Effects of Partial Replacement of Rice in a Rice Diet by Tapioca Flour on the Metabolism of Nitrogen, Calcium and Phosphorus in Adult Human Beings

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In a previous paper from this laboratory, Subrahmanyan, Murthy & Swaminathan (1954) reported that replacement of 25 % of the rice in a poor rice diet by tapioca flour did not affect the overall nutritive value of the diet as judged by the growth of young rats. Though animal experiments may provide useful information on the nutritive value of human diets, the ultimate test must be their effect on human beings. It was, therefore, felt desirable to conduct experiments on adult human beings to find out the effect on the metabolism of nitrogen, calcium and phosphorus of replacement of 25 % of rice in poor rice diets by tapioca flour. The results are reported in this paper.

METHODS

Subjects. Six healthy adult males who carried out ordinary duties in the laboratory were chosen as experimental subjects. They were first clinically examined and found free from any disease. They had not suffered from any debilitating disease in the recent past and had been maintaining a constant weight over a few months before they came under experiment. They were housed in a building specially designed for human metabolic studies on the Institute premises and were kept under strict supervision during the experimental period. Data regarding the age, height and weight of the subjects are given in Table 1.

Plan of the experiment. The subjects were fed on a rice diet (Table 2) during the first experimental period and on a rice-tapioca diet (Table 2) during the second experimental period. Each experimental period was of 12 days' duration. The first 7 days of each experimental period constituted a preliminary period to allow the subjects to get accustomed to the diet; hence the collection of urine and faeces was confined to the last 5 days of each experimental period.

Experimental diets and feeding of subjects. The composition of the diets consumed by the subjects is shown in Table 2. The rice diet was similar in composition to that consumed in normal times by a vast majority of the people in south India. The subjects ate four times a day, at breakfast, lunch, tea and dinner. Breakfast and tea consisted of a savoury dish made of rice flour, or a mixture of rice and tapioca flour, and a cup of coffee. Lunch and dinner consisted of cooked rice, unleavened cakes made of rice flour or a mixture of rice and tapioca flours, vegetable soup (a preparation containing pulses, tamarind, chillies, spices, salt and vegetables) and watered buttermilk. Careful records of the food consumed daily by the subjects were made through-

out the experiment. It was found during the preliminary periods that the quantities of food consumed by the different subjects were nearly equal. So equal quantities of the different foods were offered to the subjects during the collection period.

Table 1. *Age, height and weight of the subjects*

Subject no.	Age (years)	Height (cm)	Weight (kg)
1	26	162·5	45·5
2	37	165·0	50·9
3	35	171·5	50·9
4	29	161·0	50·0
5	31	165·0	48·2
6	22	164·0	50·0

Table 2. *Average daily food consumption of subjects on the rice and the rice-tapioca diet*

Constituent	Rice diet (g)	Rice-tapioca diet (g)
Rice	683·3	533·3
Tapioca flour	—	183·3
Red gram dhal (*Cajanus indicus*)	50	50
Groundnut oil	50	50
Potatoes	41	41
Brinjal (*Solanum melongena*)	41	41
Amaranth (*Amaranthus gangeticus*)	21	21
Whole-milk powder (Nespray)	9	9
Cane sugar	35	35
Tamarind	16	16
Common salt (crude)*	35	35
Bengal gram dhal (*Cicer arietinum*)	3·3	3·3
Black gram dhal (*Phaseolus mungo*)	3·3	3·3
Curry leaves (*Murraya koenigii*)	1·5	1·5
Coriander leaves	1·5	1·5
Onions	8	8
Chillies (green)	7·5	7·5
Lemon juice	3 ml.	3 ml.

* See text, p. 13.

Specimens of the cooked dishes (excluding rice), equivalent to the average quantities consumed daily by each subject, were collected daily and dried in an air oven, powdered and analysed for nitrogen, calcium and phosphorus. Rice was analysed separately.

Collection and preservation of urine and faeces. Urine was collected in bottles containing 100 ml. conc. HCl (A.R.) and 5 g phenol (A.R.) as preservatives. The urine samples were made up to volume daily and a portion of the daily collection was stored in a refrigerator for analysis. The faeces were mixed with 100 ml. of 5% oxalic-acid solution and 100 ml. of an alcoholic solution containing 5 g each of thymol and phenol and were dried in an air oven at 70–80°. The dried faeces were weighed, powdered and analysed for nitrogen, calcium and phosphorus.

Analytical methods. The nitrogen content of food, urine and faeces was estimated by the micro-Kjeldahl method, calcium by McCrudden's (1911–12) method, and phosphorus by the method of Fiske & Subbarow (1925). For the determination of

calcium and phosphorus in the urine, a portion of the urine to be analysed was first neutralized to pH 7 by the addition of sodium-hydroxide solution (A.R.), 2 g sodium acetate (A.R.) were then added and the mixture was evaporated to dryness in a porcelain dish over a water-bath. The residue was incinerated and the calcium and phosphorus present in the ash were determined by the methods referred to above.

RESULTS

The results obtained for nitrogen metabolism are given in Table 3, for calcium metabolism in Table 4, and for phosphorus metabolism in Table 5.

The salt used for the preparation of the diets shown in Tables 2–5 was the usual bazaar variety which is consumed over a large part of India. Our recent investigations have shown that this salt usually contains about 93–96% sodium chloride together

Table 3. *Average daily intake, excretion and balance of nitrogen of subjects on rice and rice-tapioca diets*

Diet	Calorie intake (Cal.)	Nitrogen intake (g)	Urinary nitrogen (g)	Faecal nitrogen (g)	Total nitrogen excreted (g)	Nitrogen balance (g)
Rice	3215	9·69	4·18	2·87	7·05	2·65
Rice-tapioca	3337	8·93	3·50	2·68	6·18	2·75
Difference	—	−0·76	−0·68 ± 0·27	−0·19 ± 0·22	−0·87	0·10 ± 0·30

Table 4. *Average daily intake, excretion and balance of calcium of subjects on rice and rice-tapioca diets*

Diet	Calorie intake (Cal.)	Calcium intake (mg)	Urinary calcium (mg)	Faecal calcium (mg)	Total calcium excreted (mg)	Calcium balance (mg)
Rice	3215	529·1	142·1	339·8	481·9	47·2
Rice-tapioca	3337	586·0	113·2	319·5	432·7	153·3
Difference	—	56·9	−28·9 ± 33·3	−20·3 ± 31·3	−49·2	106·1* ± 35·9

* Significant at $P = 0{\cdot}05$.

Table 5. *Average daily intake, excretion and balance of phosphorus of subjects on rice and rice-tapioca diets*

Diet	Calorie intake (Cal.)	Phosphorus intake (mg)	Urinary phosphorus (mg)	Faecal phosphorus (mg)	Total phosphorus excreted (mg)	Phosphorus balance (mg)
Rice	3215	1153·8	298·4	659·6	957·9	195·9
Rice-tapioca	3337	1178·0	238·1	470·3	708·4	469·6
Difference	—	24·2	−60·3 ± 25·7	−189·3 ± 87·8	−249·5	273·7* ± 96·5

* Significant at $P = 0{\cdot}05$.

with 0·2–0·4% calcium (mostly as calcium sulphate) associated as an impurity. As the amount of salt taken with the experimental diets was about 35 g/day, the calcium contributed by the salt to the diets was 108 mg/day. If high-grade salt such as is being used in Europe and America had been used in the diets, the total calcium content

of the diet would have been lowered by 108 mg/day, whereas through fortuitous inclusion of calcium in the bazaar salt the intake of calcium was considerably increased. The significance of this will be discussed in a later communication.

Nitrogen metabolism. The average daily nitrogen intake on the rice diet and on the rice-tapioca diet was 9·69 and 8·93 g respectively. The average loss of nitrogen in the faeces was nearly of the same order on both the diets, showing thereby that the digestibility of the food protein was not affected to any appreciable extent by the incorporation of tapioca flour. The loss of nitrogen in the urine was appreciably less on the rice-tapioca diet than on the rice diet. All the subjects were in positive nitrogen equilibrium. The average quantity of nitrogen retained daily by the subjects was nearly the same on both the diets (2·65 and 2·75 g), the difference being not statistically significant.

Calcium metabolism. Four subjects were in positive calcium balance and two subjects were in negative balance on the rice diet. All six subjects were in positive calcium balance on the rice-tapioca diet. Though the average daily intake of calcium on the rice-tapioca diet was 57 mg more than that on the rice diet, the loss of calcium in urine and faeces was 49 mg less. The average retention of calcium was 47 mg on the rice diet as compared with 153 mg on the rice-tapioca diet. The results on statistical examination showed a significant difference in the balance in favour of the rice-tapioca diet.

Phosphorus metabolism. The average intake of phosphorus was nearly the same on both diets (1155 and 1178 mg). The average absorption of phosphorus on the rice diet was 43 % as compared with 60 % on the rice-tapioca diet. The loss of phosphorus in the urine was appreciably less on the rice-tapioca diet. The average retention of phosphorus on the rice-tapioca diet was apparently greater than that observed on the rice diet, the difference being statistically significant.

DISCUSSION

It is evident from the results that about 25 % of the rice in a vegetarian diet, as used in the present experiment, could be replaced by an equal quantity of tapioca flour without lowering the retention of nitrogen, calcium and phosphorus. In fact, an increase in the retention of calcium and phosphorus was observed as a result of such replacement. On the rice-tapioca diet the subjects ate 19 oz. rice and 5·25 oz. tapioca daily. These two foodstuffs supplied about 80 % of the calories in the diet. The average daily calorie intake of the subjects was about 3200 Cal. Since the subjects were doing moderate to active physical work for about 8 h a day in the laboratory, the calorie intake cannot be considered as being in excess of their requirements (Aykroyd, Patwardhan & Ranganathan, 1951).

Basu & Basak (1939) reported that the average minimum protein requirements of adult human beings (of 70 kg body-weight) on a poor rice diet were 46·4 g when the calorie intake was 3000 Cal. On this basis the average minimum protein requirements of the subjects (average body-weight 49 kg) in the present experiment were about 33 g (equal to 5·3 g N) per day. The actual protein intake on the rice diet and on the rice-tapioca diet was 60 and 56 g respectively. The average daily retention of nitrogen in

the experimental subjects was nearly of the same order on both the diets. The high nitrogen retentions observed in the present experiment may be partly due to the fact that, in the calculation of nitrogen balance, no allowance was made for the loss of nitrogen through sensible and insensible perspiration. The high nitrogen retentions observed in the present experiment are similar to those reported by Patwardhan, Mukundan, Rama Sastri & Tulpule (1949) on diets based mainly on vegetable proteins. The results show that the rice-tapioca diet of the composition used in the present experiment supplies more than the minimum quantity of protein required for maintaining nitrogen balance in adult human beings.

The calcium requirements of adult human beings have been estimated as 10 mg/kg body-weight (Steggerda & Mitchell, 1946; Leitch, 1936–7; Holmes, 1944–5). The average calcium requirements of the subjects of the present investigation were about 500 mg/day according to the above estimate. The average intake of calcium by the experimental subjects on the rice diet and on the rice-tapioca diet was 529 and 586 mg respectively. The average retention of calcium on the rice-tapioca diet was significantly more than that observed on the rice diet. In similar studies on diets based on rice and wheat, Basu, Basak & Rai Sircar (1939) found the average calcium requirement for adult human beings to be 0·388 g/70 kg body-weight.

Basu *et al.* (1939) reported that the average phosphorus requirement of adult human beings fed on diets based on rice and wheat was 1·0 g/70 kg body-weight. According to these findings, the average phosphorus requirement of the subjects in the present investigation was about 0·7 g. The actual intake of phosphorus on the rice and rice-tapioca diets was 1·15 and 1·17 g. respectively. Even though the average intake of phosphorus was nearly the same on both the diets, the average absorption of phosphorus on the rice-tapioca diet (60%) was greater than that (43%) observed on the rice diet. This is probably due to the fact that tapioca contains very little phytate phosphorus, whereas 50% of the total phosphorus in raw milled rice is present as phytate (Sundararajan, 1938). This observation is in conformity with the findings of Walker, Fox & Irving (1948) who reported that on the same level of intake the retention of phosphorus was greater when the phytate phosphorus content of the diet was reduced.

SUMMARY

1. The metabolism of nitrogen, calcium and phosphorus was studied in six men fed on diets based on rice and on a mixture of 75% rice and 25% tapioca. The composition of the rice diet was similar to that ordinarily consumed by people belonging to the low-income groups in many parts of India.

2. The average daily intake of nitrogen on the rice diet and the rice-tapioca diet was 9·69 and 8·93 g respectively. In spite of a slightly lower nitrogen intake on the rice-tapioca diet, the average retention of nitrogen on the two diets was 2·65 and 2·75 g respectively.

3. Four of the six experimental subjects were in positive calcium balance and two in negative balance on the rice diet. All the six subjects were in positive calcium balance on the rice-tapioca diet. The average daily retention of calcium was 47·2 mg

on the rice diet and 153·4 mg on the rice-tapioca diet, the difference being statistically significant.

4. The average daily intake of phosphorus was nearly of the same order on both the diets. The average absorption of phosphorus was only 43% on the rice diet as compared with 60% on the rice-tapioca diet. The daily average retention of phosphorus was 196 mg on the rice diet and 470 mg on the rice-tapioca diet, the difference in the retention being statistically significant.

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