The metabolism of nitrogen, calcium and phosphorus in undernourished children

5.* The effect of partial or complete replacement of rice in poor vegetarian diets by ragi (*Eleusine coracana*) on the metabolism of nitrogen, calcium and phosphorus

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The food grains consumed widely in India are rice, wheat, jowar (*Sorghum vulgare*), ragi (*Eleusine coracana*) and pearl millet (*Pennisetum typhoideum*). The millets are consumed mainly by the low-income groups and ragi is the staple food of millions of people in Mysore State and the Deccan plateau of India. Ragi is unique among the cereal grains in being a rich source of calcium, containing about 0·33% as compared with other common cereals whose calcium content ranges from 0·01 to 0·06% (Aykroyd, Patwardhan & Ranganathan, 1956). Subrahmanyan, Narayanarao, Ramarao & Swaminathan (1955) studied the metabolism of nitrogen, calcium and phosphorus in adults on a poor vegetarian diet based on ragi. They found that the apparent digestibility of the proteins in the ragi diet was only 50%.

Metabolic studies carried out on children in India have so far been confined mainly to diets containing rice (Murthy, Reddy, Swaminathan & Subrahmanyan, 1955; Joseph, Narayanarao, Ganapathy, Swaminathan & Subrahmanyan, 1958). No metabolic studies have been reported on children with diets containing ragi or other millets. In view of the fact that a poor rice diet is highly deficient in Ca (Murthy *et al.* 1955; Joseph *et al.* 1958), partial replacement of rice in the diet by ragi will help to overcome the Ca deficiency in the diet. The present paper reports the effects of partial or complete replacement of rice in a poor vegetarian diet by ragi on the metabolism of N, Ca and P in children.

METHODS

Subjects. Eight girls aged between 9 and 10 years, residents of a boarding home in Mysore City, were the subjects. They belonged to the low-income groups of the population and hailed from nearby villages. They had been in the orphanage during the previous 2 years. They were subsisting on an ill-balanced poor vegetarian rice diet and their rate of growth was poor (Subrahmanyan, Bhagawan, Doraiswamy, Joseph, Bains, Bhatia, Sankaran & Swaminathan, 1958). The girls were clinically examined and found to be free from disease. They had not suffered from any debilitating disease during the previous 2 years. They were treated for worms with santonin

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1 month before the metabolic test was begun. Their ages, heights and weights are given in Table 1.

Plan of the test. The test consisted of four periods. The proportions of rice to ragi in the diet during different periods were: period 1, rice only (rice diet); period 2, rice 3 parts and ragi 1 part (25% ragi diet); period 3, rice 1 part and ragi 1 part (50% ragi diet); period 4, ragi only (ragi diet). The other ingredients in the diets were the same throughout (see Table 3). The subjects were fed on each diet for a period of 15 days, the first 10 days being treated as a preliminary period to allow them to become accustomed to the diet. Urine and faeces were collected for analysis during the last 5 days of each period.

Table 1. *Ages, heights and weights of the children at the beginning of the test*

Child no.	Age (years)	Height (cm)	Weight (kg)
1	9	113	16·4
2	10	109	16·7
3	9	107	17·0
4	9	113	16·9
5	10	119	20·0
6	9	108	15·7
7	10	112	17·0
8	10	114	18·4

Table 2. *Percentage composition of the raw milled rice and ragi*

	Rice	Ragi
Moisture	10·1	11·4
Protein (N × 6·25)	6·6	6·8
Fat (ether extractives)	0·54	1·3
Ash	0·53	2·6
Starch	81·4	67·3
Total sugars	0·3	1·2
Crude fibre	0·2	3·3
Pentosans and other hemi-celluloses (by difference)	0·3	6·1
Calcium (g/100 g)	0·013	0·34
Phosphorus (total) (g/100 g)	0·091	0·21
Phytate phosphorus (g/100 g)	0·062	0·17
Calories (kcal/100 g)	360	310

Experimental diets and feeding of the children. The chemical composition of the samples of ragi and raw milled rice was calculated by the methods of the Association of Official Agricultural Chemists (1950) and is shown in Table 2. The mean daily intake of foodstuffs and nutrients by the children is shown in Table 3. The diets were similar in composition to those eaten in normal times by the vast majority of children belonging to low-income groups in different parts of South India. The children were fed four times a day, at breakfast, lunch, tea and dinner. Breakfast consisted of a pancake made of rice and ragi flour and a cup of white coffee. Lunch and dinner consisted of dumplings made from ragi flour or cooked rice or both, and vegetable soup (containing pulses, tamarind, chillies, spices, salt and vegetables). At tea the children received only a cup of white coffee. Records of the food consumed daily

were kept throughout the test. Complete duplicates of all dishes consumed by each child were collected daily, dried in an air oven at 95–100° and weighed. They were powdered and analysed for their N, Ca and P content.

Collection and preservation of urine and faeces. The procedures were those described by Murthy, Swaminathan & Subrahmanyan (1954). Carmine was used as a marker for faeces. A check on the proper collection of urine was maintained by determining the daily excretion of creatinine in it.

Analytical methods. Total N, Ca and P in food, urine and faeces were estimated by the methods of Murthy *et al.* (1954). All the analyses were carried out in duplicate.

Table 3. *Mean daily intake of foodstuffs and nutrients by the children on the different diets*

Foodstuff or nutrient	Diet: Rice	25 % ragi	50 % ragi	Ragi
	Foodstuffs			
Rice, raw milled (g)	280	210	140	—
Ragi (*Eleusine coracana*) (g)	—	70	140	280
Red-gram dhal (*Cajanus indicus*) (g)	20	20	20	20
Groundnut oil (g)	25	25	25	25
Potato (g)	20	20	20	20
Brinjal (*Solanum melongena*) (g)	10	10	10	10
Amaranth leaves (*Amaranthus gangeticus*) (g)	10	10	10	10
Radish (g)	10	10	10	10
Skim-milk powder (g)	5	5	5	5
Cane sugar (g)	25	25	25	25
Tamarind fruit pulp (*Tamarindus indicus*) (g)	8·9	8·9	8·9	8·9
Common salt (g)	9·4	9·4	9·4	9·4
Onions (g)	5·0	5·0	5·0	5·0
Coconut kernel (g)	3·1	3·1	3·1	3·1
Condiments (garlic, coriander seeds, mustard, red chillies and turmeric) (g)	8·2	8·2	8·2	8·2
Coffee powder (g)	7·0	7·0	7·0	7·0
	Nutrients*			
Calories (kcal)	1477	1471	1469	1466
Protein (N × 6·25) (g)	27·6	27·9	28·0	28·2
Fat (g)	28·7	29·3	29·9	31·2
Carbohydrate (g)	277	274	272	268
Calcium (mg)	259	471	693	1151
Phosphorus (total) (mg)	464	577	680	887
Phytate phosphorus (mg)	264	383	502	740
Thiamine (mg)	0·30	0·55	0·80	1·31
Nicotinic acid (mg)	4·70	4·64	4·57	4·43
Vitamin A activity (mainly as carotene) (i.u.)	608	658	707	804

* All the values (except for protein, calcium and phosphorus, which were determined according to the methods referred to in the text) were calculated from figures given by Aykroyd *et al.* (1956).

RESULTS

Nitrogen metabolism. The results are given in Table 4. The mean daily intake from the different diets was nearly the same, ranging from 4·41 to 4·51 g (equivalent to about 28 g protein). The apparent digestibility of the proteins from the different

diets decreased as the proportion of ragi was raised. All the subjects were in positive balance.

Calcium metabolism. The results are given in Table 5. All the subjects were in positive balance. The mean daily intake was lowest (259 mg) on the rice diet and highest (1151 mg) on the diet in which ragi was the only cereal. The intake increased as the level of ragi in the diet was raised. The corresponding mean daily retention rose from 52 to 226 mg Ca.

Phosphorus metabolism. The results are given in Table 5. All subjects were in positive balance. The mean daily intake increased as the level of ragi in the diet was raised, from 464 mg on the rice diet to 887 mg on the diet in which ragi was the only cereal, but there were no large changes in the daily retention.

Table 4. *Mean daily intake, excretion and balance of nitrogen by the children on the different diets*

Diet*	Intake (g)	Excretion (g) Urinary	Faecal	Total	Apparent digestibility coefficient (%)	Balance (g)	
(*A*) Rice	4·41	1·64	1·29	2·93	70·7	+1·48	
(*B*) 25 % ragi	4·46	1·78	1·50	3·28	66·5 ± 1·84†	+1·18	±0·12†
(*C*) 50 % ragi	4·48	1·96	1·63	3·59	63·5 (21 d.f.)	+0·89	(21 d.f.)
(*D*) Ragi	4·51	1·88	2·11	3·99	53·2	+0·52	

* Calorie intake (kcal/child/day): *A*, 1477; *B*, 1471; *C*, 1469; *D*, 1466.
† Standard error.

Table 5. *Mean daily intake, excretion and balance of calcium and phosphorus by the children on the different diets*

Diet*	Intake (mg)	Excretion (mg) Urinary	Faecal	Total	Balance (mg)	
			Calcium			
(*A*) Rice	258	52	155	207	+ 51	
(*B*) 25 % ragi	471	43	322	365	+106	±15·5†
(*C*) 50 % ragi	693	46	472	518	+175	(21 d.f.)
(*D*) Ragi	1151	36	889	925	+226	
			Phosphorus			
(*A*) Rice	464	155	192	347	+117	
(*B*) 25 % ragi	577	116	295	411	+166	±10·4†
(*C*) 50 % ragi	680	130	425	555	+125	(21 d.f.)
(*D*) Ragi	887	118	634	752	+135	

* Calorie intake (kcal/child/day): *A*, 1477; *B*, 1471; *C*, 1469; *D*, 1466.
† Standard error.

DISCUSSION

Ragi and other millets, in view of their high roughage content, are generally considered coarse foods as compared to raw milled rice. A sudden change from a rice diet to a ragi diet generally causes digestive troubles in habitual rice eaters. Our subjects were accustomed to a mixed diet containing rice, ragi and other millets. All of them readily took diets containing ragi and none complained of digestive disorders. The sample of ragi used contained about 9·4 % roughage, i.e. cellulose and hemi-celluloses. The mean daily faecal bulk increased with the level of ragi in the diet. The dry

weights of faeces on the different diets were: rice diet, 19·6 g; 25% ragi diet, 30·2 g; 50% ragi diet, 37·8 g; ragi diet, 56·0 g. Other workers made similar observations with diets based on wholemeal bread and white bread (McCance & Walsham, 1948–9; Widdowson & McCance, 1954) or unpolished rice (Cullumbine, 1950; Joseph *et al.* 1958).

Nitrogen. The mean daily protein intake (about 28 g) by the children was very much lower than the recommended daily allowance of 57 g for children of this age group (Indian Council of Medical Research: Nutrition Advisory Committee, 1944). In spite of it, all the children were in positive N balance. Widdowson & McCance (1954) found, with German children aged 11–12 years on diets based on wholemeal or white bread, that the mean daily intake and retention of N were about 12 and 2 g, respectively. Macy (1942) reported a lower retention (0·8 g) in American children when the N intake was 12–13 g daily. In spite of a low protein intake, the retention of N by children in our investigation on the rice diet and on the diets in which 25 or 50% of the rice was replaced by ragi compared favourably with that reported by Macy (1942) for American children on a well-balanced diet. However, the N retention on the diet in which ragi replaced all the rice was less.

Calcium. Our results may be compared with those reported by other workers for children on diets adequate in Ca. Widdowson & McCance (1954) observed, with German children (11–12 years) on diets based on wholemeal bread fortified with calcium carbonate, a daily intake and retention of 2·42 and 0·23 g, respectively. Macy (1942) reported that the mean daily intake and retention of Ca by American children (11–12 years) on a well-balanced diet containing 500 g milk daily were 0·95 and 0·17 g, respectively. According to Widdowson & McCance (1954) a daily retention of 0·18 g Ca may be essential for optimum growth and bone development in children. Judged on this basis, only the 50% ragi and the 100% ragi diets promoted adequate Ca retention.

Phosphorus. A large part (60–80%) of the P in the diet was in the form of phytate P (Table 3). Widdowson & McCance (1954) reported a mean daily intake and retention of P by German children (11–12 years) on a wholemeal-bread diet of 2·14 and 0·14 g, respectively. Macy (1942) found that the daily intake and excretion of P by American children (11–12 years) on the diet containing 500 g milk daily were 1·50 and 0·12 g, respectively. The predominantly cereal diets based on rice or ragi or both consumed by the children in our study promoted a satisfactory P retention.

SUMMARY

1. The effect on nitrogen, calcium and phosphorus metabolism of replacing 25%, 50% or all of the rice in a poor vegetarian diet by ragi was studied in eight girls aged 9–10 years.

2. The daily intake of N was nearly the same, 4·41–4·51 g (equivalent to about 28 g protein), on all the diets. The apparent digestibility coefficients of the protein were 71, 67, 64 and 53%, and the mean daily N retentions 1·48, 1·19, 0·89 and 0·52 g, for the rice diet and the diets in which 25%, 50% or all of the rice was replaced by ragi. All the subjects were in positive balance.

3. The mean daily Ca intakes were 259, 471, 693 and 1151 mg, and the retentions 52, 106, 175 and 226 mg, on the rice diet and the diets in which 25 %, 50 % or all of the rice was replaced by ragi. The retentions on the three diets containing ragi were significantly higher than that on the rice diet.

4. The mean daily P intakes were 464, 577, 680 and 887 mg, and the retentions 117, 165, 125 and 135 mg, on the rice diet and the diets in which 25 %, 50 % or all of the rice was replaced by ragi.

5. Replacement of some of the rice by ragi will help to overcome the Ca deficiency of rice diets.

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