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Nutritive Value of Brown and Black Beans for Infants and Small Children

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ABSTRACT

A pre-cooked, instantized mixture of brown and black beans, with and without 0.3% DL-methionine added, served as the only source of protein in the diets of 11 recovered malnourished infants and children, 10 to 42 months of age. At 6.4-6.7% dietary protein calories stool wet weights were twice as high, apparent N absorption significantly lower (66.1 $\pm$ 5.8 and 87.7 $\pm$ 2.1% of intake), and apparent N retention much lower (9.5 $\pm$ 6.1 and 32.5 $\pm$ 9.6% of intake) than during preceding and following isocaloric and isonitrogenous casein based diets. The addition of methionine resulted in minimal improvement in N retention and a significant increase in fasting plasma free methionine. Prolonged feeding of the methionine-enriched beans at 8.0-10.0% protein calories supported satisfactory growth and serum albumin levels in two of three children, not so in the smallest one, in whom repeated balance studies demonstrated no decrease over time in stool wet weight and only marginal improvement in N absorption and retention. The poor digestibility of the protein in these beans is the first-limiting factor in its utilization by infants and small children, for whom increased consumption is repeatedly urged. These data lend support to maternal reluctance to comply with these recommendations.

The importance of legumes as protein and lysine supplements to cereal and root-based diets is recognized by the scientific community and by the many millions of people throughout the underdeveloped world who traditionally consume them in combination with cereals, roots, and starchy foods (1). These same people tend to withhold the legumes from the diets of weaned infants and small children, presumably contributing to the development of protein deficiency in this age group (1). Nevertheless, their increased consumption is generally recommended for infant and child feeding in poor societies (2,3). In order to determine if the common fear of feeding more than a small amount of legumes or any at all to the very young has a physiologic basis, we made a study of the digestibility of brown and black beans and of the utilization of their protein by infants and children between 10 and 42 months of age.

MATERIALS AND METHODS

A pre-cooked and instantized mixture of brown and black beans (Phaseolus vulgaris, from Mexico), with and without 0.3% DL-methionine added, was used. Studies in rats carried out elsewhere had indicated that the brown beans had a PER 12 to 35% of the casein PER and that the addition of 0.3% DL-methionine raised this to 71 to 79.7%. Net protein utilization was raised from 32.3 to 41.8% by the addition of methionine. For the black beans the PER was raised from 31-58% to 55-78%.4% of the casein values by the addition of methionine and the NPU from 40.5 to 42.2%. For the brown-black mixture the PER was raised from 33 and 45% to 77 and 80%. The proximate composition of the mixture used was: moisture 3.8%, fat 7.2%, ash 0.8%, crude fiber 2.8%, protein (N x 6.25) 24.0%, and carbohydrates (by difference) 61.4%. Methionine content, determined by Leuconostoc mesanteroides P-60 assay, was reported as 0.19%. After addition of 0.3% DL-methionine the L-methionine content was assayed as 0.31%.

Studies of the nutritive value of the bean mixture were carried out in eleven malnourished infants and children who were far along in their convalescence. They were 10.3 to 41.0 months of age at the time of the studies, had reached a body weight at least 80% of the expected for their heights, had a serum albumin level of at least 3.50 g/dl, had no evidence of malabsorption, and were free of any apparent infection. Informed consent was obtained in all cases from their parents.

For short-term comparative studies diets were made up so that the bean mixture was the only source of protein and this represented 6.4 to 6.7% of total energy. Vegetable oil (20% cottonseed - 80% soy) and cane sugar were added so that fat represented 53% and carbohydrate 47% of non-protein calories. The children received between 6.0 and 8.0 g of the bean product per kg body weight each day in five meals. The control diet for these studies had calcium caseinate as the only source of protein, with vegetable oil, corn starch and sugar added to equal the proportions of fat, starch and sugar in the isonitrogenous, isoenergetic bean diets. In prolonged feeding studies the bean mixture, always fortified with methionine, provided all of the 8.0 to 10.0% protein calories and the children received 8.0 to

12.0 g beans /kg body weight/day in five meals. Complete vitamin and mineral mixtures were given daily to satisfy recommended intakes (4).

In the comparative studies 9-day bean periods were invariably preceded and followed by 9-day casein periods. Complete collections of urine and stool were made during the last 6 days of each period. Stool wet and dry weights were determined, as was stool and urine nitrogen (micro-Kjeldahl). Stool wet weights, apparent nitrogen absorptions, and apparent nitrogen retentions from the bean diets were compared with the average of the preceding and following casein diets. This corrected for any change over time in the physiologic state of the subjects and also permitted any minor protein or amino acid deficits to be corrected promptly. Three subjects received the bean mixture both with and without methionine, two received only the unenriched mixture, and two received only the enriched mixture.

In three children, feeding of the methionine-enriched bean mixture as the only source of protein was prolonged to 76 days, 101 days and 47 days. In the last one nitrogen balance studies were carried out on days 4-9, 22-27, 40-42, and 43-47, primarily to determine if there were any adaptive changes in digestibility. Serum albumin level was determined at the beginning and end of the studies.

Plasma free amino acids were determined (5) in the fasting state at the completion of the nine-day comparative periods in six studies with unenriched beans and in five studies with beans enriched with methionine. They were also determined, in the fasting state, in the three children consuming the enriched beans for longer periods of time, twice in two of them. In an additional child who had been consuming a cow's milk-based diet, whole blood free amino acids were determined in the fasting state and 1,2,3 and 4 hours after consuming single feedings of the same diet, or diets based on the bean mixture or the bean mixture enriched with methionine. Amino acids were also determined in plasma from the fasting and the 3- and 4-hour post-prandial samples after the two bean-based feedings.

RESULTS

In both the comparative and the prolonged studies the bean diets were consumed without difficulty and there were no signs of intolerance.

Because there were no significant differences between the unenriched and the methionine-enriched bean diets in stool wet weight, apparent nitrogen absorption, or apparent nitrogen retention, the results of the comparisons with isonitrogenous and isocaloric casein diets have been combined in Table I.

Mean stool wet weights were twice as high during the bean periods as during the casein periods. The highest values, 182 and 201 g/day, were seen in two 17 month-old boys with height ages of 7.8 and 8.5 months, very near the median height age for all the subjects. In a limited number of samples stool fat was found to be as low as during the casein periods. There was no significant correlation between stool wet weight and stool nitrogen.

In the child who received the bean diet for 47 days and had four separate metabolic collection periods, stool wet weight was 230, 219, 220 and 188 g/day. He was receiving almost twice as much of the bean product as some of the children in the comparative studies.

Apparent nitrogen absorption as a percentage of intake was much lower from the bean product than from casein. Apparent nitrogen retention, again as a percentage of intake, was also much lower from the bean products. If the mean apparent retention of 9.5 $\pm$ 6.1% of intake were to be corrected for unmeasured losses (skin, hair, etc.) these children would barely have been in nitrogen balance. When expressed as a percentage of the apparent retentions from casein, those from the methionine-enriched beans (37.7 $\pm$ 27.5%) were only slightly higher, but not significantly, than those from the unenriched beans (29.4 $\pm$ 22.7%). There was a highly significant correlation, "r" = 0.605 between apparent absorption and retention of N from beans. This was not the case for casein, where "r" was 0.115.

During prolonged feeding of the enriched beans, at considerably higher protein intakes (Table II), the rates of gain in height age and in weight age of the first two children were characteristic of those seen in the unit at the corresponding stage of recovery (6). The first child, #366, received only 8.0% of calories as protein during 76 days and, along with satisfactory linear growth and accelerated weight gain, maintained high normal serum albumin levels. The second child, #378, received 8.0% protein calories during the first 37 days and gained weight at an accelerated rate but serum albumin fell from 3.72 to 3.02 g/dl. Protein was increased to 10.0% of calories during an additional 64 days and serum albumin recovered to 3.85 g/dl, a normal level, while the child maintained satisfactory linear growth and accelerated weight gain. The third child, #396, though close in age to the other two, had a much younger "height age". His linear growth was not as satisfactory and gain in weight, though accelerated, was not as impressive. Serum albumin fell in 47 days from 4.16 to 3.40 g/dl, just below our lower limit of normal, despite a diet with 9.6% of calories from protein. In the four metabolic collections stool wet weight decreased very little over time, as already indicated. Apparent absorption of nitrogen increased from 62.5 and 62.5% to 68 and 71.5% of intake. Apparent retention of nitrogen was 27, 22, 24 and 34% of intake in the four periods.

There was no difference between methionine-enriched and unenriched bean diets in the levels of total (2569 ± 347 and 2760 ± 636 micromoles/liter) and total essential (696 ± 110 and 791 ± 202 micromoles/l) fasting plasma free amino acids. There was also no difference in the ratio of total essential to total amino acids: 0.271 ± 0.026 and 0.287 ± 0.029. Methionine levels, as the molar fraction of total essentials, were 0.031 ± 0.005 and 0.025 ± 0.006, with unpaired "t" = 1.949 and $P<0.1$. When the results in only those children receiving beans with and without methionine were compared by a paired test, "t" = 4.103 and $P<0.01$. The means were 0.030 ± 0.004 and 0.022 ± 0.003.

In the one child who received single feedings of the bean mixture and of the same with added methionine, the post-prandial changes in whole blood total and total essential free amino acids were very similar after each of the two bean feedings and after a feeding of modified cow's milk, all with 8.0% protein calories. The same was true for the ratio between essential and total amino acids and for the ratio of each essential and semi-essential amino acid to their total, with the exception of the sulfur-containing amino acids. Before and after the milk feeding the molar fraction for methionine was 0.030, 0.034, 0.028, 0.030 and 0.031 at 0, 1, 2, 3 and 4 hours while for ½ cystine it was 0.045, 0.046, 0.050, 0.042 and 0.049. Before and after the single bean feeding, without added methionine, the fractions were 0.017, 0.018, 0.020, 0.014 and 0.014 for methionine and 0.021, 0.025, 0.019, 0.016 and 0.020 for ½ cystine. Before and after the single methionine-enriched bean feeding the fractions were 0.017, 0.030, 0.027, 0.031 and 0.025 for methionine and 0.018, 0.027, 0.023, 0.028 and 0.023 for ½ cystine. Post-prandial changes in the plasma total and total essential free amino acids and in the ratios between them were not different for the two bean feedings. They were also not different for the individual amino acids with the exception of methionine. Its molar fraction decreased from a fasting level of 0.034 to 0.021 and 0.019 at 3 and 4 hours after the bean feeding. After the methionine-enriched bean feeding the molar fraction of methionine went from a fasting value of 0.034 to 0.035 and 0.031 at 3 and 4 hours.

DISCUSSION

The elevated stool weights found during the consumption of small amounts of a brown and black bean mixture by infants and small children suggest that their complex carbohydrates are poorly digested. More important is the poor digestibility of their protein, as their nutritional importance is precisely as a source of supplementary protein and lysine to poor diets. The high degree of correlation between nitrogen absorption and nitrogen retention and the disappointing improvement in nitrogen retention obtained with methionine enrichment suggest that poor protein digestibility was the major factor in determining the poor nitrogen retention found when this bean mixture was fed at critical levels of protein intake to infants and small children. During prolonged feeding at considerably more generous protein intakes, the satisfactory growth observed in two of three small children suggests that this deficiency can be overcome by more generous intakes and possibly by adaptive improvements over time in digestion. A gradual introduction of legumes has been suggested for small children (7). In the third c[illegible], however, growth was not satisfactory despite a generous protein intake; a falling serum albumin level was indicative of protein deficiency. Although there was a moderate improvement over time in nitrogen absorption and retention, it is likely that this was not enough to meet the needs of this child, who was "biologically" younger than the other two.

The post-prandial fall in blood and plasma methionine after feeding a single meal of unenriched beans merely serves to confirm their known limitation in methionine (8); the prevention of this fall by DL-methionine enrichment suggests that this was adequate to correct the methionine deficiency. This is also suggested by higher fasting plasma methionine levels after more prolonged feeding. The methionine enrichment obviously does nothing to correct the poor protein digestibility which severely limits the utilization of the protein in this particular legume by children of the age and nutritional status of those participating in these studies. Whether perfectly normal children would have been able to utilize the beans more effectively is a moot question: the needs for supplementary protein and lysine and the recommendations for legume consumption are in children of the underdeveloped world, most of whom are no better nourished than our subjects were at the time of the studies.

These limited studies with one legume processed in a particular fashion can obviously not to be used to make generalizations about all legumes but because the beans used are those with most widespread consumption, the results call for caution in making recommendations about legume consumption by the very young. They also lend strong support to the misgivings most poor mothers express about the feeding of legumes to their very young children. It may well be necessary to process legumes more extensively, as in the case of the soybean, before they can be fed safely and profitably to infants and small children.

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Table I

Stool wet weights and apparent nitrogen absorptions and retentions of seven convalescent malnourished infants (age 10.3-41.0 months, "height age" 4.7-23.9 months) consuming isocaloric and isonitrogenous diets with casein or beans as the source of protein (6.4-6.7% of calories)

Protein Source (# of Studies)	Stool Wet Wt. g/day	N Absorption % of Intake	Apparent Nitrogen Retention % of Intake	Apparent Nitrogen Retention % of Casein
Casein (11)	55.9 ± 23.6	87.7 ± 2.1	32.5 ± 9.6	100.0
Beans (11)	111.7 ± 41.7	66.1 ± 5.8	9.5 ± 6.1	33.2 ± 24.1
P	<0.001	<0.0001	<0.0001	--