Protein-Energy-Requirement Studies in Developing Countries: Results of International Research

Edited by William M. Rand, Ricardo Uauy, and Nevin S. Scrimshaw

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32. PROTEIN DIGESTIBILITY OF COMMON BEANS: THE ROLE OF POLYPHENOLIC COMPOUNDS

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It is well recognized, from data obtained in experimental animals and humans, that bean protein digestibility is relatively low compared with that in other vegetable protein sources. Various factors have been proposed as responsible; however, very little evidence has been developed to demonstrate their specific role. Beans have been shown to contain polyphenolic compounds, which could partially contribute to their low protein digestibility.

Objectives

1. To determine the protein digestibility of common beans *(Phaseolus vulgaris).*

2. To establish the possible role of polyphenolic compounds in bean-protein digestibility.

Experimental Design

Subjects

A total of 12 healthy, young adult male subjects described in table 1 were used in each of six digestibility asays. The same subjects were used in all trials.

Environment

The subjects lived in their homes in Guatemala City and worked at INCAP. All their meals were eaten in the Metabolic Unit of the Division of Food and Agricultural Chemistry. The daily ambient temperature ranged from 21° to 25° C. Relative humidity ranged from 72 to 85 per cent. Guatemala City is 1,510 metres above sea-level.

TABLE 1. Physical Characteristics of Experimental Subjects

Subject	Age (years)	Height (cm)	Weight (kg)	
			Study 1	Study 2
C.E.	28	164	64.7	66.4
F.M.	25	157	55.4	55.7
A.O.	29	158	52.7	50.9
V.R.	19	164	48.6	50.1
A.G.	30	169	58.1	58.0
M.R.	29	167	58.1	61.3
O.B.	23	157	55.0	58.2
R.S.	22	157	53.4	56.1
M.M.	32	160	59.0	59.5
S.F.	19	167	55.7	57.7
J.P.	23	167	56.4	59.6
R.C.	32	157	49.9	49.7
Average ± SD	30	162	55.5 ± 4.3	56,9 ± 4.4

TABLE 2. Basal Low Nitrogen Containing Diet

Food	Quantity (g)
Soluble coffee	3
Sugar	25
Apple marmalade	50
Bread[a]	300
Margarine	60
Soup[b]	240
Guisquil (vegetable)	100
Cooked pineapple	100
Whole apple	100
Artificial fruit drink (glasses)	4
Vitamin and mineral supplement (tablet/day)[c]	1
Energy sources to meet 45 kcal/kg/day	
Carbonated drink (units)	1
Sweet drink	Variable
Cookies[a]	Variable
Candies	Variable

a. Made from wheat starch.
b. Made from corn starch, margarine and herbs.
c. UNICAP-T.

TABLE 3. Calories, Protein, and Polyphenolic Compounds in Dried Cooked Samples

Protein Source	Protein	kcal/100 g	Polyphenolic Compounds	
			As Cat. Equivalent (mg %)	As Tannic Acid (g %)
Red beans	22.1	419.8	27.4	0.83
Black beans (I)	20.6	406.6	55.5	1.01
Black beans (J)	25.7	465.8	60.2	1.02
White beans	5.5	467.8	7.5	0.28
Black/white mixture	26.6	444.2	25.5	0.62
White cheese	42.2	600.0	—	—
Basal low-N diet	1.9	393.0	—	—

Physical Activity

All men performed their usual chores.

Experimental Diets

Basal diet: This diet is described in table 2. It contained 2,400 kcal and provided about 25 mg N/kg/day.

Common bean samples: Four bean cultivars of different seed-coat colour were chosen: one red, one white, and two black. An additional sample was included consisting of an equal weight mixture of black and white. Protein from white cheese made from skim milk was used as a reference. The bean samples were cooked with water in a ratio of one part beans to three parts water at 15 pounds per square inch (psi) for 30 minutes. They were then put with the cooking liquid into a forced-draught oven at 60° C until dry. The samples were ground, analysed as shown in table 3, and stored at 4° C until used. The amount of bean powder for each experimental subject was weighed daily, hydrated with hot water to a paste, and consumed as such. The total amount per individual per day was fed in three equal portions at 8 a.m., 12 noon, and 5.30 p.m.

Experimental Details

Two studies with the same individual were performed. In each, a modified Latin square design was used. In both studies, four continued experimental periods were conducted. During the first three the protein sources were randomly assigned. During the last period the low-protein diet was fed. In Study 1, cheese and red and black beans (J) were assayed. In Study 2, the samples were the black bean (I), the white

TABLE 4. Apparent Protein Digestibility of Beans and Cheese

Subject	Red Beans (R)	Black Beans (Jalpatagua) (BJ)	White Beans (W)	White/Black Beans 50:50 (W:B)	Black Beans (Ipala) (BI)	Cheese (C)
C.E.	83.4	55.2	66.6	60.1	47.8	82.2
F.M.	53.2	47.3	52.9	50.8	55.9	77.8
A.O.	45.9	50.4	47.6	55.3	44.5	72.2
V.R.	74.9	46.6	82.6	82.9	64.5	77.6
A.G.	51.5	39.9	59.0	46.3	54.6	72.2
M.R.	42.7	40.6	50.1	49.9	42.7	67.6
O.B.	39.2	71.3	57.8	57.9	48.0	73.2
R.S.	58.6	64.5	58.7	54.6	61.7	75.2
M.M.	46.6	45.4	61.7	53.0	48.3	69.1
S.E.	82.0	44.5	76.0	58.9	55.6	78.9
J.P.	35.3	35.7	64.9	61.4	54.1	77.4
R.C.	55.4	55.9	67.5	58.4	62.7	84.1
$\bar{x} \pm$ S error	55.7 ± 4.60	49.6 ± 2.95	62.1 ± 2.92	57.4 ± 2.65	53.4 ± 2.08	76.2 ± 1.40
Standard deviation	16.2	10.2	10.1	9.1	7.2	4.9
Coefficient of var. %	29.1	20.6	16.3	16.0	13.5	6.5

1. F = 9.45%
2. Apparent digestibility (%) = $\frac{\text{N intake (mg/kg/day)} - \text{faecal nitrogen (mg/kg/day)}}{\text{Nitrogen intake (mg/kg/day)}}$

TABLE 5. Regression Equations between Absolute Intakes of Tannic Acid (TA) and of Catechin (C) and Faecal Nitrogen (FN) and Protein Digestibility (PD) in Adult Humans

FN =	38.08 + 0.008 (abs. TA int.)	$r = +0.33^a$
FN =	40.24 + 0.147 (abs. C int.)	$r = +0.37^a$
PD (%) ap =	65.54 − 0.010 (TA mg %)	$r = -0.32^b$
PD (%) ap =	62.71 − 0.200 (C mg %)	$r = -0.35^a$

a. $P < 0.01$.
b. $P < 0.05$

bean, and the black-and-white-bean mixture. Each study lasted six days, of which three were used for adaptation and three for collection of urine and faeces. Faecal markers were given with the last meal of the adaptation period and with the last meal of the experimental period. Collections of faeces and urine were made daily. Protein intake was adjusted at 0.6 g/kg/day with calories at 45 kcal/kg/day.

Summary of Main Results

The individual apparent protein digestibility of the bean cultivars and of the reference protein is shown in table 4. Variability among individuals for bean samples was high for red beans, intermediate for black and white, and more uniform for cheese. All bean samples gave a significantly lower protein digestibility than cheese; however, white beans showed the highest value among bean samples and black beans the lowest.

Absolute intakes of tannic acid or of catechin were positively correlated ($P > 1\%$) with faecal nitrogen excretion. Conversely, polyphenolic compounds expressed as tannic acid or as catechin equivalents were negatively correlated with protein digestibility, as shown in table 5.

Conclusions and Comments

From the results presented it is evident that polyphenolic compounds are contributing factors in decreasing the protein digestibility of beans. Their elimination from beans would probably cause an increase in average apparent digestibility from a value of 56 per cent to around 64 per cent. However, it must be noted that in the present study, varietal differences among beans, independent of polyphenolic compounds, may have obscured the specific effect of polyphenolic compounds – an aspect that must be clarified. Furthermore, catechin, the monomeric unit of many condensed

tannins, is more effective in decreasing digestibility than tannic acid, although there is a highly significant correlation ($r = +0.89$) between tannic acid and catechin equivalent. This suggests the need for a better identification of polyphenolic compounds in beans. From the data it appears that 1 mg per cent of catechin in bean dry matter decreased nitrogen absorption by 0.23 mg/kg/day. Of importance also is the role of polyphenolic compounds in relation to the forms of bean consumption and their impact when consumed in mixed diets.