
Cooking quality	Good	Good	Reasonable	[a]
Storage quality	Good	←Intermediate→	←Intermediate→	[b]

[a] Unacceptable. A stiff peel or coat of bran is formed.
[b] Prone to insect damage; develops rancidity.

and 6.3%-polished rice, together with shelled rice from the same variety, formed the cereal portion in the diet fed to the experimental subjects.

The diet was similar in other respects to the "poor South-Indian diet" (3) which has been adopted as typical of what is consumed by the majority of rice eaters belonging to the low-income groups in South India (2). It is mainly vegetarian and contains very little milk, and for this reason is very deficient in calcium. Ingredients of the daily diet per individual were:

	g.
Rice	500.0
Thur dhal (*Cajanus cajan*)	50.0
Ground nut oil	50.0
Leafy vegetable (*Amaranthus tricolor*)	21.0
Nonleafy vegetables (potato and brinjal)	82.0
Whole milk powder (Nespray)	9.0
Cane sugar	35.0
Other pulses (Bengal gram, black gram, etc.)	6.6
Flavoring and spicing ingredients, including coffee beverage	26.5
Common salt	20.6
(Total calories, 2,900 to 3,000)	

Chemical composition: protein ($N \times 6.25$), 48.7–51.2 g.; fat, 55–62 g.; calcium, 401–419 mg.; phosphorus, 1,431–2,183 mg. (The change in the degree of polishing of rice used in the feeding periods causes slight variation.)

The daily feeding pattern consisted of breakfast, lunch, tea, and dinner. A rice semolina or flour preparation along with coffee was served at breakfast; cooked rice, spiced vegetable gravy (*sambar*), and buttermilk were given at lunch and dinner. Coffee was served between lunch and dinner.

The general plan of the experiments was to feed the above rice diet for 12 days to the subjects and collect excretions in the last 5 days of the feeding period for analysis. The dietary regimen during the four consecutive feeding periods was identical except for a change in the degree of polishing of the rice forming the main constituent of the diet. A week's rest period was allowed for the subjects between two metabolism periods. In order to get the subjects slowly adapted from the polished to the undermilled or brown rice in the diet, the 6.3%-polished rice was fed in the first experimental period. The 4.1%- and 2.9%-polished rices and brown rice were fed in the second, third, and last periods, respectively. The same subjects were used for the four metabolism periods, although one of the subjects dropped out of the experiment for the last two periods for unavoidable reasons.

The 24-hour urine and fecal samples for each subject collected and preserved under antiseptic conditions (acid was also used to bind free ammoniacal nitrogen) were pooled together for 5 days for subsequent analysis. Carmine was used as feces-marker. Aliquots of urine and dried fecal samples were used for analysis of nitrogen, calcium, and phosphorus. Identical portions of diet servings fed at each sitting were removed and dried. The dried total diet for each experimental period was mixed and pulverized, and aliquots were used for analysis.

In representative samples of the rice, diet, and excretions, the following were determined:

1) Nitrogen (by micro-Kjeldahl procedure)
2) Calcium; experimental materials subjected to dry ashing, taken up with hydrochloric acid and determined by oxalate precipitation (1)
3) Phosphorus; materials solubilized by wet digestion according to Gerritz (7) and estimated by the colorimetric procedure of Fiske and Subbarow (6)
4) Phytin phosphorus, by the method of McCance and Widdowson (13)
5) Thiamine by the thiochrome method as modified by Kik and Williams (12)

Results and Discussion

From the point of view of chemical composition, there is a gradual loss of all nutrients with progressive polishing of the rice (Table II), the maximum losses being found in thiamine (65%) and phosporus (40%). Loss of protein content due to polishing is, however, less than 10% even at the highest level of polishing. The total phosphorus, as well as the phytin phosphorus, decreases during the polishing process.

The diet used in these experiments contained other minor constituents, but rice formed over 70% of the total diet; therefore the effects observed may be ascribed largely to the rice in the diet, and the differences in the results obtained with the different diets may be ascribed to changes in the degree of polishing of the rice. Results (Table III) show the effect of polishing on the balances of nitrogen, calcium, and phosporus. In spite of slightly higher intakes of nitrogen in the diet as a result of their higher protein content, the brown and undermilled samples of rice did not produce greater nitrogen balances than the better-polished samples. Large individual variations among subjects in nutrient balances (see Table III) have precluded a strict statistical analysis of the data; even so, the results indicated a slightly higher nitrogen balance in the polished rice diet (Cullumbine *et al.,* 4,5). In any case, the polished rice did not produce a lower nitrogen balance than the brown rice or the two undermilled rice samples. The results of calcium balances are more striking. Brown rice and 2.9%-polished rice produced a slightly negative average calcium balance (four subjects on each of the diets had negative balances), whereas 4.1%-polished and 6.3%-polished rice induced small positive balances of the order of 36 and 77 mg., respectively. Positive phosphorus balances were recorded for all the subjects during each of the four dietary periods, although the underpolished samples did not produce higher balances as would be expected merely on the basis of their much higher total phosphorus contents. In general, these results are similar to those obtained by Kantha Joseph *et al.* (10) on the effect of feeding children rice polished to different degrees.

These results on calcium and phosphorus balances are explained on the basis of the higher content of phytin phosphorus in the samples with a low degree of polishing. Although a fair amount of phytin phosphorus is hydrolyzed in the intestines (5,14,16) as a result of gastro-intestinal enzymes or enzymes of bacterial origin in the lower part of the intestines, it exerts a deleterious effect on calcium absorption. The higher fibrous and indigestible residue in unpolished rice is also responsible for the apparent low digestibility of the nutrients on such

TABLE III

AVERAGE DAILY INTAKE AND BALANCE OF NUTRIENTS ON DIETS BASED ON RICE
(Variability is expressed in terms of standard error of the mean values)

DEGREE OF RICE POLISH AND NO. OF SUBJECTS [a]	INTAKE	EXCRETION			BALANCE
		Urinary	Fecal	Total	
		Nitrogen, g.			
Brown — 6	8.19	4.32 ± 0.21	3.25 ± 0.15	7.57	0.62 ± 0.31
2.9% — 6	7.95	4.36 ± 0.23	2.74 ± 0.15	7.10	0.85 ± 0.04
4.1% — 7	7.93	4.43 ± 0.21	2.73 ± 0.19	7.16	0.77 ± 0.08
6.3% — 7	7.80	4.18 ± 0.29	2.76 ± 0.07	6.94	0.86 ± 0.24
		Calcium, mg.			
Brown — 6	419	63 ± 8.8	361 ± 11.1	424	−5 ± 6.9
2.9% — 6	411	60 ± 8.9	357 ± 32.9	417	−6 ± 27.9
4.1% — 7	403	73 ± 10.9	294 ± 16.4	367	36 ± 13.7
6.3% — 7	401	42 ± 8.7	282 ± 19.5	324	77 ± 15.5
		Phosphorus, mg.			
Brown — 6	2,183	479 ± 24.8	1,362 ± 15.3	1,841	342 ± 29.5
2.9% — 6	1,804	429 ± 23.8	955 ± 96.1	1,384	420 ± 63.7
4.1% — 7	1,581	422 ± 22.4	785 ± 18.3	1,207	374 ± 23.0
6.3% — 7	1,431	408 ± 18.5	588 ± 25.3	996	435 ± 26.3

[a] The successive order of feeding of the rice samples was, as stated in the text, in decreasing order of the degree of polishing of the rice. The data are, however, presented in reverse order for convenience.

TABLE IV
APPARENT DIGESTIBILITY OF NUTRIENTS

Type of Rice Used in Diet	Dry Fecal Bulk	Apparent Digestibility		
		Nitrogen	Calcium	Phosporus
	g/day	%	%	%
Brown	64.1	60.3	13.9	37.6
2.9%-Polished	50.4	64.5	12.8	48.5
4.1%-Polished	50.7	65.6	27.1	50.3
6.3%-Polished	46.3	64.6	28.2	58.9

diets (see Table IV). The fecal bulk on the dry basis was much higher on the unpolished rice diet. Differences between 6.3-, 4.1-, and 2.9%-polished rice were, however, small, indicating that the type of fiber which increases fecal bulk is removed much faster in the earlier stages of the polishing itself.

Brown rice and 2.9%-polished rice have poor culinary and storage qualities and also produced negative calcium balances when fed in the rice diet. The 6.3%-polished rice is otherwise acceptable in every respect, but its thiamine content is the lowest (1.1 γ per g.). Even so, it can reasonably be expected to retain a large amount of this thiamine in the cooked state, provided washing losses are eliminated. The 4.1%-polished rice can be considered a *via media* stage of polishing. Although it has a dull appearance and is not suitable for prolonged storage, it is, on the whole, the best from the nutritional point of view. For those sections of the people whose diet contains other sources of thiamine, the fully polished rice may be adequate; while for those whose intake of thiamine is dependent largely on the rice in the diet, a 4%-degree of polishing can be recommended (slightly higher extraction rate may be allowed for coarse varieties with thicker bran layers). In spite of its high thiamine content, the use of unpolished rice or rice with a very low degree of polishing (below 2–3%) cannot be recommended unreservedly in view of its deleterious effect on dietary calcium absorption. The consumption of "parboiled," "converted," or "malekized" rice which retains higher proportions of thiamine, even when polished, is a safer and more suitable means of meeting the thiamine requirements than the exclusive intake of brown rice.

The capacity of human subjects to maintain small positive balance even at low levels of calcium intake and their ability to adapt themselves to low levels of dietary calcium has been demonstrated in Ceylonese (15), African (18), and Peruvian adults (9). This has more recently been demonstrated in dogs also (8). In the present experiments, as well as in similar experiments on children (10), negative calcium balances have been found in many of the subjects fed brown or 2.9%-polished rice. For this reason, the feeding of completely unpolished rice over prolonged periods, especially to children in the growing age group, may lead to slow depletion of body calcium and should be viewed with caution. In such borderline cases, at least, the possible need for supplementing the diet with extra calcium and the best means of doing it should be kept in mind.

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