

## The metabolism of nitrogen, calcium and phosphorus in undernourished children

### 6\*. The effect of partial or complete replacement of rice in poor vegetarian diets by kaffir corn (*Sorghum vulgare*)

BY P. P. KURIEN, M. NARAYANARAO, M. SWAMINATHAN AND  
V. SUBRAHMANYAN

Central Food Technological Research Institute, Mysore, India

(Received 17 November 1959—Revised 25 January 1960)

Kaffir corn (*Sorghum vulgare*) is one of the important food crops widely cultivated in different parts of India. Over considerable parts of the Deccan plateau and Central India it is eaten as a staple food by millions of people. It is also grown to a considerable extent in other countries, especially in Africa, China, the U.S.A. and Latin America. The grain is usually ground to flour and cooked and eaten as dumplings or unleavened bread. The poorer classes generally prefer kaffir corn to softer grains like rice because of its cheapness and sustaining qualities. Diets containing kaffir corn and other cereals have been compared in growth experiments on albino rats (Sur, Swaminathan & Subrahmanyam, 1955; Subrahmanyam, Kuppuswamy, Ramarao, Swaminathan & Bhatia, 1954). These studies have shown that the general nutritive value of a poor vegetarian diet containing kaffir corn is higher than that of rice, but slightly less than that of similar diets containing ragi (*Eleusine coracana*) or wheat. Our metabolic studies carried out on children in India have so far been confined to diets containing rice and ragi (Murthy, Reddy, Swaminathan & Subrahmanyam, 1955; Joseph, Narayanarao, Ganapathy, Swaminathan & Subrahmanyam, 1958; Joseph, Kurien, Swaminathan & Subrahmanyam, 1959). We have not previously reported any metabolic studies in children on kaffir corn diets. Because of the acute shortage of rice in the country, the use of kaffir corn and other millets as partial substitutes for rice needs to be studied. The present paper describes the results of investigations on the effects of partial or complete replacement of rice in a poor Indian diet by kaffir corn on the metabolism of nitrogen, calcium and phosphorus in children.

#### EXPERIMENTAL

*Subjects.* Seven boys aged 10–11 years who were residents of a boarding home in Mysore City were selected as experimental subjects. All of them

\* Paper no. 5: Brit. J. Nutr. (1959), 13, 213.

belonged to the poorer classes and were accustomed to eating millets such as kaffir corn or ragi. They were clinically examined and found to be free from any disease likely to interfere with the metabolic experiment. They had been dewormed by santonin given orally about a month before the experiment. Information about their ages, heights and weights is given in Table 1.

*Plan of experiment.* The experiment consisted of four periods. The proportions of rice to kaffir corn in the diet given during different periods were: period 1, rice only (rice diet); period 2, rice 3 parts and kaffir corn 1 part (25% kaffir corn diet); period 3, rice 1 part and kaffir corn 1 part (50% kaffir corn diet); and period 4, kaffir corn only (kaffir corn diet). The other ingredients in the diets were the same throughout. The subjects were fed on each diet for a period of 15 days, the first 10 days being treated as a preliminary period of adjustment. 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	11	137	28.6
2	10	135	23.6
3	11	140	24.6
4	11	135	24.6
5	10	131	25.5
6	10	130	23.6
7	11	135	24.6

TABLE 2. *Percentage composition of the raw milled rice and kaffir corn used*

	Raw milled rice	Kaffir corn
Moisture	9.9	12.2
Protein (N $\times$ 6.25)	6.7	7.7
Fat (ether extractives)	0.5	2.2
Ash	0.5	1.7
Starch	81.4	66.5
Total sugars	0.3	1.3
Crude fibre	0.2	2.8
Pentosans and other hemicelluloses (by difference)	0.5	5.6
Calcium	0.01	0.037
Phosphorus (total)	0.139	0.245
Phytate phosphorus	0.087	0.194
Calories (kcal/100 g)	357	322

*Chemical composition of kaffir corn and rice.* The chemical composition of the samples of rice and kaffir corn used was determined by the methods of the Association of Official Agricultural Chemists (1955). The phytate P was estimated by the method of McCance and Widdowson (1935). The results are presented in Table 2.

*Experimental diets and the feeding of the subjects.* The mean composition of the diets eaten daily by the subjects is shown in Table 3: The diet consisted mainly of cereals and contained small amounts of pulses, vegetables, meat and milk; it was similar to that eaten in normal times by most children of the classes to which the experimental subjects belonged. They were fed three times a day. Breakfast consisted of a pancake made of rice flour or of

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

Foodstuff or nutrient	Diet			
	Rice	25% kaffir corn	50% kaffir corn	kaffir corn
Foodstuffs (g)				
Rice, raw milled	360	270	180	—
Kaffir corn ( <i>Sorghum vulgare</i> )	—	90	180	360
Red gram dhal ( <i>Caajanus indicus</i> )	25.6	25.6	25.6	25.6
Groundnut oil	25.6	25.6	25.6	25.6
Potato	25.6	25.6	25.6	25.6
Brinjal ( <i>Solanum melongena</i> )	13.0	13.0	13.0	13.0
Amaranth leaves ( <i>Amaranthus gangeticus</i> )	13.0	13.0	13.0	13.0
Radish	13.0	13.0	13.0	13.0
Onions	12.3	12.3	12.3	12.3
Tamarind fruit pulp ( <i>Tamarindus indicus</i> )	11.3	11.3	11.3	11.3
Cocunut kernel	8.3	8.3	8.3	8.3
Meat	28.0	28.0	28.0	28.0
Skim-milk powder	6.4	6.4	6.4	6.4
Common salt	14.4	14.4	14.4	14.4
Cane sugar	11.0	11.0	11.0	11.0
Condiments (garlic, coriander seeds, mustard, red chillies, and turmeric)	9.6	9.6	9.6	9.6
Tea leaves	2.0	2.0	2.0	2.0
Nutrients*				
Calories (kcal)	1849	1819	1787	1725
Protein (N x 6.25) (g)	40	40	41	43
Fat (g)	36	37	39	42
Carbohydrate (g)	344	331	319	294
Calcium (mg)	355	381	410	441
Phosphorus (total) (mg)	744	835	928	1091
Phytate phosphorus (mg)	364	461	557	750
Thiamine (mg)	0.59	0.81	1.03	1.47
Nicotinic acid (mg)	7.67	8.21	8.75	9.83
Vitamin A activity (mainly as carotene) (i.u.)	776	898	1020	1265

\* 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, Patwardhan and Ranganathan (1956).

kaffir corn flour or of both, chutney made from red gram dhal and a cup of tea. Lunch and dinner consisted of cooked rice or unleavened bread (*rotti*) made from kaffir corn flour or of both, vegetable soup (a preparation containing pulses, tamarind, chillies, spices, salt and vegetables and dilute 'buttermilk'. The 'buttermilk' was prepared by reconstituting with water a part of the milk powder included in the diet and then converting it into sour curd by seeding with a small quantity (1% by volume) of sour curd and incubating at 30° for 16 h. The sour curd thus obtained was diluted with four times its volume of water and agitated with a stirrer for 5 min to yield 'buttermilk'. Records of the food eaten daily by the subjects were kept throughout the experiment. Complete duplicates of all dishes eaten by each subject were collected daily, dried in an air oven at 95–100° and weighed. They were powdered and analysed for N, Ca and P.

*Collection and preservation of urine and faeces.* The procedure for the collection and preservation of urine and faeces was that of Murthy, Swaminathan and Subrahmanyam (1954). Carmine was used as a marker for the collection of faeces. A check on the proper collection of urine was maintained by determining the daily excretion of creatinine.

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

## RESULTS

*Nitrogen.* The results for N metabolism are given in Table 4. The mean daily intake of N from the different diets increased slightly with the increase in the amount of kaffir corn in the diet and ranged from 6.34 to 6.91 g (equivalent to about 40–43 g protein). The mean daily excretion of N in the

TABLE 4. Mean daily intake, excretion and balance of nitrogen of boys on the different diets

Diet		Intake (g)	Excretion (g)			Apparent digestibility coefficient (%)	Balance (g)
Description	Calorie value (kcal/day)		Urinary	Faecal	Total		
Rice ...	1849	6.34	2.93	1.60	4.53	74.7	+1.80
25 % kaffir corn ...	1819	6.42	2.90	1.97	4.87	69.3	+1.55
50 % kaffir corn ...	1787	6.50	2.86	2.36	5.22	63.7	+1.28
Kaffir corn ...	1725	6.91	2.95	3.08	6.03	55.4	+0.88
Standard error of the mean of (18 d.f.)						±1.42	±0.065

faeces increased as the level of kaffir corn in the diet was raised and was highest (3.08 g) on the diet containing the whole of the cereal as kaffir corn. The apparent digestibility coefficients

$$\frac{\text{N intake} - \text{faecal N}}{\text{N intake}} \times 100$$

of the proteins in the different diets were: rice diet 74.7%, 25% kaffir corn diet 69.3%, 50% kaffir corn diet 63.7%, and kaffir corn diet 55.4%. The mean daily N retention on the different diets was 1.80, 1.55, 1.28 and 0.88 g, respectively. All the subjects were in positive N balance.

**Calcium.** The results of the metabolic study are given in Table 5. All the subjects were in positive balance on the different diets. The Ca intake increased slightly as the level of kaffir corn in the diet was raised. The mean daily retention of Ca on the different diets was: rice diet 123 mg, 25% kaffir corn diet 109 mg, 50% kaffir corn diet 97 mg and kaffir corn diet 74 mg. The Ca retention on the different diets decreased with the increase in the level of kaffir corn in the diet.

**Phosphorus.** The results of the metabolic study are given in Table 5. All the subjects were in positive P balance on the different diets. The intake of P was lowest on the rice diet and increased as the level of kaffir corn in the

TABLE 5. Mean daily intake, excretion and balance of calcium and phosphorus of boys on the different diets

Description	Calorie value (kcal/day)	Intake (mg) Calcium	Excretion (mg)			Balance (mg)
			Urinary	Faecal	Total	
Rice	1849	355	57	175	232	+123
25% kaffir corn	1819	381	49	223	272	+109
50% kaffir corn	1787	410	55	258	313	+97
Kaffir corn	1725	441	50	317	367	+74
Standard error of the mean (18 d.f.)	...					±5.4
		Phosphorus				
Rice	1849	744	296	279	575	+169
25% kaffir corn	1819	835	254	377	631	+204
50% kaffir corn	1787	928	292	403	695	+233
Kaffir corn	1725	1091	232	550	782	+309
Standard error of the mean (18 d.f.)	...					±17.0

diet was raised. The mean daily retention of P on the different diets was: rice diet 169 mg. 25% kaffir corn diet 204 mg. 50% kaffir corn diet 233 mg. and kaffir corn diet 309 mg.

*Faeces.* The dry weights of the faeces on the different diets were: rice diet 23.9, 25%, kaffir corn diet 30.8, 50%, kaffir corn diet 38.8 and kaffir corn diet 53.0 g/day.

#### DISCUSSION

Kaffir corn 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 kaffir corn diet generally causes digestive upsets in habitual rice eaters. The subjects of the present study were accustomed to a mixed diet containing rice, kaffir corn and other millets. All of them readily ate the diets containing kaffir corn and none experienced digestive disorders. The sample of kaffir corn used contained 8.4% roughage, i.e. cellulose and hemicelluloses. The mean daily faecal bulk increased directly with the level of kaffir corn in the diet. Other workers have made similar observations with diets based on wholemeal bread (McCance and Walsham, 1948-9; Widdowson and McCance, 1954), unpolished rice (Cullumbine, 1950; Joseph *et al.* 1958) and ragi (Joseph *et al.* 1959).

*Nitrogen.* The mean daily protein intake (40-43 g) was lower than the recommended allowances of 57 g for children of this age (Indian Council of Medical Research: Nutrition Advisory Committee, 1944). Nevertheless, all the children were in positive N balance. The mean apparent digestibility of the proteins in the diet and the mean retention of N progressively decreased as the level of kaffir corn in the diet was increased. The results are similar to those reported earlier by Joseph *et al.* (1959) in experiments with diets containing ragi.

*Calcium.* The mean daily Ca intake on the different diets ranged from 0.35 to 0.44 g and was very much lower than the recommended daily allowance of 1 g for children of this age group (Indian Council of Medical Research: Nutrition Advisory Committee, 1944). Nevertheless, all the children were in slight positive balance. The mean daily retention of Ca decreased as the level of kaffir corn in the diet was raised, which may have been due to the high phytate P content of kaffir corn as compared with raw milled rice (Table 1). Widdowson and Thrussell (1951) observed that the intake and retention of Ca in German boys on a diet based on wholemeal bread were 0.75 and 0.085 g, respectively. According to Widdowson and 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, none of the diets used in the present study promoted adequate Ca retention. In this connexion it may be of interest to mention that Nicholls and Nimalasuriya (1939) presented evidence

indicating that Sinhalese children in the poorer classes frequently received not more than 0.2–0.4 g of Ca daily from their diet and yet their bones were normal in structure and composition. The children, however, were small in stature. These authors suggested that a process of adaptation to low levels of Ca intake had taken place.

**Phosphorus.** The mean P intake on the different diets ranged from 0.74 to 1.09 g. A large part (48–70%) of P in the diet was in the form of phytate P (Table 3). Nevertheless, the mean daily retention of P on the different diets ranged from 0.17 to 0.31 g. These findings are similar to those of Widdowson and Thrussell (1951) who observed that the intake and retention of P in German children on a diet based on wholemeal bread were 2.51 and 0.23 g, respectively.

#### SUMMARY

1. The effect on the metabolism of nitrogen, calcium and phosphorus of replacing 25%, 50% or all of the rice in a poor Indian diet by kaffir corn was studied in seven boys aged 10–11 years.

2. The daily intake of N was nearly the same (equivalent to about 40–43 g protein) with all the diets.

3. The apparent digestibility coefficients of the protein and the mean daily N retentions diminished as the proportion of kaffir corn in the diet was increased. All the subjects were in positive N balance.

4. Although the addition of kaffir corn led to a higher Ca intake, the amount of Ca retained decreased as the proportion of kaffir corn in the diet was increased.

5. Kaffir corn also provided a higher P intake, which resulted in a higher P retention.

We are grateful to Mr A. N. Sankaran and Miss K. Indiramma for the statistical analysis of the results and to Mr V. A. Daniel for technical assistance.

#### REFERENCES

- Association of Official Agricultural Chemists (1955). *Official Methods of Analysis*, 8th ed. Washington: Association of Official Agricultural Chemists.
- Aykroyd, W. R., Patwardhan, V. N. and Ranganathan, S. (1956). *The Nutritive Value of Indian foods and the Planning of Satisfactory Diets*, 5th ed. New Delhi: Manager of Publications.
- Cullumbine, H. (1950). *Brit. J. Nutr.* 4, 129.
- Indian Council of Medical Research: Nutrition Advisory Committee (1944). *Report of the Scientific Advisory Board for the Year 1944*. New Delhi: Indian Council of Medical Research.
- Joseph, K., Kurien, P. P., Swaminathan, M. and Subrahmanyam, V. (1959). *Brit. J. Nutr.* 13, 213.
- Joseph, K., Narayanarao, M. Ganapathy, S., Swaminathan, M. and Subrahmanyam, V. (1958). *Ann. Biochem.* 18, 51.
- McCance, R. A. and Walsham, C. M. (1948–9). *Brit. J. Nutr.* 2, 26.

- McCance, R. A. and Widdowson, E. M. (1935). *Biochem. J.* 29, 2694.
- Murthy, H. B. N., Reddy, S. K. Swaminathan, M. and Subrahmanyam, V. (1955). *Brit. J. Nutr.* 9, 203.
- Murthy, H. B. N., Swaminathan, M. and Subrahmanyam, V. (1954). *Brit. J. Nutr.* 8, 11.
- Nicholls, L. and Nimalasuriya, A. (1939). *J. Nutr.* 18, 363.
- Subrahmanyam, V. Kuppaswamy, S., Ramarao, G., Swaminathan, M. and Bhatia, D. S. (1954). *Bull. cent. Fd. technol. Res. Inst.* 3, 187.
- Sur, G., Swaminathan, M. and Subrahmanyam, V. (1955). *Bull. cent. Fd. technol. Res. Inst.* 4, 133.
- Widdowson, E. M. and McCance, R. A. (1954). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 287.
- Widdowson, E. M. and Thruswell, L. A. (1951). In *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 275, p. 296.