APPENDIX V-g

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Protein Quality and Digestibility of Sorghum in Preschool Children: Balance Studies and Plasma Free Amino Acids

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ABSTRACT

The protein quality and digestibility of two high lysine (2.9-3.0 g/100 g protein) and two conventional varieties (lysine content 2.1-2.2 g/100 g protein) of whole grain sorghum milled as flour were assessed through balance studies in 13 children 6 to 30 months of age. Sorghum protein provided 6.4% or 8.0% of dietary energy in study diets. Control diets contained 6.4% protein Kcal as casein. Children consumed 100-150 Kcal/kg body weight/day, constant for each child throughout the study. A nine-day control period was followed by one nine-day and one seven-day sorghum dietary period (high lysine and conventional sorghums alternated) and a final nine-day control period. Balance studies were carried out during the last six days of each dietary period.

Sorghum consumption was associated with very poor weight gain or weight loss. Preliminary analysis showed no difference by variety in apparent nitrogen absorption or retention. Mean absorption and retention of nitrogen (± S.D.) from 26 sorghum dietary periods were 46±17% and 14±10% of intake, respectively (corresponding preceding casein control values: 81±5% and 38±3%). Stool weight and energy losses during sorghum periods averaged 2.5 to 3 times control values.

Plasma amino acids were determined in eleven children after 16 days of sorghum consumption. Fasting concentration of total amino acids (TAA) was similar to values previously obtained with wheat protein at similar levels of intake. Total concentration of essential amino acids (TEAA) was low as were concentrations of Lys and Thr. Analysis of postprandial changes of the Lys/TEAA and Thr/TEAA molar ratios confirmed that Lys was the first limiting amino acid.

When compared with other major staple foods, wheat, rice, potato and maize, whole grain sorghum is markedly inferior to all as a source of dietary protein or energy for small children.

Key Words

Infant Nutrition
Protein Quality
Plasma Amino Acids
Sorghum
Staple Foods

Sorghum is among the world's major cereal crops. Although it is used primarily as an animal feed crop or in making beer in most parts of the world, there is substantial direct human consumption in the less well-off areas of Africa and Asia. Sorghum production is increasing: between 1952 and 1968 there was an increase of 1288% in acreage and an 80% increase in yield per acre of sorghum worldwide (1).

During the last 15 years there has been considerable research directed at the improvement of the protein quality and content, the digestibility, and the yield of sorghum. Wide variability in protein content, amino acid composition, and digestibility of different sorghums offer the promise of improving all three aspects as they relate to human nutritional requirements. Particularly desirable is an increase in the content of lysine, the essential amino acid present in lowest concentration relative to the FAO/WHO provisional scoring pattern (2).

The current studies were undertaken to evaluate the protein quality and digestibility in children of four varieties of sorghum made available by Purdue University. Sorghum is currently distributed to many areas of the world as part of U.S. food aid programs. Although the PER of conventional sorghums is low, higher lysine varieties have substantially higher PER's and offer the expectation of increased nutritional benefit in the human. Young children have the highest relative nutritional requirements and the most limited digestive capacities and consequently represent the major nutritional problem for most countries. If staple foods of improved protein quality and digestibility are to help in the alleviation of malnutrition around the world, they must be able to be consumed and utilized by this age group. Although animal studies play an

important role in the evaluation of protein quality and digestibility, their results are not always predictive of those obtained in the human, especially in children. For this reason, human testing under the carefully monitored conditions of a metabolic ward should be an important part of such breeding improvement programs.

MATERIALS AND METHODS

Patients (Table 1): Children in long-term recuperation from protein-energy malnutrition participated in the studies with the consent of their parents[2]. Table 1 shows the ages, heights, weights and hospital day at the beginning of the study. Height and weight ages can be compared with chronologic age and with each other to give an indication of the stage of recovery. The children ranged in age from 6 to 30 months and weighed between 4.7 and 9.7 kg at the outset. All were free of infection and parasites and were gaining weight well prior to entering into the study. Initial serum albumin concentrations ranged from 3.4 to 4.8 g/dl.

Diets: Four samples of whole grain sorghum flour were submitted for evaluation: Sorghum 954114 was reported to have a protein content of 12.7% and a PER in rats of 0.80, P721-OP9 a protein content of 13.6% and a PER of 1.28. Number 954063 had been analyzed to contain 11.5% protein and a PER of 0.58 had been measured. IS11758 contained 15.8% protein and the PER was reported to be 1.67 (Casein control, PER 2.31). All four sorghums had been ground on an air-impact grinder through a 0.27 inch RHD screen by Quaker Oats Company, Barrington, Illinois. The proximate analysis of the four samples is shown in Table 2. Total N content in our laboratory was generally slightly lower than that reported by Purdue University. Our analyzed values were used in the diet calculations.

Based on these values, four sorghum diets were designed (Table 3). The amount of sorghum in each case was that needed to provide 256 mg N (1.6 g protein, N x 6.25) per 100 Kcal. A blend of soybean-cottonseed oils (80:20) was added to provide 30% of calories. Sucrose completed the rest of calories. Na, K and Cl were adjusted to constant intakes. Vitamins and major and trace mineral intakes were assured with mixtures standard for the unit[2] and exceeded Recommended Dietary Allowances (3).

The sorghum flours were boiled for a period of 15-20 minutes and were then blenderized with the oil, sucrose, minerals and vitamins. Water was added t adjust the final energy density to approximately 0.67 to 0.8 Kcal/ml. Because of the very poor results obtained in the early studies, concern arose that cooking time was insufficient. In later studies, cooking time was increased to 45 minutes, at which time there was no question that gelatinization of the starch component had occurred. Subsequent analysis showed no effect of increasing the cooking time.

A control diet based on casein parallelled the sorghum diets. Protein supplied 6.4% of calories. Fat provided 30%. Cornstarch, dextrimaltose, and sucrose provided carbohydrate. Minerals and vitamins were the same as in the sorghum diets. During preparation, the cornstarch was cooked to the point of gelatinization and was then blenderized with the casein, oil, sucrose and dextrimaltose. Calorie density was the same as that of the sorghum diets. All children consumed 100-150 Kcal/kg body weight/day, constant for each child throughout the study.

When the results of studies in the initial six children indicated that the apparent digestibility of nitrogen of sorghum was extremely poor, the amount of nitrogen in the diet was increased for subsequent studies.

In these later studies, N intakes from sorghum were 320 mg per 100 Kcal (protein - 2.0 g/100 Kcal, 8% of calories). Carbohydrate calories were reduced proportionately. Fat intake remained unchanged. For these studies the N intake from the casein diet was not increased. In this way it was hoped that the amount of nitrogen absorbed from both diets would be more nearly equal. Because of the unequal N intakes (sorghum vs. casein) a bias against finding a difference between the two diets was introduced into the studies at this point.

Protocol: The planned sequence of dietary periods for the studies is shown in Table 4. Because of problems during many of the studies, not all sequences were used as planned. In most instances one child completed the first half of the sequence while a second child completed the last half. As planned, a nine-day control period (casein) was to be followed by a nine-day sorghum period and a second sorghum period of seven days. A second nine-day casein period was to be followed by two further sorghum periods of nine and seven days and a final nine-day control period. The order of consumption of the four sorghums was varied so as always to sequence one high lysine sorghum with one of the low lysine varieties.

After either a three-day or one-day period of adaptation to each new diet, the child was placed in a metabolic bed where collections of urine and stool were carried out during the last six days of each dietary period, using methods standard for the unit (4). Three-day adaptation periods always followed a change from casein to sorghum or sorghum to casein. A single day of adaptation to the second sorghum in each sequence was used to keep consumption of a protein of expectedly inferior quality to a minimum.

Blood samples for determination of hematocrit, serum total protein (Biuret) and albumin (acetate gel electrophoresis) concentrations, and cholesterol and triglyceride concentrations were obtained on the first day of periods 2, 4, 5 and 7, i.e., just prior to and after completing the sorghum diets. On the last day of periods 3 and 6, blood samples for plasma free amino acids, fasting and 3 and 4 hours after the 8 a.m. feeding, were to be obtained.

All stools were weighed wet and after drying. Fecal and urinary nitrogens were determined by the micro-Kjeldahl method in three-day pooled collections (5). Fecal fat was determined by the method of Van de Kamer et al (6). Energy intake and fecal energy losses were determined by bomb calorimetry (7). Apparent absorptions and retentions of nitrogen were calculated. Statistical analysis, where appropriate, was carried out by Student's "t" test for paired and unpaired data (8).

Plasma samples for amino acid analysis were separated, sealed in glass ampules and frozen to -20°C within one hour of being obtained. They were subsequently shipped to our laboratory in Baltimore for analysis by liquid column chromatography (9, 10, 11) using norleucine as an internal standard.

RESULTS

Data from the nitrogen balance studies are summarized in Table 5. Because of poor weight gain, or weight loss, and inadequate nitrogen retention most children failed to complete the full sequence of diets. Initial analysis showed no significant differences among the four varieties or between the high lysine and low lysine sorghums in any of the parameters measured. Further analysis was carried out with all 26 sorghum dietary periods combined.

There were strikingly significant differences between the preceding casein control and the sorghum values for all parameters except fecal fat excretion and final serum albumin concentration. The rate of weight gain during sorghum consumption decreased from the control value of 4.9± 2.6 g/kg body weight/day to 1.0±3.2 g/kg body weight/day ($P<0.001$). Similarly, apparent nitrogen absorption and retention decreased from 81±5% and 38±3% to 46±17% and 14±10%, respectively (both, $P<0.001$). Stool weights, wet and dry, and stool energy losses were markedly elevated during sorghum consumption. Energy losses in the stool averaged 21% of intake (range: 8.9 to 34.6%). This was attributable to undigested protein and carbohydrate. No significant differences in serum albumin concentrations occurred with any diet. Maintenance of normal serum albumin concentrations in association with slowed rates of weight gain is a documented response to inadequate protein intake in children of this age (12).

During the casein control period that followed consumption of sorghum, there was a prompt return to rapid weight gain. Apparent nitrogen absorption did not differ from preceding control. In contrast, apparent nitrogen retention increased dramatically and was significantly greater than preceding control (49±11% vs 38±3%, $P<0.01$). Stool wet weight decreased from the values associated with sorghum consumption but was still significantly greater than the preceding control value.

Plasma for amino acid determinations was obtained at the end of five low lysine and six high lysine sorghum dietary periods. Preliminary analysis showed no differences between the two groups. Selected results of all eleven studies combined are shown in Table 6. The fasting

concentration of total amino acids (TAA) was below the range previously documented with milk protein (6.4% protein Kcal) (13) but was similar to that obtained when wheat (14) provided all dietary protein (6.4% protein Kcal). The total concentration of the essential and semi-essential amino acids (TEAA), 515±125 μmoles/Liter, was lower than the 708±92 μmoles/Liter seen with milk-based diets (13) but similar to the 515±51 μmoles/Liter seen after 27 days of wheat protein consumption (14). The low value for TEAA was reflected in the low TEAA/TAA ratio. Fasting plasma lysine concentration was quite low as was the molar ratio of Lys/TEAA. The fasting concentration of threonine, the second limiting essential amino acid relative to the FAO/WHO provisional scoring pattern was lower than that previously seen with wheat (107±29 μmoles/Liter) but similar to that documented with rice (78±29 μmoles/Liter (15)). The fasting Thr/TEAA molar fraction was, however, similar to that seen with both of the other cereals.

Postprandially there was an expected increase in TAA and TEAA with no change of the TEAA/TAA ratio. Plasma lysine concentration did not change at three hours but tended to decline at four hours. There was a significant decrease of Lys/TEAA at four hours ($P<0.01$), indicative of dietary lysine inadequacy (14). This fall in the Lys/TEAA ratio occurred to the same degree in both high and low lysine varieties. Plasma threonine concentration increased significantly at three hours and was returning toward fasting values at four hours. There was no significant postprandial change of the Thr/TEAA ratio.

DISCUSSION

Whole grain sorghum is a bulky and poorly digestible source of dietary energy for children. The poor absorption (46±17%) and retention (14±10%)

of nitrogen from sorghum in this form make it a very poor source of dietary protein in the diets of infants and children. Sorghum consumption was associated with a dramatic slowing of the rate of weight gain, which presumably resulted from excessive fecal energy losses and as a response to inadequate quantity and quality of dietary protein (12). The return to the control diet was associated with prompt resumption of weight gain and a rebound in apparent nitrogen retention, the latter further indicative of protein inadequacy during the sorghum period.

To place the present results in perspective, the mean values of selected parameters of these studies have been compared with similarly obtained data from studies in which four other staple foods, wheat (16), rice (17), potato (18) and maize (19), provided all dietary protein (Table 7). These values are also compared with those for casein (this study). Apparent nitrogen absorption from sorghum was only 70% of that from rice and potato -- the lowest of the other four staples. The apparent retention of nitrogen from sorghum was less than half of that from wheat, a third of that from rice and maize, and a quarter of that from potato. Because of the excellent digestibility of wheat, lysine supplementation markedly improves nitrogen retention. New varieties of maize (opaque 2 and sugary 2-opaque 2) have already yielded results superior to those presented for normal maize in Table 7 (19). Protein quality of the potato is obviously quite high. Our studies have suggested that the major drawback to the use of potato for child nutrition is its bulkiness and the relative indigestibility of the carbohydrate component. Yet, fecal energy losses with potato-based diets were less than half of those with sorghum.

The postprandial plasma amino acid values obtained in these studies confirm that lysine is the first limiting amino acid in sorghum. Supplementation of sorghum with lysine was demonstrated in one study to improve the PER in rats, from 1.99 to 2.71 (20). The further addition of threonine to the mixture only resulted in minimal additional improvement of the PER to 2.80. The 38-43% increase in lysine content of two of the varieties tested in the present studies (Table 2) resulted in no measurable improvement in either nitrogen retention or the plasma aminogram. These results contrast with those of Daniel et al (21) in which the addition of lysine alone and lysine plus threonine to sorghum-based diets fed to 11-12 year old girls was associated with apparent nitrogen retentions of 13.3% and 21.8% respectively, compared with 8.6% obtained with unsupplemented sorghum. A follow-up six-month growth study carried out in 48 seven to twelve year old girls showed significant improvements of linear growth (2.9 vs 1.8 cm) and weight gain (1.74 vs 0.80 kg) with lysine supplementation (22). Both of these studies are difficult to place in perspective, however, because all diets contained moderate amounts of legumes and small amounts of milk. Brown et al (23) have documented the dramatic effects on nitrogen retention from rice-vegetarian diets when as little as 28 ml of milk per kg body weight is added to the diet.

Other studies have documented the poor apparent digestibility and nitrogen balance from sorghum-based diets. Kurien et al (24) substituted increasing amounts of sorghum for rice in the poor, predominantly vegetarian diet of 10-14 year old boys. Apparent nitrogen absorption decreased progressively from 75% to 55% of intake as apparent nitrogen balance fell from 4.5% to 2.1%. Stool dry weights doubled. Increased amounts of sorghum in the diet were associated with decreased calcium

absorption and retention.

Nicol and Phillips (25) fed diets providing 0.4 g protein and 43 Kcal per kilogram body weight per day to Nigerian men. Diets based on cassava, rice and sorghum (sorghum sativa) were compared to egg protein. Apparent nitrogen retention was -0.41 g/day when milled whole grain sorghum was used. Home pounded and winnowed sorghum was found to have 6% less fiber and to support somewhat better nitrogen retention, 0.01 g/day. True digestibility of sorghum was lower than any other protein; biologic value was superior only to that of cassava.

A single previous study has examined the nutritional value of sorghum in preschool age children (26). Diets based on sorghum in combination with redgram or blackgram were fed to 20 children cared for at a day care center, and their growth was compared to 20 control children not attending the center. That growth and weight gain of study children exceeded those of control children at the end of one year was not surprising in view of the fact that study children received 33% more protein and energy on 5 or 6 days of each week. No qualitative information on the diet of the control children was provided. Nitrogen balance data were also reported. Apparent nitrogen absorption from the two sorghum diets was reported to average 90%, apparent retention 70%! Values such as these are rarely seen even in the rapidly growing newborn fed high quality milk protein and are difficult to accept as an accurate representation of the quality of the cereal-legume combination that was fed.

Our studies leave unanswered the question of the degree to which processing, especially, and amino acid supplementation can be expected to improve digestibility and nitrogen utilization of sorghum. In some areas of the world sorghum is either boiled in alkali or fermented prior to use.

In the Sudan, for example, nasha, a fermented sorghum batter boiled in water, is used as a baby food. How these processes improve digestibility is unstudied. Simple boiling, as in our studies, or baking of milled or pounded and winnowed whole grain sorghum is also common in many countries (27). In none of the studies quoted above, in which experimental diets parallelled local food dishes, was processing other than boiling or baking used. Our previous experience with a heat-extruded blend of 80% wheat-soy and 20% dehulled sorghum (Thriposha) suggests that this form of processing could be useful. Apparent nitrogen absorptions and retentions from Thriposha by infants and children were 76±5% and 36±11%, respectively (28). Stool weights were increased relative to control values (105 g/day vs 70 g/day) but were not excessive. The extent to which these results reflect the sorghum in the blend, however, is probably limited.

Based on the present studies whole grain sorghum flour cannot be recommended for consumption by small children. Although plans had been made to study the effect of lysine supplementation of the four flours, these were abandoned in view of the very poor energy and protein digestibilities encountered. Any of the other major staple foods, if available, would be a better source of energy and protein.

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FOOTNOTES

[1] This study was supported by Research Contract AID/ta-C-1286 with the Agency for International Development, U.S. Department of State and by Research Grant HD 10111 from the National Institutes of Health, U.S.P.H.S.

[2] The protocol for these studies was approved by the Joint Committee on Human Investigation, School of Medicine, The Johns Hopkins University, and the Committee on Human Subjects of the Instituto de Investigacion Nutricional.

[3] Generously provided by Mead Johnson and Company, Evansville, Indiana 47721.

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Table 1

Summary data on children at the beginning of the studies

Pt. No.	Hosp. Day	Age mos.	Ht cm	Height* Age mos.	Weight g	Weight* Age mos.	[Albumin] g/dl
525	167	22	73.0	10.5	9020	9.0	3.87
549	320	26	81.1	17.5	9680	10.8	4.81
561	214	21	72.6	10.3	7960	6.8	4.38
568	78	26	75.6	12.5	8850	8.5	3.72
569	97	16	70.4	8.5	9200	9.5	3.71
570	20	27	71.7	9.5	7160	5.4	3.96
571	20	12	68.5	7.3	6580	4.5	3.74
572	112	6	61.7	3.5	5870	3.3	3.63
575	81	10	59.5	2.7	4740	1.3	3.76
587	140	8	61.0	3.3	5850	3.3	4.17
589	78	15	73.8	11.3	6680	4.7	4.17
594	66	30	74.2	11.5	8950	8.8	3.99
596	48	8	66.0	6.0	6140	3.7	3.38

* Age at which child's height or weight corresponds to the 50th percentile value of the Boston reference data.

Table 2

Proximate analysis of four samples of sorghum evaluated in these studies. All values per 100 g except lysine*

	954114	P721-OP9	954063	IS11758
Nitrogen - mg	1916.78	1983.97	1638.31	2326.40
Protein (N x 6.25) - g	11.98	12.40	10.24	14.54
Lysine - g/100 g protein	2.2	3.0	2.1	2.9
Fat - g	3.35	3.73	3.15	5.02
Ash - g	1.68	2.06	1.62	2.48
Fiber - g	3.28	4.22	1.30	5.62
Carbohydrate-by difference - g	71.11	69.24	74.54	63.84
Moisture - g	8.60	8.35	9.15	8.50
Energy - Kcal	362.51	360.13	367.47	358.70

* Analysis of nitrogen was carried out in the Instituto de Investigacion Nutricional. Lysine content is that reported by Purdue University. All other analyses were done by the Food Analysis Laboratory of the Department of Nutrition, Universidad Nacional Agraria, La Molina (Lima), Peru.

Table 3

Composition of the four sorghum and the casein control diets per 100 Kcal[1,2]

	954114	P721-0P9	954063	IS11758	Casein Control
Sorghum - g	13.36	12.90	15.63	11.00	--
Soybean-Cottonssed (80:20) oil - ml	3.28	3.24	3.23	3.16	3.74
Sucrose - g	6.40	6.97	4.25	8.88	5.63
Dextrimaltose - g	--	--	--	--	6.00
Corn Starch - g	--	--	--	--	5.00
Casec®[3] - g	--	--	--	--	1.86
Calorie Distribution					
Protein - %	6.4	6.4	6.4	6.4	6.4
Fat - %	30.0	30.0	30.0	30.0	30.0
Carbohydrate - %	63.6	63.6	63.6	63.6	63.6

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1 Diets as shown provided 6.4% of energy as protein. After the initial six patients, protein calories in the sorghum diets were increased to 8.0%. Sucrose calories were reduced proportionately. Fat continued to provide 30% of calories.

2 All diets were supplemented with a major and trace mineral mixture and a vitamin mixture to meet or exceed Recommended Dietary Allowances. Na and K intakes were constant at 2.1 and 4:7 mEq/100 Kcal.

3 Casec (Mead Johnson): 1 g provides 0.86 g protein, 0.02 g fat, 3.70 Kcal.

Table 4

Planned sequence of dietary periods*

Period No.	1	2	3	4	5	6	7
No. Days	9	9	7	9	9	7	9
Pt. No.							
1	C	S_1	S_2	C	S_3	S_4	C
2	C	S_1	S_2	C	S_4	S_3	C
3	C	S_2	S_1	C	S_3	S_4	C
4	C	S_2	S_1	C	S_4	S_3	C
5	C	S_1	S_4	C	S_2	S_3	C
6	C	S_1	S_4	C	S_3	S_2	C
7	C	S_4	S_1	C	S_2	S_3	C
8	C	S_4	S_1	C	S_3	S_2	C

* S_1, S_2, etc., refer to different varieties of sorghum

Table 5

Summary of balance studies with sorghum

Diet	n	Δ Weight g/kg/day	NITROGEN Abs. % Int.	NITROGEN Ret. % Int.	STOOL Weight Wet g/d	STOOL Weight Dry g/d	STOOL Fat % Int	STOOL Energy[a] % Intake	Serum [Albumin][a] g/dl Final	Serum [Albumin][a] g/dl Δ
Casein-Pre	14	4.9 ±2.6	81 ± 5	38 ± 3	95 ±35	15.5 ± 3.0	12 ± 7	7.2(11) ± 1.7	3.83(14) ±0.41	-0.14(6) ±0.40
Sorghum All	26	1.0[d] ±3.2	46[d] ±17	14[d] ±10	224[d] ±66	39.0[d] ±11.8	15 ±12	21.0(16)[d] ±13.5	3.58(17) ±0.50	-0.18(17) ±0.39
Sorghum 954114	9	0.5 ±2.1	46 ±21	12 ±10	205 ±75	38.2 ±15.3	17 ±14	19.8(5) ±11.9	3.52(5) ±0.79	-0.30(5) ±0.41
Sorghum 954063	5	-0.4 ±5.9	47 ±16	18 ±12	238 ±97	39.7 ±12.1	13 ± 6	15.2(4) ± 3.5	3.56(3) ±0.26	-0.19(3) ±0.17
Sorghum P721-OP9	7	2.8 ±1.4	54 ±15	16 ±10	232 ±48	34.9 ± 7.5	12 ± 9	17.5(3) ± 6.2	3.43(4) ±0.47	-0.12(4) ±0.47
Sorghum IS11758	5	0.8 ±3.0	35 ±13	11 ± 9	232 ±40	45.2 ± 9.6	19 ±15	20.8(4) ± 4.1	3.78 ±0.33	-0.10 ±0.46
Casein-Post	11	6.5 ±3.2	81 ± 4	49[c] ±11	129[b] ±32	18.2 ± 3.7	12 ± 5	7.0(10) ± 1.5	3.72(10) ±0.23	0.07(10) ±0.38

[a] Not determined in all children in each group. The n's, if different from whole group, are in parentheses.

[b] Differs from corresponding pre-casein control period by unpaired "t" test, $P<0.05$.

[c] Differs from corresponding pre-casein control period by unpaired "t" test, $P<0.01$.

[d] Differs from corresponding pre-casein control period by unpaired "t" test, $P<0.001$.

Table 6

Selected results of fasting and postprandial amino acids during sorghum consumption (n=11)

	Fasting	3 Hours Postprandial	4 Hours Postprandial
TAA[a] - µmoles/Liter	2364±346	2814[b]±534	2557±512
TEAA[a] - µmoles/Liter	515±125	615[b]±186	577[b]±155
TEAA/TAA	0.217±0.037	0.213±0.032	0.224±0.029
Lys - µmoles/Liter	70±36	71±21	58±22
Lys/TEAA	0.136±0.044	0.120±0.033	0.104[c]±0.033
Thr - µmoles/Liter	76±35	97[b]±47	87±35
Thr/TEAA	0.142±0.042	0.135±0.050	0.146±0.023

[a] TAA = total amino acids; TEAA = total essential amino acids

[b] Differs from corresponding fasting value by paired "t" test, $P<0.05$

[c] Differs from corresponding fasting value by paired "t" test, $P<0.01$

Table 7

Comparison of various results of sorghum studies with similarly obtained corresponding data from other staple foods

	Apparent N Balance		Stool Weight		Stool Energy
	Abs %	Ret %	Wet g/d	Dry g/d	Kcal/d
Sorghum[1]	46	14	224	39.0	183
Wheat[2]	81	20	95	13.3	60
Rice[3]	66	26	67	11.6	58
Potato[4]	66	34	165	20.3	78
Maize[5]	73	27	133	26.8	117
Casein[6]	81	38	95	15.5	63

1 Mean values of all 26 sorghum periods

2 Studies of all wheat pasta, reference 16

3 Data from studies of two varieties of rice, reference 17

4 Data from balance studies with potato, reference 18

5 Data from six studies with whole kernel normal maize, reference 19

6 Data from the 14 preceding casein control periods of these studies