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The nutritional value of diets based on starchy foods and common beans

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Abstract. Feeding trials were carried out to determine the minimum amount of common beans, with and without methionine supplementation, needed to obtain positive weight gains of rats fed cassava, sweet potato, plantain and potato flours. The protein content of these materials was 1.4, 3.8, 3.1 and 9.5% on a dry weight basis as compared to 22.8% in common beans. The amount of beans added varied from 0 to 40.0% without and with 0.3% methionine. Without methionine addition, the amount of beans required to maintain body weight was 24.8% for plantain, 19.3% for cornstarch, 20.0% for cassava and 40.1% for sweet potatoes. With just potato flour in the diet, the animals gained weight. With methionine addition, the amount of beans required for body weight maintenance was: 20.1% for plantain, 10.1% for cornstarch, 14.5% for cassava, 14.6% for potato and 29.3% for sweet potatoes. Mixtures of potatoes with as little as 10% beans with methionine gave excellent protein quality values. The results confirm previous findings on sulfur amino acid contents of beans. It is of interest to point out that factors other than a low level of protein in the starchy food tested are influencing the level of beans needed in the presence or absence of methionine supplementation.

Introduction

The food consumption systems prevailing in many areas of the world are based on variable amounts of cereal grains with variable amounts of food legumes [9, 10]. For Latin America such systems are based on corn and beans and, to a lower extent, rice and beans. In Asia, the system is characterized by rice with various legume species, while in Africa the system is based on corn or sorghum and cowpeas. However, there are large groups whose system of consumption is based on starchy roots such as cassava or on plantain and common beans [1, 16]. These latter systems of consumption have received little attention. However, they deserve investigation, since one of the components of the system does not provide protein, in contrast to the cereal/food legume pattern. In the latter, the food legume provides the limiting amino acid of the cereal grain, mainly lysine, while the cereal grain provides, to a very large extent, the methionine lacking in the food legume [5, 6, 17]. With starchy foods, the quality of the food legume plays a larger

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role and its nutritional value must be of a better quality, at least with respect to the content of sulfur amino acids [7, 16].

Based on the above, the purpose of the present study was to establish the minimum amount of food legume protein, with and without added methionine, needed to maintain the body weight of rats fed on starchy foods.

Materials and methods

Starchy foods

For the purpose of the present study, the starchy foods selected were cassava, sweet potatoes and plantains. Potatoes were also studied alone, since on a fresh basis they contain small amounts of protein.

The cassava roots were washed, peeled, and then cooked in the autoclave for 30 min with sufficient water. They were then cut into small pieces, dried with air at 60 °C, and then ground into a fine flour. The sweet potatoes were peeled, washed, ground and dried using the same procedure as for the cassava.

The plantains, half mature, were peeled by placing them in hot water to remove the skins. The fruit was then chopped into small pieces and dried and ground as indicated above.

The potatoes were processed in the same manner as the cassava and ground into a fine flour.

The food legume used was the common black bean, processed into a cooked flour as described elsewhere [4, 8].

Chemical and biological tests

All samples were analyzed for their proximate chemical composition by the AOAC Official Methods of Analysis [2].

For the feeding tests, the diets described in Table 1 were prepared. The starchy food made up 50 to 90% of the diet, while bean flour accounted for 0 to 40% of the diet. At each level of beans two diets were fed, one with 0.3% DL-methionine added and the other without methionine added. All diets were supplemented with 4% mineral mixture [11], 5% refined cottonseed oil, 1% cod liver oil and 5 ml of a complete vitamin solution per 100 gm of mixed diet [15]. As a control, a cornstarch/common bean series of diets was also prepared.

A total of 8 weanling rats of the Wistar strain were assigned to each diet. The average initial weight of each dietary group was 42 ± 1; each group included 4 female and 4 male rats. The animals were placed in individual all-wire screen cages and were fed *ad libitum* with water available at all times. Temperature in the rat laboratory varied form 22 24 °C, with relative humidity varying from 80 to 85%. Weight changes and food intake were measured every 7 days during the 28-day experimental period.

Table 1. Components (g/100 g) in the experimental diets

Ingredients	Diet no. 1	2	3	4	5	6	7	8	9	10
Starchy food[a]	90.0	80.0	79.7	70.0	69.7	60.0	59.7	50.0	49.7	78.7
Bean flour	–	10.0	10.0	20.0	20.0	30.0	30.0	40.0	40.0	–
DL-Methionine	–	–	0.3	–	0.3	–	0.3	–	0.3	–
Casein	–	–	–	–	–	–	–	–	–	11.3
Mineral mixture	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Cottonseed oil	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Cod liver oil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Vitamin solution (ml)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

[a]Cassava or plantain, potato flour, sweet potato, cornstarch as control

Table 2. Chemical composition (%) of cassava, plantain, potato, sweet potato and bean flour

Chemical composition	Cassava	Plantain	Potato	Sweet potato	Bean flour
Moisture	6.7	7.5	12.1	7.2	11.6
Ether extract	1.0	0.7	0.3	1.0	1.7
Crude fiber	2.5	1.5	2.6	4.4	4.6
Protein (N × 6.25)	1.4	3.1	9.5	3.8	22.8
Ash	4.6	3.0	4.7	4.1	4.4
CHO	83.8	84.2	70.8	79.5	54.9

All diets were analyzed for nitrogen content by the macro Kjeldahl procedure [2], and from food intake data, protein intake was calculated.

The results were analyzed statistically and simple linear regressions were calculated from feed and protein intakes and weight.

Results and discussion

Table 2 presents the proximate chemical composition of the main diet components. Protein content was 1.4% in cassava, 3.1% in plantain, 3.8% in sweet potatoes, 9.5% in potatoes and 22.8% in bean flour. Only cassava, sweet potatoes and plantain may be considered as true starchy foods, with over 80% of their weight as carbohydrate. On the other hand, potato flour is closer to a cereal grain in gross composition.

The weight gains of the animals on the series of diets when beans were and were not supplemented with methionine are shown in Table 3. In the first case, the data show that even with 10% beans in the diet, the animals were losing weight with the cassava, plantain, sweet potato and cornstarch diets. However, with only potato flour, weight gains were positive and significantly different from the other diets. This, of course, was expected. When methionine was present in the diet, 10% bean flour resulted in some weight gain, which again was striking for the potato/bean diet.

Table 3. Average weight gain (g) of animals fed with different flours and different levels of cooked bean flour without and with methionine supplementation[a]

Level of beans in diet (%)	Cassava	Plantain	Potato	Sweet potato	Corn-starch
	Without methionine supplementation				
0	– 13.5	– 11.6	53.8	14.5	– 14.1
10	– 6.6	– 1.2	70.8	– 10.6	– 5.8
20	9.1	10.9	75.9	– 1.7	2.0
30	22.0	34.2	87.1	5.6	21.6
40	34.4	58.8	87.6	22.5	46.5
	With methionine supplementation				
10	0	7.5	102.8	3.6	1.0
20	43.4	46.1	114.5	31.5	42.9
30	74.4	80.6	117.4	56.7	42.9
40	105.9	101.2	127.6	85.2	116.6

[a] 8 animals per experimental group

Table 4. Regressions between food intake and weight gain

Feeding systems	Weight = a + b (food intake)		Feed intake for 0 wt gain (g)
Plantain/common beans	$Y = -45.15 + 0.264\,X$	0.898	171
Plantain/common beans/ methionine	$Y = 66.35 + 0.384\,X$	0.930	172
Cornstarch/common beans	$Y = -51.22 + 0.268\,X$	0.955	191
Cornstarch/common beans/ methionine	$Y = -72.21 + 0.395\,X$	0.987	183
Cassava/common beans	$Y = -47.01 + 0.250\,X$	0.911	188
Cassava/common beans/ methionine	$Y = -69.76 + 0.378\,X$	0.946	184
Potato/common beans	$Y = 23.01 + 0.262\,X$	0.731	88
Potato/common beans/ methionine	$Y = 68.14 + 0.434\,X$	0.825	157
Sweet potato/common beans	$Y = -28.16 + 0.187\,X$	0.827	150
Sweet potato/common beans/ methionine	$Y = -48.15 + 0.353\,X$	0.958	136

Since protein intake increased as the percentage of beans in the diet increased, regression analysis was used to estimate the minimum amounts of beans needed for body weight maintenance. Table 4 presents the regression equations for feed intake on weight gain. The regressions of protein intake on weight gain are shown in table 5. All correlations were statistically significant. The regression coefficients were significantly higher with beans plus added methionine. The lowest correlation was observed for potato flour with unsupplemented beans.

From the regression equations of feed intake on body weight gain and of protein intake on body weight gain, the amounts of diet and of protein needed to maintain body weight gains were calculated. These figures, from which the percentage of beans were estimated, are shown in Table 6. These

Table 5. Regressions between protein intake and weight gain

Feeding systems	Weight = a + b (protein intake)		Protein intake for 0 wt gain (g/28 days)
Plantain/common beans	$Y = -19.23 + 1.99\,X$	0.965	9.66
Plantain/common beans/ methionine	$Y = -23.13 + 2.91\,X$	0.985	7.95
Cornstarch/common beans	$Y = -15.80 + 1.88\,X$	0.986	8.40
Cornstarch/common beans/ methionine	$Y = -12.83 + 3.04\,X$	0.987	4.22
Cassava/common beans	$Y = -17.40 + 2.02\,X$	0.967	8.61
Cassava/common beans/ methionine	$Y = -20.73 + 3.41\,X$	0.979	6.08
Potato/common beans	$Y = 6.54 + 1.74\,X$	0.837	–
Potato/common beans/ methionine	$Y = -14.98 + 2.87\,X$	0.929	5.22
Sweet potato/common beans	$Y = -18.80 + 1.37\,X$	0.926	13.72
Sweet potato/common beans/ methionine	$Y = -22.90 + 2.52\,X$	0.983	9.09

Table 6. Amount of diet intake and of protein intake for body weight maintenance

Feeding system	Diet intake (g)	Protein intake (g)	Beans in diet for 0 weight gain (%)
Plantain/common beans	171	9.66	24.8
Plantain/common beans/ methionine	173	7.95	20.1
Starch/common beans	191	8.40	19.3
Starch/common beans/ methionine	183	4.22	10.1
Cassava/common beans	188	8.61	20.0
Cassava/common beans/ methionine	184	6.08	14.5
Potato/common beans	88	–	–
Potato/common beans/ methionine	157	5.22	14.6
Sweet potato/common beans	150	13.72	40.1
Sweet potato/common beans/ methionine	136	9.09	29.3

figures show that for the 5 sources of starch, the level of beans needed varied from 19.3% for cornstarch to 40.1% for sweet potatoes, suggesting that plantain, sweet potatoes, and cassava contain factors which tend to increase the need for beans in such diets. One possibility is the fact that the protein of these roots is deficient in sulfur amino acids. When the beans were supplemented with methionine, the amounts needed in the diets decreased as it would be expected because of the improved protein quality derived from supplementation. However, lower levels were apparently required for cornstarch than for sweet potatoes, cassava flour and plantain, which needed 19.3, 14.5 and 20.1%, respectively. This again suggests an interference with the methionine supplemented bean protein. This may be due to factors present in sweet potatoes, plantain and cassava, or to a lower carbohydrate availability of these three sources of starch, as compared to purified cornstarch.

Similar calculations were not made for potato flour since this food, even without beans added to it, resulted in good weight gain because of its superior protein content and quality.

The unsupplemented potato diet, at 8% protein, resulted in a PER of 2.05, while that of beans with cornstarch at an equivalent protein level showed a PER of 1.40. Therefore, the addition of beans to a potato diet did not change protein quality, although total protein content would be expected to increase. Supplementation of the potato/bean mixtures with methionine resulted in PER values of 2.71, 2.63, 2.52 and 2.45 for 10, 20, 30 and 40% beans added to potato flour. This would be expected because of the deficiency of sulfur amino acids in both bean and potato protein [12–14, 18]. When discussing nutritional standards for beans, little emphasis is made on the need to increase sulfur amino acid content when beans are consumed with cereal-based diets [3]. The reason is that cereal grains do contribute some sulfur amino acids to bean protein when consumed together, resulting in a protein complementary effect [3, 5, 6, 17]. However, the same cannot be expected when beans are consumed with starchy foods such as those used in the present study. Under these conditions, both total protein content and sulfur amino acid contents are important. However, it is suggested that the dietary level of sulfur-containing amino acids should be increased, independent of the type of diet consumed, since even with cereal/bean diets, a positive response is observed with the addition of sulfur amino acids [3, 5, 6, 17].

At the highest level of bean supplementation (40%) without addition of methionine, the highest PER was observed with potato (1.85), followed by plantain (1.60) and starch and cassava (1.41, 1.34) and sweet potatoes (0.82), all lower than casein (2.68). However, the addition of 0.3% methionine resulted in significant increases to values of 2.85 for cassava, 2.00 for starch, 2.32 for plantain, 2.01 for sweet potatoes and 2.45 for potato. Therefore, beans with a higher sulfur amino acid content result in a significant increase in protein utilization in diets based on starchy food.

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