Effects of Partial Replacement of Rice, Wheat or Ragi (*Eleusine coracana*) by Tuber Flours on the Nutritive Value of Poor Vegetarian Diets

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Consequent on the present shortage of rice and other cereals both in India and in other parts of Asia, it has become increasingly necessary to make up the deficit of starchy foods from other sources. The most promising sources are roots and tubers like tapioca and sweet potato which give two to three times higher yields of calories per acre than the commoner cereals. In fact, in Travancore and certain other parts of southern India, tapioca already forms a substantial part of the diet of the people. Tapioca and sweet potato, however, are deficient in proteins, and by themselves can serve mainly as sources of energy.

In an earlier publication from this laboratory (Murthy, Swaminathan & Subrahmanyan, 1950) it was reported that in experimental animals: (1) poor diets, based mainly on tapioca or sweet-potato flour, did not support life; (2) addition of groundnut-cake flour at a level of 20% to these diets enhanced the nutritive value of the diets to an even higher level than that of rice diet; and (3) replacement of rice in a poor rice diet to the extent of 25% by a mixture of four parts of tapioca flour and one part of groundnut-cake flour produced a marked improvement in the nutritive value of a rice diet.

Further systematic studies were therefore undertaken with a view to confirming the above findings, and to find out whether similar beneficial results could be obtained with other cereals. At the same time, it was considered to be of some practical importance to investigate the effect on the nutritive value of the rice diet of replacing varying percentages of rice by tapioca flour.

METHODS AND RESULTS

Tuber flours and mixtures of tuber flours with groundnut-cake flour as partial substitutes for cereals

The effect of replacing rice, wheat or ragi (*Eleusine coracana*) to the extent of 25% by one of the following was first studied: (1) tapioca flour; (2) sweet-potato flour; (3) a mixture of sweet-potato flour (80%) and groundnut-cake flour (20%); and (4) a mixture of tapioca flour (80%) and groundnut-cake flour (20%).

The analyses of the foodstuffs were carried out according to Association of Official Agricultural Chemists (1950) methods. Thiamine, riboflavin and nicotinic acid were determined according to Swaminathan (1942*a–c*). The results are given in Table 1. The compositions of the experimental diets are given in Tables 2–4. The overall

nutritive values of the different diets thus prepared were determined by the rat-growth method.

Table 1. *Chemical composition of cereals and tubers used in the experiment*

(Values per 100 g)

Cereal or tuber	Moisture (g)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	Carbohydrate (g)	Calorific value (Cal.)	Calcium (g)	Phosphorus (g)	Thiamine (mg)	Nicotinic acid (mg)	Riboflavin (mg)
Tapioca flour*	9·0	1·7	0·5	1·9	1·4	85·5	353	0·06	0·08	0·12	1·8	—
Sweet-potato flour	8·3	1·6	0·9	2·5	3·5	82·9	346	0·11	0·13	0·15	2·8	0·05
Groundnut-cake flour (without red cuticle)	11·0	52·7	8·9	1·0	4·6	21·8	378	0·07	0·50	0·95	19·5	0·20
Raw milled rice†	12·2	6·7	0·3	—	0·6	80·2	351	0·01	0·13	0·12	1·1	0·10
Whole wheat flour	12·5	11·8	1·3	1·8	1·6	71·1	343	0·04	0·30	0·43	4·4	0·14
Ragi (*Eleusine coracana*)	12·8	6·9	1·3	—	2·1	76·9	343	0·37	0·25	0·36	1·1	—

* Mean value for samples of tapioca flour used in the different experiments.
† Mean value for samples of raw milled rice used in the different experiments.

Table 2. *Percentage composition of experimental diets based on rice*

Ingredient	Diet no. 1	2	3	4	5
Raw milled rice	78·5	58·9	58·9	58·9	58·9
Tapioca flour	—	19·6	—	15·7	—
Sweet-potato flour	—	—	19·6	—	15·7
Groundnut-cake flour	—	—	—	3·9	3·9
Tur dhal (*Cajanus indicus*)	5·0	5·0	5·0	5·0	5·0
Non-leafy vegetables (potato and brinjal (*Solanum melongena*))	8·2	8·2	8·2	8·2	8·2
Leafy vegetables (*Amaranthus gangeticus*)	2·1	2·1	2·1	2·1	2·1
Groundnut oil	5·0	5·0	5·0	5·0	5·0
Milk powder	0·9	0·9	0·9	0·9	0·9
Common salt	0·3	0·3	0·3	0·3	0·3

Table 3. *Percentage composition of experimental diets based on wheat*

Ingredient	Diet no. 1	2	3	4	5
Whole wheat flour	78·5	58·9	58·9	58·9	58·9
Tapioca flour	—	19·6	—	15·7	—
Sweet-potato flour	—	—	19·6	—	15·7
Groundnut-cake flour	—	—	—	3·9	3·9
Tur dhal (*Cajanus indicus*)	5·0	5·0	5·0	5·0	5·0
Non-leafy vegetables (potato and brinjal (*Solanum melongena*))	8·2	8·2	8·2	8·2	8·2
Leafy vegetables (*Amaranthus gangeticus*)	2·1	2·1	2·1	2·1	2·1
Groundnut oil	5·0	5·0	5·0	5·0	5·0
Milk powder	0·9	0·9	0·9	0·9	0·9
Common salt	0·3	0·3	0·3	0·3	0·3

Young albino rats, about 4 weeks old and weighing 40–55 g each, were used for the experiments. To make the feeding uniform the cereals and pulses were powdered and mixed with the rest of the diet. Mixed diets were cooked with two-and-a-half times

their weight of water to a pasty mass and fed *ad lib.* to the rats. Systematic records of daily food intake were kept for all the groups. The rats were weighed weekly. The average weekly increases in body-weight of different groups of animals are given in Tables 5–8, together with standard errors obtained from an analysis of variance eliminating the effects of sex, diet, and their interaction.

Table 4. *Percentage composition of experimental diets based on ragi*

Ingredient	Diet no. 1	2	3	4	5
Ragi (*Eleusine coracana*)	78·5	58·9	58·9	58·9	58·9
Tapioca flour	—	19·6	—	15·7	—
Sweet-potato flour	—	—	19·6	—	15·7
Groundnut-cake flour	—	—	—	3·9	3·9
Tur dhal (*Cajanus indicus*)	5·0	5·0	5·0	5·0	5·0
Non-leafy vegetables (potato and brinjal (*Solanum melongena*))	8·2	8·2	8·2	8·2	8·2
Leafy vegetables (*Amaranthus gangeticus*)	2·1	2·1	2·1	2·1	2·1
Groundnut oil	5·0	5·0	5·0	5·0	5·0
Milk powder	0·9	0·9	0·9	0·9	0·9
Common salt	0·3	0·3	0·3	0·3	0·3

Table 5. *Effect of replacing 25% of rice in a rice diet by tuber flours, or by a mixture of tuber flours with groundnut-cake flour, on the growth of young rats*

Diet	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight (g)	
Raw milled rice 78·5%	3 ♂, 3 ♀	8·4	7·1	4·92	
Rice 58·9% + tapioca flour 19·6%	3 ♂, 3 ♀	7·2	8·2	7·23	
Rice 58·9% + sweet-potato flour 19·6%	3 ♂, 3 ♀	7·2	7·2	6·22	
Rice 58·9% + tapioca flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	9·6	8·6	9·05	±0·44 (20 D.F.)
Rice 58·9% + sweet-potato flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	9·6	8·8	9·55	

Rice diets. Comparing the individual diets it is found that (1) replacement of 25% of rice by tapioca (2, Table 2) or sweet-potato flour (3, Table 2) produced a significant increase in the gain in weight over the gain in weight on the rice diet (1, Table 2) and (2) replacement of 25% of rice by a mixture of tuber flours and groundnut-cake flour in the ratio of 4:1 (4 and 5, Table 2), produced a highly significant improvement in the growth rate. It is also interesting to note that sweet-potato flour and tapioca flour were equivalent in their nutritive value in this respect.

Wheat diets. Comparison of the control wheat diet (1, Table 3) separately with each of the remaining four diets shows that, excepting the diet of wheat and sweet potato (3, Table 3), the remaining three diets were significantly superior.

Ragi diets. It is seen that: (1) there was no significant difference in the gains in weight between the control ragi diet (1, Table 4) and the diets involving 25% replacement of ragi by tuber flours (2 and 3, Table 4), and (2) replacement of 25% of ragi by a mixture of tuber flours and groundnut-cake flour in the ratio of 4:1 (4 and 5, Table 4) produced a significant increase in weight over the control ragi diet.

Table 6. *Effect of replacing 25% of wheat in a wheat diet by tuber flours, or by a mixture of tuber flours with groundnut-cake flour, on the growth of young rats*

Diet	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight (g)
Wheat 78·5%	3 ♂, 3 ♀	13·9	8·6	7·87±0·54 (4 D.F.)
Wheat 58·9% + tapioca flour 19·6%	3 ♂, 3 ♀	10·9	9·7	10·23±0·68 (4 D.F.)
Wheat 58·9% + sweet-potato flour 19·6%	3 ♂, 3 ♀	10·9	9·4	9·81±0·70 (4 D.F.)
Wheat 58·9% + tapioca flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	13·4	11·2	10·87±0·84 (4 D.F.)
Wheat 58·9% + sweet-potato flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	13·6	9·9	10·30±0·82 (4 D.F.)

Table 7. *Effect of replacing 25% of ragi in a ragi diet by tuber flours, or by a mixture of tuber flours and groundnut-cake flour, on the growth of young rats*

Diet	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight (g)	
Ragi 78·5%	3 ♂, 3 ♀	8·9	9·6	8·41	
Ragi 58·9% + tapioca flour 19·6%	3 ♂, 3 ♀	7·8	8·8	7·56	
Ragi 58·9% + sweet-potato flour 19·6%	3 ♂, 3 ♀	7·8	9·2	7·61	
Ragi 58·9% + tapioca flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	10·9	10·4	10·85	±0·55 (20 D.F.)
Ragi 58·9% + sweet-potato flour 15·7% + groundnut-cake flour 3·9%	3 ♂, 3 ♀	10·1	10·2	10·91	

Rice-tapioca diets. In view of the beneficial effect obtained by replacing 25% of rice by tapioca flour, a result contrary to normal expectations, the experiment was repeated using different specimens of rice and tapioca flour. Table 8 shows the results of these experiments, together with those obtained in other studies reported in Tables 5, 10 and 14, which included the control rice diet (see Table 10) and a diet based on rice and tapioca in the ratio of 3:1 (Table 10).

It will be seen from Table 8 that out of the seven experiments reported, six showed significant differences in growth rate in favour of the rice-tapioca diet, thus confirming the observation made earlier. It will also be seen that the food intake on the rice-tapioca diet was generally higher than that on the rice diet.

Table 8. *Average weekly increase in body-weight of young rats during 8 weeks on rice and rice-tapioca diets*

(Different samples of rice and tapioca were used in each experiment)

Exp. no.	Protein on moisture-free basis: Rice diet (%)	Protein on moisture-free basis: Rice-tapioca diet (%)	Average daily food intake on moisture-free basis: Rice diet (g)	Average daily food intake on moisture-free basis: Rice-tapioca diet (g)	Average weekly gain in weight: Rice diet (g)	Average weekly gain in weight: Rice-tapioca diet (g)	Difference in gain in weight (g)
1	7·6	6·7	7·1	8·2	4·92 (3 ♂, 3 ♀)	7·23 (3 ♂, 3 ♀)	2·31** ± 0·62†
2	8·3	7·1	7·1	8·5	3·71 (4 ♂, 2 ♀)	6·11 (4 ♂, 2 ♀)	2·40** ± 0·38‡
3	7·4	6·5	6·9	8·4	4·10 (3 ♂, 3 ♀)	6·43 (3 ♂, 3 ♀)	2·33** ± 0·66§
4	7·4	6·5	Not determined		4·74 (3 ♂, 3 ♀)	6·48 (3 ♂, 3 ♀)	1·71** ± 0·39
5	Not determined				3·82‖ (3 ♂, 3 ♀)	6·67‖ (2 ♂, 3 ♀)	2·85** ± 0·78
6	8·4	7·2	8·5	9·1	4·36 (6 ♂, 6 ♀)	7·67 (6 ♂, 6 ♀)	2·31** ± 0·45
7	8·5	7·2	7·8	8·4	4·62 (6 ♂, 6 ♀)	5·10 (6 ♂, 6 ♀)	0·39 ± 0·34

† Calculated from Table 5 involving five diets.
‡ Calculated from Table 14 involving five diets.
§ Calculated from Table 10 involving six diets.
‖ Calculated by the method of fitting constants on account of an unequal number of males and females in the two diets.
** Significant at $P = 0{\cdot}01$.
Figures in parentheses indicate the number and sex of rats used.

Paired-feeding experiment with rice and rice-tapioca diets

In the foregoing experiments it was observed that: (1) the average weekly growth rate of rats fed on the rice-tapioca diet was significantly higher than that observed on the control rice diet, and (2) the rats on the rice-tapioca diet consumed more food than those on the rice diet alone. Since the food intake was greater on the rice-tapioca diet, it was considered desirable to carry out paired-feeding experiments to determine the difference in growth response when identical quantities of foods were consumed by the experimental animals on the above diets.

Two groups of freshly weaned albino rats (six in each group) were fed with similar diets in which (1) rice alone and (2) a mixture of rice (75 %) and tapioca flour (25 %) were the main ingredients. The paired feeding by the method of Mitchell & Smuts (1932) was for a period of 8 weeks. The average weekly increases in body-weights of the two groups are shown in Table 9.

Table 9. *Effect of replacement of 25 % of rice in a rice diet by tapioca flour on the growth of young rats in paired-feeding experiments*

Diet	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight (g)
Rice	3 ♂, 3 ♀	8·5	6·2	4·53 ± 0·43
Rice-tapioca	3 ♂, 3 ♀	7·2	6·2	4·95 ± 0·39
Difference	—	—	—	0·42 ± 0·58

The results showed that, when the food intake was equalized, the difference in growth rates between the two diets was not statistically significant.

Calcium content of tapioca and its relation to the supplementary effect of tapioca flour on rice diet

It may be seen from Table 8 that the improved growth response to the rice-tapioca flour mixture was obtained in spite of a slight lowering in the level of protein in the diet. This may have been due to the minerals present in tapioca, especially calcium. The calcium content of rice is low (Aykroyd & Krishnan, 1937). The sample of rice used for the above experiments contained about 10 mg calcium/100 g, whereas the

Table 10. *Calcium content of tapioca and its relation to the supplementary value of tapioca added to a rice diet*

Diet*	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight (g)	
Rice 78·5 %	3 ♂, 3 ♀	7·4	7·2	4·10	
Rice 58·9 % + tapioca flour 19·6 %	3 ♂, 3 ♀	6·5	8·4	6·43	
Rice 58·9 % + tapioca starch 19·6 % + ash of 19·6 g of tapioca flour	3 ♂, 3 ♀	6·2	7·3	5·49	
Rice 58·9 % + tapioca starch 19·6 % + supplements of calcium and phosphorus† equivalent to that present in 19·6 g of tapioca flour	3 ♂, 3 ♀	6·2	7·4	5·87	±0·45 (24 D.F.)
Rice 57·4 % + tapioca flour 18·1 % + salt mixture‡ 2 %	3 ♂, 3 ♀	6·4	9·0	8·58	
Rice 76·5 % + salt mixture‡ 2 %	3 ♂, 3 ♀	7·2	9·3	9·35	

* The other ingredients were the same as in diets given in Tables 2–4.
† In the form of calcium lactate and disodium phosphate.
‡ Salt mixture suggested by Hubbel, Mendel & Wakeman (1937).

mixture of rice with 25 % tapioca contained 20 mg/100 g. Further animal experiments were therefore undertaken to find out whether the increased growth rate was due to the higher calcium content of the rice-tapioca diet. The plan of the experiment was similar to that mentioned on p. 1. The compositions of the experimental diets and the results are given in Table 10. On comparing the individual diets it is seen that: (1) addition of extra calcium and phosphorus to a rice diet corresponding in amount to that contributed by 25 % tapioca (diet 4, Table 10) or by the equivalent amount of ash as obtained from a corresponding quantity of tapioca (diet 3, Table 10) produced nearly as much improvement in growth rate as that obtained by the incorporation of the tapioca flour itself (diet 2, Table 10); (2) supplementation of the rice diet (diet 1, Table 10) and of the rice and tapioca diet (diet 2, Table 10) with extra amounts of calcium in the form of a salt mixture (diets 6 and 5, Table 10) produced additional improvements in the growth-promoting value of the diets. This finding shows that tapioca met only a part of the calcium deficiency of the rice diet. It is of interest to

note that there was no significant difference in the average weekly gains in weight of rats fed on the rice-salt mixture diet and on the rice-tapioca-salt mixture diet respectively, in spite of a slightly lower protein content of the latter diet.

Nitrogen and calcium metabolism of rats on a rice diet as compared with that on a rice-tapioca diet

It was concluded from the previous experiments that the improvement in growth obtained by giving the rice-tapioca flour mixture was mainly due to the calcium contributed by the tapioca flour to the diet. It was considered desirable to provide corroborative evidence by carrying out experiments to determine the retention of nitrogen and calcium in rats fed on rice and on rice-tapioca diets. These studies were

Table 11. *Nitrogen metabolism of rats fed on diets based on rice and on a mixture of rice and tapioca*

(Figures represent daily averages)

Diet	No. and sex of rats	Nitrogen content of the diet on moisture-free basis (mg/100 g)	Average body-weight of rats during metabolism period		Food intake on moisture-free basis (g)	Nitrogen intake (mg)	Urinary nitrogen (mg)	Faecal nitrogen (mg)	Nitrogen balance (mg)
			Initial (g)	Final (g)					
Ad lib. feeding									
Rice	3 ♂, 3 ♀	1370	50	56	6·0	82·03	26·90	15·12	40·01
Rice + tapioca	3 ♂, 3 ♀	1078	63	76	7·8	84·32	23·92	20·12	40·28
Difference	—	—	—	—	—	2·29	−2·98	5·00	0·27 ± 2·29
Paired feeding									
Rice	2 ♂, 3 ♀	1392	58	65	5·5	76·69	31·66	17·28	27·75
Rice + tapioca	2 ♂, 3 ♀	1020	66	70	5·5	66·24	23·66	21·22	21·36
Difference	—	—	—	—	—	−10·45	−8·00	3·94	−6·39* ± 1·53

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

carried out in the first instance on two groups of young rats fed *ad lib.* on the rice diet and on the rice-tapioca diet respectively. Since the food intake on the latter diet was definitely higher than on the rice diet alone, another metabolism experiment was done subsequently in which two groups of animals were given equal quantities of the two diets according to the paired-feeding technique of Mitchell & Smuts (1932). Urine and faeces were collected during the 4th and 5th weeks of the experimental period and were preserved according to the method of Swaminathan (1937). Careful records of food intake were kept for all the animals. Nitrogen in the food, urine and faeces was estimated by the micro-Kjeldahl method, and calcium by McCrudden's (1911–12) method. The results obtained are given in Tables 11 and 12.

It is evident from the results that the retention of nitrogen was of the same order in the rats fed *ad lib.* on both the diets, but when the animals were pair-fed the retention of nitrogen was significantly lower in rats on the rice-tapioca diet as compared to that on the rice diet. The calcium retention in rats fed on the rice-tapioca diet was significantly higher than that on the rice diet in both the *ad lib.* and paired-feeding

experiments. The average weekly retention of calcium by rats on the rice-tapioca diet was 6 and 4 mg more than that observed in rats on the rice diet when the animals were fed *ad lib.* and by paired feeding respectively. According to Henry & Kon (1937) growing rats will increase in weight by 1 g for every 6 mg of calcium retained in the body, when their diet, deficient in calcium but adequate in other respects, is supplemented with suboptimal amounts of calcium. Hence the extra growth observed in rats fed *ad lib.* on the rice-tapioca diet is mainly due to the extra amounts of calcium retained by them.

Table 12. *Calcium metabolism of rats fed on diets based on rice and on a mixture of rice and tapioca*

(Figures represent daily averages)

Diet	No. and sex of rats	Calcium content of the diet on moisture-free basis (mg/100 g)	Average body-weight of rats during the metabolism period		Food intake on moisture-free basis (g)	Calcium intake (mg)	Urinary calcium (mg)	Faecal calcium (mg)	Calcium balance (mg)
			Initial (g)	Final (g)					
Ad lib. feeding									
Rice	3 ♂, 2 ♀†	36·7	51	58	6·4	2·29	0·26	0·75	1·28
Rice + tapioca	3 ♂, 3 ♀	44·9	63	76	7·8	3·50	0·20	1·17	2·13
Difference	—	—	—	—	—	1·21	−0·06	0·42	0·85* ±0·38
Paired feeding									
Rice	2 ♂, 3 ♀	52·0	58	65	5·5	2·87	0·32	0·50	2·05
Rice + tapioca	2 ♂, 3 ♀	62·2	66	70	5·5	3·42	0·40	0·39	2·63
Difference	—	—	—	—	—	0·55	0·08	−0·11	0·58** ±0·12

† 3 ♂ and 3 ♀ used for the experiment, the urine sample for 1 ♀ was lost.
* Significant at $P=0·05$. ** Significant at $P=0·01$.

Nutritive value of rice diets containing different proportions of tapioca flour

The results obtained in the previous experiments showed that 25 % of rice in a rice diet can be replaced by tapioca flour without affecting the overall nutritive value of the diet.

Aykroyd & Krishnan (1939), who carried out a dietary survey in Travancore, have reported that the ratio of rice to tapioca in the diet consumed by the poor people in that State was 1:2 and that a similar diet fed to young rats gave a growth response of 3·3 g/week, which corresponded roughly to that obtained with the poor rice diet alone. Hence it was considered desirable to investigate the nutritive value of a rice diet (Table 13) containing different proportions of tapioca flour. The results of rat-feeding experiments are given in Table 14. It is seen from Table 14 that replacement of rice by tapioca flour, even up to 50 %, gave a significantly higher gain in weight than the control rice diet. Further, even a 2:1 tapioca-rice mixture induced a growth rate that was not significantly different from that on the control rice diet. These results are in conformity with the findings of Aykroyd & Krishnan (1939). The exclusive use of tapioca flour in place of rice in the diet was unsatisfactory; in fact, four out of six animals died in the course of the experiment.

Table 13. *Percentage composition of diets containing different proportions of rice and tapioca flour*

Ingredient	Diet no. 1	2	3	4	5
Raw milled rice	78·5	58·9	39·3	26·1	—
Tapioca flour	—	19·6	39·2	52·4	78·5
Tur dhal (*Cajanus indicus*)	5·0	5·0	5·0	5·0	5·0
Non-leafy vegetables (potatoes and brinjal (*Solanum melongena*))	8·2	8·2	8·2	8·2	8·2
Leafy vegetables (*Amaranthus gangeticus*)	2·1	2·1	2·1	2·1	2·1
Groundnut oil	5·0	5·0	5·0	5·0	5·0
Milk powder	0·9	0·9	0·9	0·9	0·9
Common salt	0·3	0·3	0·3	0·3	0·3

Table 14. *Effect of replacing different percentages of rice in a rice diet by tapioca flour on the growth of young rats*

Diet (see Table 13) Rice (%)	Tapioca (%)	No. and sex of rats	Protein on moisture-free basis (%)	Average daily food intake on moisture-free basis (g)	Average weekly gain in weight* (g)	
78·5	0	4 ♂, 2 ♀	8·3	7·1	3·71	
58·9	19·6	4 ♂, 2 ♀	7·1	8·5	6·11	±0·27
39·3	39·2	4 ♂, 2 ♀	5·9	9·4	5·20	(16 D.F.)
26·1	52·4	4 ♂, 2 ♀	4·8	8·2	3·17	
0	78·5	4 ♂, 2 ♀	3·3	—	—†	

* Adjusted for the inequality in the number of rats between the sexes.
† Four out of six animals died within the period.

SUMMARY

1. Substitution of rice, wheat or ragi by tapioca or sweet-potato flour to the extent of 25 % in a poor vegetarian diet did not lead to any deterioration in the overall growth-promoting value of the diet when fed to albino rats. On the other hand, there was some distinct improvement in the growth response of rats on the rice-tapioca diet, as compared with that on the rice diet.

2. The incorporation of groundnut-cake flour, together with tuber flours, (in the ratio of 1:4) as a partial substitute for rice, wheat or ragi led to further improvement in the overall nutritive value of the diet.

3. Paired-feeding experiments showed that when the food intake was equalized, the average weekly increase in body-weight of rats on the rice-tapioca diet was not significantly different from that observed on the rice diet.

4. Experiments designed to study the supplementary value of minerals present in tapioca showed that the value was mainly due to the extra calcium contributed by tapioca.

5. The nitrogen and calcium metabolism in rats fed on diets based on rice, and on a mixture of rice and tapioca, were studied. The retention of nitrogen was of the same order in the animals fed *ad lib.* on both diets, but when the animals were pair-fed the

retention of nitrogen was significantly lower in the rats on the rice-tapioca diet than in those on the rice diet. The average weekly retentions of calcium by rats on the rice-tapioca diet were 6 and 4 mg more than those observed in rats on the rice diet when the animals were fed *ad lib.* and by the paired-feeding technique respectively.

6. The effect of replacing different percentages of rice by tapioca flour on the nutritive value of a poor vegetarian rice diet was studied. The results showed that, even when 50% of the rice was replaced by tapioca flour, there was no deterioration in the overall growth-promoting value (as compared with an exclusive rice diet) provided the diet was fed *ad lib.*

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