NUTRITIONAL EVALUATION OF SOME VARITIES OF *PHASEOLUS VULGARIS*

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SUMMARY

Different varieties of common beans (*Phaseolus vulgaris*) differ significantly in their ability to support the growth of *Tribolium castaneum* larvae. Raw beans were toxic. The toxic components could be removed by autoclaving, and partially by water extraction. The water and aqueous methanol (20% water) did extract different toxicants. Beans differed in their antinutrient contents.

Varietal differences were observed in their amino acid profiles. The beans, in general, were deficient in methionine. Even after methionine supplementation, varietal differences in nutritive value of beans were observed that were not correlated to the color of the beans.

For screening nutritional value, the growth of the tribolium larvae can be used for bioassay.

The varietal differences in beans were also observed for supporting growth of Japanese quail.

INTRODUCTION

The bulk of our food is supplied by the following two plant families: Graminae or the grass family consisting of most of the cereal grains; and Leguminosae or the legume family consisting of most of the beans and pulses. The term legume refers to the seed or fruit of a pod-bearing plant that have nodules on the roots housing Rhizobium capable of meeting the nitrogen needs of the host plant by fixing atmospheric nitrogen. The Leguminosae family is one of the largest families of flowering plants.

The subfamily Papilionodea can be subdivided on the basis of common usage into forage legumes and food-grain legumes. The food-grain legumes, rich in oil are called oilseeds and the ones low in oil are pulses or beans. There is some confusion in the classification of beans. A large number of beans have been classified under the genus *Phaseolus* and some of these are from the new world and the others are from the old. According to a more recent suggestion, new world beans should belong to the genus Phaseolus and the old-world beans are better classified under the genus Vigna (Evans, 1979).

The developing countries harvested 12,413,000 metric tons of dry beans while the developed world harvested only 2,251,000 metric tons in 1980. Beans have been aptly called the poor man's meat as these are the main source of protein in the developing countries where, unfortunately, their cultivation is being replaced with that of cereals. The world grows more oilseeds than dry beans as is evident by a production of 83,480,000 metric tons of soybeans during the same time. The bulk of the soybeans are fed to animals in the developed countries!

The literature on nutritional value 'of *Phaseolus vulgaris* has been reviewed by Tobin and Carpenter (1978), and on toxic proteins and amino

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acids by Roy (1981). In general, raw beans (*Phaseolus vulgaris*) contain many antinutrients and even toxic substances. For this reason, beans are poorly utilized by monogastric animals. The plant breeders tend to select varieties that are low in antinutrients. The antinutrients may be involved in protecting beans against insects and fungi (Gatehouse et al. . . . . . Raw beans were growth depressing and often fatal for quail (Jayne-Williams and Burgess 1974), chickens (Untawale and McGinnis 1979) and rats (Jaffe and Lette 1968); and caused acute gastroenteritis in humans (Noah et al. 1980; Bender and Reaidi 1982).

The beans need heat processing to get rid of their antinutrient properties. The heat-labile anti-nutrients are proteinous in nature and include lectins or hemagglutinins (Liener 1962; Jaffe 1980; Pusztai atl . 1981; Bender and Reaidi 1982), and antienzymes and non-specific protease inhibitors (Kakade et al. 1973; Jaffe, 1973, Whitaker and Feeny 1973; Liener and Kakade 1980). The overheating of beans is also deleterious as it causes a browning reaction and reduces the availability of lysine (Almas and Bender 1980; Antunes and Sgarbieri 1980) and certain other amino acids (Evans and Bauer 1978). Again, even the properly processed beans do not support the optimal growth of animals unless supplemented with methionine (Tobin and Carpenter 1978). Phytate also has some role in poor utilization of beans (Alli and Baker 1981).

White beans are reported to support the growth of rats better than the colored varieties, and the poor protein digestibility of colored beans was attributed to tannins and other polyphenols in the seed coat (Elias et al. 1979; Phillips et al. 1981).

The beans orginating in the New World cannot be eaten safely by soaking and sprouting (Bender and Reaidi 1982) as is customarily done for mung beans (Khan and Ghafoor 1978) and soybeans in the Old World.

We have attempted to screen the nutritional value of white and colored beans by an insect assay and find it useful in testing small sized samples and fractions. A further evaluation was done using Japanese quail.

MATERIALS AND METHODS

The beans of known varieties were cultivated at Davis for these studies. The proximate composition was determined by the procedures outlined in AOAC (1970). The amino acid profile of the samples was determined after acid hydrolysis by ion-exchange chromatography. Tryptophan was determined by the method of DeVries et al. (1980). Trypsin inhibitor activity was measured by the procedure of Kakade et al. (1974). The processing and fractionation procedures involved autoclaving, extractions with water or aqueous methanol (20% water) , freeze drying and heating.

The larvae of an insect *Tribolium castaneum* were used for screening the nutritional value of beans and their fractions according to the procedures described by Shariff et al. (1981) and Wyckoff et al. (1983a). Tribolium were maintained on a white, unbleached wheat flour diet containing 10% brewers yeast in an incubator at 33 ± 1°C and 70 ± 5% relative humidity. After placing about 500 adults on fresh diet, eggs were sieved out after 8 to 24 hours and placed on fresh diet. After 6 days, larvae were collected, and about 50 larvae were transferred to test diets for acclimatization for 2 days. The larvae were sieved again through silk screens and 10 larvae per triplicate were transferred to

2.5 x 5 cm glass vials each containing about 2 g of test diets and incubated for 6 more days before sieving out the larvae, counting and weighing them.

The five varieties of beans, Dark Red Kidney (DRK), Light Red Kidney (LRK), Sutter Pink (SP), Black Turtle Soup (BTS), and Small White (SW) were further evaluated for the growth of Japanese quail following the usual husbandry procedures. The body weights were determined and some of the tissues were also weighed.

The statistical significance of the data was evaluated at $P<0.05$ using analysis of variance.

RESULTS AND DISCUSSION

Table 1. Proximate analysis, trypsin inhibitor (TI) activity, and amino acid profiles of raw beans (Wyckoff et al. 1983a)

Bean*	SW	DRK	BTS	LRK	SP
Moisture, %	7.43	7.46	7.29	7.22	7.49
Ash, %	4.05	3.70	5.98	3.81	4.39
Lipid, %	2.10	2.15	2.48	2.23	2.73
Protein, %	21.88	22.98	24.34	25.34	21.36
TI-activity (TIU/mg)	89.84	34.02	90.70	43.86	52.96
Amino acid profile, g amino acid/16 g N					
Arginine	6.22	6.05	4.92	5.58	5.07
Aspartic acid	10.01	10.18	7.96	5.01	9.37
Glutamic acid	24.36	16.67	18.81	14.18	14.98
Glycine	3.34	3.66	3.62	3.13	3.14
Histidine	2.83	2.55	2.15	2.63	2.88
Isoleucine	3.70	4.48	2.84	3.53	3.69
Leucine	7.08	7.79	5.53	6.69	6.69
Lysine	7.68	5.63	6.10	3.95	4.76
Methionine	2.35	2.32	2.49	2.05	1.67
Phenylalanine	5.26	5.47	4.10	4.52	3.63
Proline	-	2.26	-	-	2.10
Serine	5.71	5.83	4.39	5.31	4.92
Threonine	4.11	4.31	3.37	3.17	3.79
Tryptophan**	1.22	1.21	1.13	1.09	1.29
Tyrosine	3.34	3.48	2.68	2.95	3.18
Valine	4.00	4.92	3.37	3.80	5.10

* SW, Small White; DRK, Dark Red Kidney; BTS, Black Turtle Soup; LRK, Light Red Kidney; SP, Sutter Pink.

** By method of DeVries et al. 1980.

COMPOSITION AND AMINO ACID PROFILES:

The data of proximate analysis, trypsin inhibitor activity and amino acid profiles of 5 beans are given in Table 1. The varietal differences are evidence from these data.

TESTING OF BEAN VARIETIES:

Thirteen different varieties of raw beans, beans autoclaved at 1.266 kg/sq. cm (18 lb/sq. inch) and water extracted powdered beans were fed to tribolium larvae in a diet containing 35% bean powder, 5% brewers yeast and 65% corn starch. The results are presented in Table 2.

Table 2. Average larval weight on diets containing raw, autoclaved or water extracted ground beans (*Phaseolus vulgaris*), along with crude protein content of test samples.'

Bean variety	Crude Protein, %	Bean treatment		
		Raw	Autoclaved	Water extracted
		Larval weight, mg		
7664	18.2	0.46 (1)*	2.59 (0)	2.32 (0)
7772	18.5	0.23 (4)	2.55 (0)	2.29 (0)
79130	19.5	0.31 (7)	2.57 (0)	2.34 (0)
79131	20.2	0.42 (3)	2.59 (0)	2.36 (0)
Dark red kidney	20.2	0.94 (1)	2.87 (0)	2.61 (0)
Chief	20.9	0.58 (0)	2.88 (0)	2.70 (0)
7799	21.7	0.28 (3)	2.56 (0)	2.33 (0)
Carioca	24.4	0.48 (2)	2.72 (0)	2.58 (0)
Red kidney	24.4	1.07 (3)	2.97 (0)	2.88 (0)
Venzuela	24.5	0.39 (3)	2.60 (0)	2.41 (0)
7653	26.0	0.39 (6)	2.57 (0)	2.30 (0)
Rico 23	26.4	0.50 (0)	2.71 (0)	2.54 (0)
Control diet	13.0	2.96 (0)	2.96 (0)	2.96 (0)
LSD (P<0.05) for comparing any two means in any column		0.05	0.03	0.03

* The number of dead larvae for the 3 combined treatments is given in the paranthesis.

(Shariff et al. 1981)

The raw beans,' in general, significantly reduced the growth of larvae. The larvae developed better on the raw Red and Dark Red Kidney beans than on the other test samples. Some varieties caused more mortality than the others.

Varietal differences were present even after the beans have been autoclaved as the growth of larve on Red Kidney, Chief and Dark Red Kidney diets was as good as on the control diet. Relatively, the best and the worst raw beans still retained that ranking on autoclaving.

The water extraction improved the residual beans, but the larval growth was less than on autoclaved beans.

T. castaneum could differentiate between nutritive value of different varieties of raw, autoclaved or water extracted beans. Similar observations had been reported with chickens (Reddy et al., 1980). The varietal differences may be due to amino acid profiles or presence of

some other heat stable toxicants including complex carbohydrates (Sathe and Salunkhe 1981; Rogel and Vohra 1981).

TESTING OF BEAN FRACTIONS:

Six different varieties of beans were subjected to the following treatments: autoclaving at 112°C for 30 minutes, extraction of ground beans (14 g) with distilled water (40 ml) or aqueous methanol (20% water) 3 times and with acetone before drying at room temperature. The extracts were freeze dried. The crude protein content of these fractions are given in Table 3. The protein content of the residue decreased after water extraction and increased after aqueous methanol extraction. Methanol extracts more of free sugars, and water extracts both sugars and albumins and globulins.

Table 3. The effect of water and aqueous-methanol (20% water) extraction on the protein content of bean residues; and the dry matter of extracts.

Bean variety	Crude protein, %				
	Beans			Extracts	
	Raw	Methanol	Water	Methanol	Water
Small White 7799	20.9	30.4	12.9	7.6	17.9
Pink Gloria	21.1	27.3	16.4	12.0	8.1
Red Pinquito	21.7	25.0	17.2	10.4	6.9
Small White Auroa	22.3	30.6	12.5	21.6	6.7
Pinto UI-111	22.4	30.4	20.2	13.3	6.9
Black Turtle Soup	22.4	38.5	17.3	16.2	6.3

(Wyckoff et al. 1983b)

The test diets (Table 4) for tribolium assay contained- 16% protein and half of it was provided by the beans or their fraction.

The results of feeding of these residual beans and dried extracts in stock diet to tribolium larve are given in Table 5. (Wyckoff et al. 1983). As expected, raw beans were significantly poorer than autoclaved beans in supporting larval growth. The larval growth was better on autoclaved Small White Auroa and Red Pinquito varieties than on Pinto UI-111, Pink Gloria or 7799, thus confirming varietal differences.

A detailed fractionation of ground raw Black beans was carried out as described in Fig. 1. The numbers underneath each fraction indicate average larval growth, and the mortality is indicated in parenthesis. The average larval weights on the wheat-flour control was 2.71 mg and Mean Standard Error for the experiment was .044. The larval growth was significantly improved by autoclaving the residue left after extraction with aqueous methanol but not by water. The heating of the freeze-dried water extract significantly improved the larval growth as compared to that on unheated water-extract. No significant improvement on heating was observed for methanol-extract. The two solvents can be used for extracting different antinutrients. As water extracts globulins and albumins, these were denatured on heating. Methanol extracts mostly free sugars and these are not influenced on heating and antinutrient

properties were maintained.

Table 4. Composition of the test diets (g 10^{-1} g diet)

	Small White	Pink Gloria	Red Pinquito	Small White Auroa	Pinto UI-111	Black Turtle Soup
Raw or autoclaved*	3.58	3.80	3.68	3.59	3.57	3.57
Methanol-extd.	2.62	2.93	3.19	2.62	2.64	2.08
Water-extd.	6.39	4.87	4.65	6.39	3.96	4.64
Starch		--------- to make 8.84 g ---------				
Premix**	1.16	1.16	1.16	1.16	1.16	1.16

* The required amount of any one bean sample per 8.84 g mix with starch.

** Contained in g: brewers yeast, 0.5; isolated soybean protein, 0.65; DL-methionine, 0.0045.

(Wyckoff et al. 1983b)

Table 5. Mean larval weights on various beans and bean fractions

	Bean variety						
Treatment	Small White	Pink Gloria	Red Pinquito	Small White Auroa	Pinto UI-111	Black Turtle Soup	Average
	- - - - Larval wt. (mg) - - - -						
Raw	0.73 (8)	0.59 (16)	0.66 (7)	0.50 (8)	0.55 (17)	0.94 (17)	0.66^{z}
Autoclaved	1.13 (7)	1.15 (8)	1.40 (4)	1.47 (1)	1.04 (4)	1.27 (7)	1.24^{wxy}
Methanol extracted	0.94 (2)	1.25 (0)	1.19 (11)	0.93 (3)	1.08 (2)	1.17 (7)	1.10^{y}
Water extd.	1.12 (0)	1.19 (1)	1.32 (1)	1.28 (1)	1.13 (2)	1.27 (2)	1.22^{xy}
Extract methanol	1.28 (1)	1.28 (1)	1.39 (7)	0.94 (8)	1.50 (1)	1.42 (7)	1.30^{wx}
Extract water	1.34 (11)	1.12 (1)	1.45 (2)	1.34 (3)	1.19 (6)	2.04 (4)	1.41^{w}
Average	1.09 b	1.10 b	1.24 a	1.08 b	1.08 b	1.35 a	

Different superscripts in either a column or a row indicate significant differences ($P<0.05$). The numbers in parenthesis give the dead out of a total of 30 larvae.

(Wyckoff et al. 1983b)

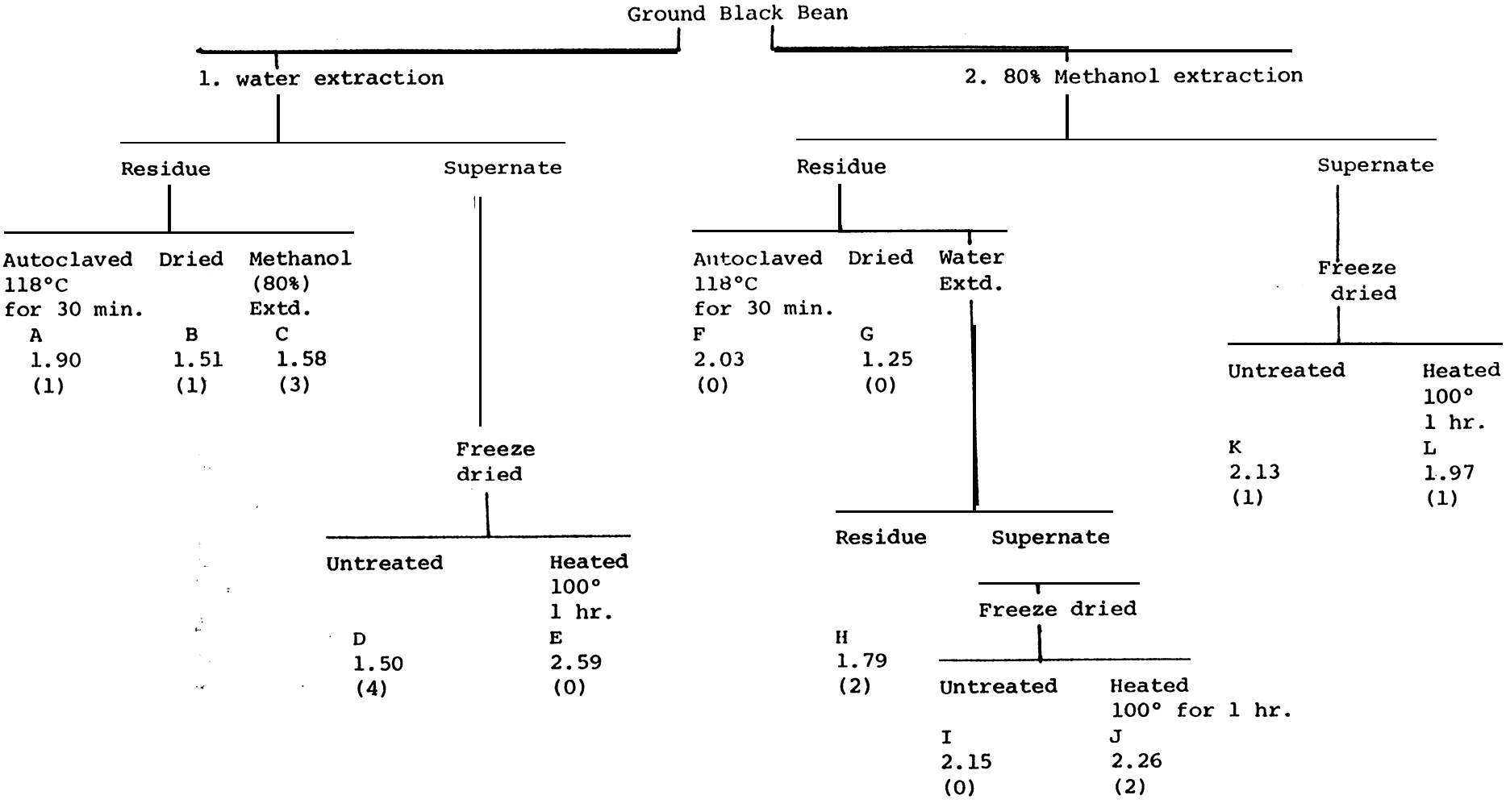

Fig. 1. Treatment of bean and mean weights of larvae. The numbers in parenthesis indicate the number of dead out of 30 larvae. MSE = 0.044.

THE INFLUENCE OF COLOR ON NUTRITIVE VALUE OF BEANS:

In a collaborative study, Dr. George F. Freytag of the Mayaguez Institute of the Tropical Agriculture, Puerto Rico prepared extracts from hand-dissected coats of white and colored beans. The extracts were added back to the extracted sample at equivalent or twice that amount and dried. The bioassay of these samples was done at Davis using tribolium larvae. The unpublished data are presented in Table 6. The data suggest that tribolium larvae respond to varietal differences in beans. However, the polyphenols as such were of less importance. We could not confirm the major role of color coat of beans in determining nutritive value as suggested by Phillips et al. (1981).

The Small White Bean (7813) was more thoroughly investigated by fractionation as outlined in Fig. 2.

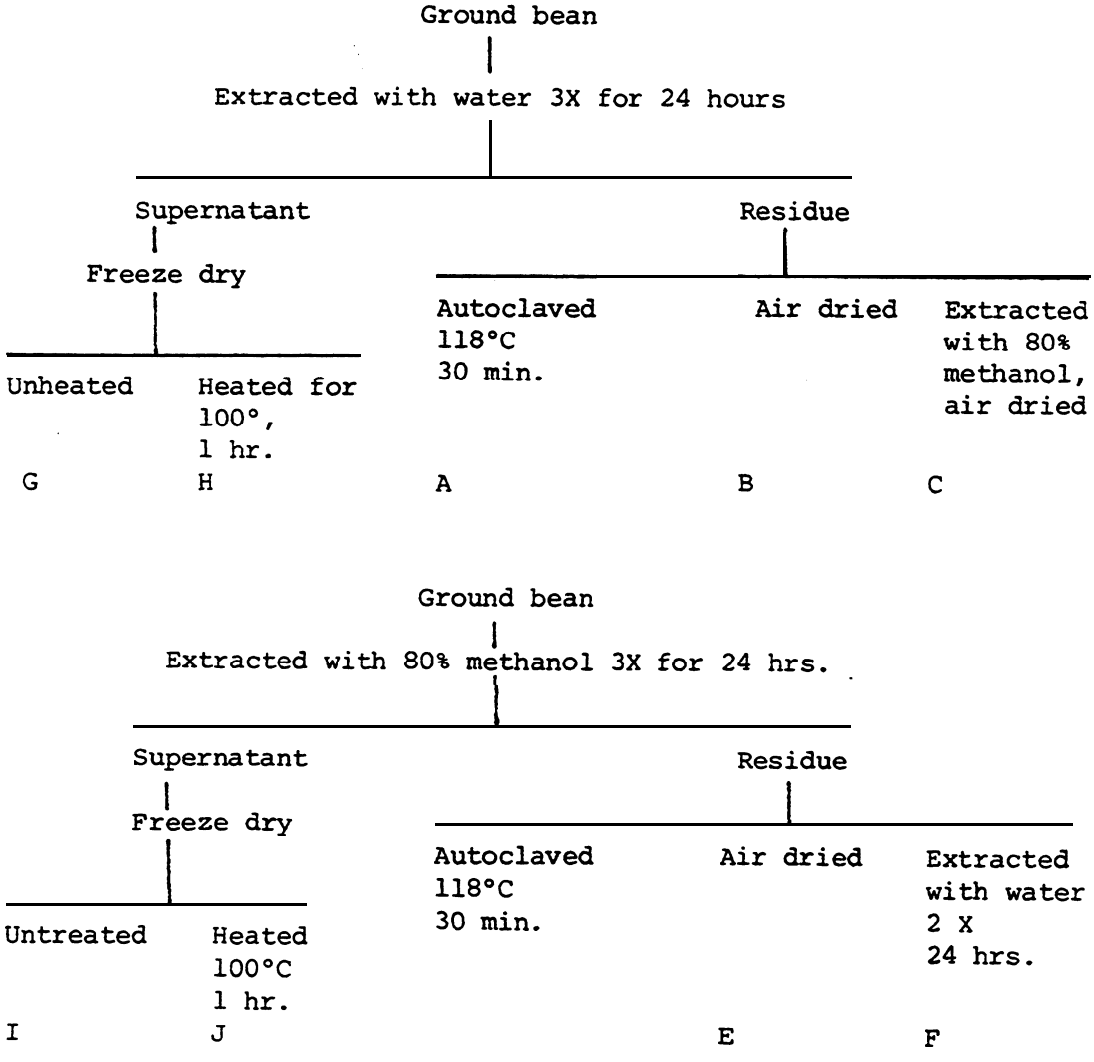

Fig. 2. Preparation of Small White bean (7813) fractions.

When the various fractions of Small White bean were fed to quail, all the birds died on fractions B,C,E and F (Fig. 3) in the first one week. The rest of the data are presented in Table 9. The growth of birds on autoclaved fractions A and D was about the same, but better than of birds fed isolated soybean protein diets.

These data bring out the importance of varietal differences, and of the difficulty of designing diets for evaluation of an ingredient.

Studies at Davis also suggested that autoclaved beans are a good source of tryptophan and can be used in supplementing a cereal such as corn when used up to 39% of the diet (Penz et al. 1983).

Table 6. Average larval weights fed 4 different bean flour preparations, arranged according to bean seed color, type and origin.

Varieties		Treatments* A	B	C	D	Mean
White, U.S.						
	U.S. 693	1.36a	2.17b	2.34b	2.14ab	1.99
	Tara	2.39	2.49	1.82	1.86	1.93
	Mean	1.88	2.33	2.08	2.00	
White, Tropical						
	Bonita	2.57b	1.61a	2.05ab	1.94ab	1.68
	W-117-21	1.45a	2.33b	1.72ab	2.08ab	1.51
	2W-33-2	2.61b	1.81ab	2.10a	1.42a	2.01
	Bunsi	2.30	1.80	1.95	2.16	2.05
	Mean	2.23	1.89	1.96	1.90	
	White, mean	2.11	2.04	2.00	1.93	
Black, U.S.						
	BTS	1.62	1.88	1.49	1.50	1.62
Black, Tropical						
	La Vega	1.83	1.71	2.00	2.16	2.19
	B-190	1.59ab	1.06a	2.07b	2.02b	2.04
	ICA-Pijao	1.85	1.92	2.07	1.75	1.94
	Porrillo	2.08	1.85	1.72	1.71	1.84
	Jamapa	2.01	2.09	2.34	2.46	2.23
	Mean	1.87	1.73	2.04	2.02	
	Black, mean	1.83	2.04	2.00	1.93	

* Feed based on: A = Bean flour embryo before polyphenol extraction.
B = Polyphenol extracted flour.
C = Extracted flour with extract replaced.
D = Extracted flour with double portion of extract replaced.

The data suggest that tribolium larvae can be used for screening nutritive value of beans. However, the information developed on tribolium cannot be strictly extrapolated to poultry or rats; and the use of data from these animals to predict the effect on humans is equally questionable.

The beans do possess antinutrients and toxins which can be overcome with proper heating. The heated beans still need supplementation with methionine. The importance of methionine supplementation of beans is well documented (Infante et al. 1979; Tobin and Carpenter, 1979). However, varietal differences are evident even after methionine supplementation.

EVALUATION WITH JAPANESE QUAIL

The results of feeding these beans to quail are given in Table 7.

Table 7. The body weights, pancreas and liver weights of Japanese quail fed bean diets unsupplemented with methionine, or a commercial poult starter.

Treatment	Body weight gain, g	Feed/gain ratio	Pancreas g/100 g	Liver body wt.
Soybean meal	65 a (15)	3.51	0.31	3.5
Small White	76 b (17)	3.59	0.34	3.2
Dark Red Kidney	74 b (17)	3.28	0.36	3.4
Black turtle Soup	73 ab(16)	3.48	0.38	3.3
Light Red Kidney	71 ab(20)	3.34	0.41	2.9
Sutter Pink	72 ab(14)	3.66	0.35	3.3
Poult starter	80 B (12)	3.34	0.37	2.8
Mean Square error	72.9	0.046	0.008	0.24

Numbers in paranthesis represent surviving birds.
Different letters in a column indicate statistical significance ($p<0.05$).
(Wyckoff et al. 1983a).

The results of feeding experiment (Table 7) indicated that without methionine supplementation, the growth of quail was significantly less on diets containing heated soybean meal than on diets containing autoclaved beans. The colored varieties were inferior to the white variety in absence of supplementary methionine. No significant differences were observed in pancreas and liver weights.

These varietal differences disappeared after supplementation of the diets with 0.4% methionine (Table 8). Liver weights were significantly lower on diets containing soybean meal and Sutter Pink beans than on other treatments. If methionine was not deficient in the diet, bean color had no influence on their nutritive value.

Table 8. The effect of methionine supplementation of beans on the gain in body weight, pancreas and liver weights of Japanese quail.

Treatment	Weight gain g	Feed/gain ratio	Pancreas g/100 g body wt.	Liver
Soybean meal	82 (20)	3.93	0.29	2.9 a
Small White	82 (19)	3.67	0.27	3.4 b
Dark Red Kidney	85 (19)	3.38	0.29	3.3 b
Black Turtle Soup	82 (20)	3.48	0.25	3.5 b
Light Red Kidney	81 (20)	3.29	0.29	3.6 b
Sutter Pink	84 (18)	3.67	0.30	2.8 a
Mean Square Error	34.3	0.014	0.0018	0.144

Wyckoff et al. 1983a.

Table 9. The effect of Small White bean fractions on weight gains, pancreas and liver weights of Japanese quail.

Treatment	Weight gain, g	Feed/gain ratio	Pancreas g/100 g body wt.	Liver, dry
Poult starter	70 a	2.84 a	0.37 ab	0.97 ab
Residue D	64 ab	4.60 abc	0.40 b	0.85 ab
Residue A	63 ab	4.83 bc	0.31 ab	0.78 a
ISP + heated methanol ext. J	57 bc	3.20 ab	0.27 a	0.95 abc
ISP + methanol ext. I	56 bcd	3.24 ab	0.36 ab	
ISP + Heated water ext. H	54 bcd	3.93 abc	0.32 ab	0.96 abc
ISP + water ext. G	50 c	3.41 abc	0.32 ab	0.95 abc
Isolated soybean protein, ISP	52 C	4.88 c	0.35 ab	1.16 c
Main Square Error	56	0.13	0.006	0.03

The birds on fractions B,C,F, and E died in the first week.

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