Trans. Nat. Acad. Science & Tech. (Phils.)
1988: 10: 305-322

FACTORS AFFECTING THE NUTRITIONAL QUALITY AND ACCEPTABILITY OF MUNG BEAN (*VIGNA RADIATA* (L.) WILZECK)*

Evelyn Mae T. Mendoza, Charlene F. Barroga, Felicito M. Rodriguez, Ma. Jamela R. Revilleza and Antonio C. Laurena

Institute of Plant Breeding, College of Agriculture
University of the Philippines at Los Banos
College, Laguna 3720

ABSTRACT

The nutritional quality and acceptability, as well as factors affecting these characteristics, of nutritionally and economically important mung bean were studied.

Mung bean has a relatively high protein content ranging from 21 to 25% and a chemical score of 65% based on its amino acid composition, and cysteine and methionine as limiting amino acids. Mungbean PER increases two to three-fold when it is dehulled, sprouted and/or cooked indicating presence of anti-nutritional factors. The trypsin inhibitor activity (TIA) of mung bean ranges from eight to 10 units/mg protein. Boiling mung bean in water for 30 min. decreases TIA by 98% while roasting in 20% residual TIA.

Polyphenols in mung bean have low protein precipitating capacity, relatively high flavanol levels and are concentrated in the seed coat. Soaking seeds in water reduces assayable polyphenol content from 24 to 50%. Boiling further reduces polyphenol content to 73%, but not roasting which reduces it to only 17%. Mung bean sprouts have 36% less polyphenols than the mature seeds. Condensed tannins isolated from mung bean decrease in vitro protein digestibility of mung bean by 3-6%.

Oligosacchrides which produce flatulence are present in mature seeds of mung bean and are not detectable in mung bean sprouts. Hemagglutinins follow a similar trend.

Hard seeds or "patol" range from 0 to 3.8% in four varieties and four seed lots of mung bean analyzed. After boiling, hard seeds remain uncooked, are hard, brownish and wrinkled. They have thicker seed coats and are twice as hard as normal seeds. Hardseededness can be accounted for by the significantly high lignin and silica content in the seed coat of mung bean. This report also summarizes relevant work on mung bean by other workers.

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*Paper presented during the Annual Scientific Meeting of the National Academy of Science and Technology, July 8, 1988, Manila Hotel.

Introduction

The Philippines produces about 33,000 mt of mung bean (*Vigna radiata* (L.) Wilczek) annually (BAECON, 1981-1983) with average yield of 0.651 5/ha from 50,000 ha. Mung bean bean is widely utilized as whole or germinated seeds and can be processed into flour or noodles. Thus, whole mung bean seeds are used in native delicacies such as "butse-butse" and "hopia", as a soup, or combined with sugar as snacks or dessert (PCARR, 1977). Germinated seeds or sprouts are mixed with shrimp and/or meat and used as vegetable dish. A portion of wheat flour can be substituted with mung bean flour to obtain high-protein bread (Mabesa and Novero, 1985). Mung bean cereal combinations are the basis of "nutripaks", nutritious food packets for children. These are also useful as weaning foods (Payumo, 1977). Mung bean flour is also the material used for the production of a popular transluscent noodle called sotanghon. Mung bean is also widely consumed in other Southeast Asian countries and in East Africa (Kay, 1979).

The Institute of Plant Breeding has a strong breeding program for mung bean and has released several widely accepted green and yellow seeded-varieties. Because of the economic significance of this legume and its being a good source of protein in the Filipino diet, our laboratory has undertaken extensive work on its nutrtional quality and acceptability and factors affecting them. This paper aims to review our work in the last five years on this topic as well as those of others which are relevant to the topic.

Chemical Composition and Nutritional Quality

Chemical Constituents

Proteins and carbohydrates are the major constituents of mung bean seeds at 17-25% and 59-61%, respectively (Table 1) (Rodriguez *et al.*, 1985). Fats comprise 1.1 to 1.5% only. Similar to other legumes, mung bean protein is rich in lysine and threonine but is deficient in the sulfur-containing amino acids, cysteine and methionine (Luse *et al.*, 1975; Del Rosario *et al.*, 1980). Its amino acid score of 65% is similar to that of cowpea and lima bean (Luse *et al.*, 1975). It is interesting to note that among legume crops, mung bean has the lowest protein productivity of 1.9 kg/ha/day compared with soybean and cowpea of 8.9 and 3.6 kg/ha/day, respectively (Luse *et al.*, 1975). The results on chemical composition are similar to those obtained by others (Kylen and McCready, 1975).

Germination of mung bean and other seeds generally results in an overall decrease in most constituents due to the increase in moisture from 10 to 90% (Kylen and McCready, 1975; Fordham *et al.*, 1975; IPB Report, 1985; Noel, 1985). On a dry weight basis, protein content increased by 15% which could be due to protein synthesis and to the loss of leachable sugars and seed coats during the germination. Fat content decreased. Starch, as expected, also decreased with concomitant increase in free sugars (Kylen and McCready, 1975; Noel, 1985).

Table 1. Proximate composition of mature seeds of mung bean

Variety Moisture	Moisture (%)	Fat (%)	Protein (% N x 6.25)p	Ash (%)	Fiber (%)	Nitrogen Free Extract (%)		
						Free Sugars (%)	Starch (%)	Others (%)
CES 87	7.22	1.46	21.21	4.12	5.07	5.40	49.70	5.82
Pag-asa 1	7.29	1.19	22.84	3.98	4.51	7.76	41.80	10.63
Pag-asa 2	7.24	1.06	24.96	3.56	4.15	7.99	41.26	9.78
Pag-asa 3	7.12	1.12	23.42	3.64	4.56	7.81	41.43	10.90

(From Rodriguez, et a., 1985).

Nutritional Quality

Protein quality. Several studies using animal assay have been made on the nutritional quality of mung bean and mung bean-based diets (Eusebio and Eusebio, 1984; Juliano, 1985). Although the protein efficiency ratio (PER) was measured to be low for raw whole seeds (0.63), this increased to 1.64 and 1.34 for dehulled and sprouted mung bean, respectively (Eusebio and Eusebio, 1984). Similar nitrogen protein utilization (NPU), biological value (BV) and digestibility values were earlier obtained for raw mung bean seeds (Gonzales *et al.*, 1982). Roasting and boiling also increased PER to 1.1; while its combination with cereal resulted in a PER of 2.41, comparable to that of the control skimmlik (Eusebio and Eusebio, 1984). An increase in digestibility and nitrogen protein utilization (NPU) of mung bean seeds also resulted from dehulling, germination and cooking. Dehulling, aside from increasing protein digestibility, also results in higher energy and lower levels of phenolics, neutral detergent fiber and nonreducing sugars (Eggum *et al.*, 1984).

Using a mixed enzyme assay of raw mature seeds of mung bean the *in vitro* protein digestibility (IVPD) level of 77% and 74% increased significantly after boiling to 85.50 and 83.3% and 90.44 and 89.56% for the green and yellow varieties, with and without broth, respectively (Table 2) (Barroga *et al.*, 1985b). As will be shown below, tannins leached from the seed coat to the soak water or broth decrease protein digestibility, and thus, the nutritional quality, of mung bean.

Table 2. In vitro protein digestibility of raw and boiled mung bean seeds

	IVPD %	
Sample	*Pag-asa 1 (green)*	*Pag-asa 3 (yellow)*
Raw whole seed	77.34[c]	76.54[c]
Boiled seeds, with brother	85.50[c]	83.31[b]
Boiled seeds, without broth	90.44[a]	89.56[a]

[a]Means followed by a common letter in a column are not significantly different at the 5% level (Duncan's multiple-range test, DMRT).

From Barroga et al., 1985b.

Carbohydrate digestibility. Since mung bean contains 59-61% carbohydrates, 37-54% of which consist of starch (Reddy *et al.*, 1984), its overall nutritional quality will also be influenced by the digestibility of its carbohydrates. *In vitro* digestibility values measured by determining carbohydrate intake and excretion in rats showed that raw mung bean has 92% *in vitro* digestibility. Processing by boiling, pressure-cooking, roasting and fermentation increased slightly the digestibility (Reddy *et al.*, 1984). In general, legume starches are highly digestible with 99% digestibility coefficient (Fleming and Vose, 1979).

Nutrients and Mung bean

In addition to their high protein content, mung bean and other legume seeds are a good source of minerals and vitamins (Kylen and McCready, 1975). Sprouting seeds generally results in higher vitamin content (on a dry weight basis). Notably, while the ascorbic acid content of seeds of mung bean and soybeans is too low to measure, the sprouts contain considerable amounts of ascorbic acid (Kylen and McCready, 1975; Prudente and Mabesa, 1981). Light does not have any effect on the vitamins of the sprouted mung bean (Prudente and Mabesa, 1981). Cooking by stir-frying results in little nutrient losses except for niacin and ascorbic acid in alfalfa sprouts (Kylen and McCready, 1975). Mineral contents of sprouts are also usually the same as the seeds except for absorption of calcium from the tap water.

Anti-Nutritional Factors

Although legumes have relatively high protein content, they also contain chemical substances which lower their overall nutritional quality and, to some extent, also affect their acceptability. These anti-nutritional factors are the following: condensed tannins, trypsin inhibitors, hemagglutinins, flatulence factors, phytic acid, saponins and alkaloids. Our studies on the anti-nutritional factors in mung bean revolve on measurement, characterization, effects on nutritional quality, and ways of removal. Among these anti-nutritional factors, tannins or polyphenols have been the most extensively studied perhaps because of their perceived detrimental effects suggested by earlier studies.

Tannins or Polyphenols

Levels and Localization. Tannins or polyphenols have been found to lower the protein digestibility of several legumes and cereals presumably due to the ability of tannins to bind with proteins. Mung bean seeds contain a high level of flavanol groups as measured by the vanillin test which may be monomers or oligomers that are too short to precipitate proteins (Table 3) (Barroga *et al.*, 1985a). The low values obtained from the protein precipitation method, ranging from 0.1 to 0.6 mg of tannic acid/g of sample (TAE), are very much lower than the values reported for cowpea (1.44-4.77 TAE) (Laurena *et al.*, 1984a), common beans (1.61-5.2 TAE) (Bressani *et al.*, 183) and sorghum (1.03-5.66 TAE) (Bullard *et al.*, 1981).

Eighty-one to 85% of the tannins are localized in the seed coat while 15-18% are in the cotyledon (Barroga *et al.*, 1985a). Similar findings have been reported for sorghum and other legumes.

Effect on in vitro protein digestibility (IVPD). Isolated condensed tannins from mung bean and commercially available tannic acid reduced significantly the IVPD values of boiled seeds (without broth) by 5-6% and 3-4% for the green and yellow varieties, respectively (Table 4) (Barroga *et al.*, 1985b). The reduced digestibility values approximated those of boiled seeds with broth as show in the table

Table 3. Analysis of polyphenol content of selected mung bean cultivars by three methods (dry weight basis)

		Polyphenol Content		
Sample	*seed coat color*	*modified vanillin assay (mg of catechin/g)*	*Prussian blue assay (mg of catechin/g)*	*protein precipitation method (mg of tannic acid/g)*
CES ID-21 (Pag-asa 1)	green	8.28^{ab}	4.04^{b}	0.41^{bc}
CES 3H-5	green	5.49^{e}	3.07^{de}	0.28^{d}
CES 2N-4	green	6.19^{cd}	3.21^{d}	0.19^{e}
V 2184	green	5.73^{cde}	3.54^{c}	0.17^{e}
CES 5G-1	green	4.49^{f}	3.21^{d}	0.10^{f}
CES 77-78-6	yellow	8.90^{a}	3.73^{c}	0.42^{bc}
CES 2F-1 (Pag-asa 2)	yellow	5.57^{de}	2.95^{de}	0.16^{e}
EGMY 161-1	yellow	6.34^{c}	3.09^{de}	0.43^{b}
CES 2G-4 (Pag-asa 3)	yellow	5.96^{cde}	2.83^{e}	0.29^{d}
VC 1469-4-3B	yellow	8.59^{ab}	4.50^{a}	0.61^{a}a
a				

[a]In a coulumn, means followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.
From Barroga et al., 1985a.

above. A similar 4% decrease in IVPD of raw white cowpea was obtained after treatment with condensed tannins from red cowpea and tannic acid (Laurena *et al.*, 1984a).

When polyuinylpolypyrrolidone (PVP), a tannin-complexing agent was added to the boiled seeds (without broth), IVPD increased significantly by 2% (Table 4). However, when PVP was added to boiled seeds with broth, the slight increase in IVPD was not significant. The results indicate that the broth contained large amounts of condensed tannins which bound the PVP.

Table 4. Effect of tannins and PVP on the in vitro protein digestibility of boiled mung bean seeds

	IVPD %	
Sample	*Pag-asa 1 (green)*	*Pag-asa 3 (yellow)*
Boiled seeds (without broth)	90.44[a]	89.56[a]
Boiled seeds + tannic acid	84.88[c]	84.39[d]
Boiled seeds + PVP + tannic acid	85.32[c]	85.64[c]
Boiled seeds + condensed tannins	86.24[b]	86.49[b]
Boiled seeds + PVP + condensed tannins	86.76[b]	86.05[bc]
Boiled seeds, without broth	90.44[b]	89.56[b]
+50 mg PVP	92.02[a]	89.51[b]
+100 mg PVP	92.19[a]	90.90[a]
+150 mg PVP	91.82[a]	90.25[ab]
Boiled seeds with broth	85.50[a]	83.31[a]
+50 mg PVP	86.08[a]	83.66[a]
+100 mg PVP	86.24[a]	83.16[a]
+150 mg PVP	86.22[a]	83.34[a]

[a]Means followed by a common letter within a treatment are not significantly different at the 5% (DMRT). Tannic acid (10 mg) or isolated condensed tannins were added to 25 mL of aqueous suspensions of boiled seeds containing 6.25 mg of protein/mL.

[b]PVP (50 mg) was added first to the boiled seeds followed by condensed tannins/tannic acid after about 5 min.

From Barroga et al., 1985b.

When boiled seeds (without broth) were treated with PVP, then with condensed tannin or tannic acid, the IVPD was comparable to values obtained from treatments without PVP and boiled seeds with broth. This indicates that condensed tannins or tannic acid overcomes the effect of the added PVP on the IVPD of boiled seeds without broth. Addition of more PVP could possibly increase IVPD (Barroga *et al.*, 1985b).

Removal of condensed tannins. Several simple methods of pre-cooking and cooking techniques such as soaking, boiling, roasting and germination were tested to determine the extent of removal of polyphenols from mung bean.

(a) Soaking of mung bean seeds in water reduced the assayable polyphenol content from 25 to 50% (Barroga *et al.*, 1985a) with the seed coat losing most of the polyphenols (see Table 5). The soak water had two to three times greater polyphenols than the whole seed. This large difference could be due to the greater reactivity of polyphenols when not in contact with endosperm constituents. A similar finding had been obtained with cowpea (Laurena *et al.*, 1984a). Soaking in water has been reported to result in a 40-70% tannin removal from high tannin sorghum (Reichert *et al.*, 1980) and 15-24% from cowpea (Laurena *et al.*, 1986).

Table 5. Effect of soaking on polyphenol content of whole mung beans seeds, cotyledon, and coat at different temperatures

	polyphenol content (mg of catechin/g)		
Sample/part	*5 C*	*15 C*	*30 C*
Pag-asa 1			
whole	2.04 (406.0)[b]	2.23 (41.0)	2.00 (47.1)
cotyledon	1.43	1.10	1.23
seed coat	25.62 (24.5)	21.69 (36.1)	22.36 (34.1)
Pag-asa 3			
whole seeds	1.75 (50.0)	2.02 (42.61)	1.91 (45.7)
cotyledon	1.05	1.01	0.94
seed coat	21.29 (35.1)	20.66 (37.0)	20.38 (37.9)

[a]Analyzed by Prussian blue assay of unsoaked seeds (in mg of catech in/g): 3.78 for Pag-asa 1; 3.52 for Pag-asa 3. Values in parentheses refer to percent polyphenol reduction. Ten grams of seeds were soaked in 20-35 mL of H_2O for 18 h.

From Barroga et al., 1985a.

(b) Boiling more efficiently removed polyphenols from mung bean up to 73% an protein-precipitable phenols by to 91% (Barroga *et al.*, 1985a).

(c) Roasting decreased the polyphenol content of mung bean seeds by 16.67% (roasted seeds had 3.15 mg of catechin/g of sample compared to 3.78 mg of catechin/g of the raw seeds). For cowpea, 68% of polyphenol was removed by rosting (Laurena *et al.*, 1987).

(d) Germination also reduced polyphenol content but only by 23-36% with maximum removal occurring after 48 hours. Continued germination up to 120 hours resulted in a decrease in polyphenol removal or an increase in polyphenols content (Barroga *et al.*, 1985b). It was observed that the filter paper on which the seeds were germinated significantly browned which indicates the leaching out of the polyphenols. Formation of insoluble protein tannin complexes and unreactive tannins may also explain the decrease in polyphenol content (see Table 7).

Loss in polyphenol content could be due to: (a) reduced extractability; (b) actual removal as in leaching out of the polyphenols into the water or (c) change in chemical reactivity. Soaking and boiling could resul in lowered polyphenol content through the second mechanism. Roasting which involves dry heat could bring about a change in chemical reactivity of the polyphenols. Laurena *et al.*, (1984a) noted that although a large reduction in assayable polyphenol content was brought about by roasting, the increase in IVPD was not as much as in boiling on germination.

Table 6. Effects of boiling on tannin content of mung bean seeds

boiling time (min)	*polyphenol content (mg of catechin/g of seeds*	*protein-precipitable phenols (mg of tannic acid/g of seeds)*
0	3.70	0.86
15	1.38 (62.7)	0.35 (59.1)
20	1.08 (70.8)	0.27 (68.2)
30	1.00 (73.0)	0.17 (80.3)
45	1.22 (67.0)	0.20 (77.3)
60	1.25 (66.2)	0.16 (81.8)
90	1.28 (65.4)	0.08 (90.9)

[a]Twenty-five grams of Pag-asa 1 seeds were placed in a 500-mL Erlenmeyer flask containing 250 mL of H_2O and cooked for 15-90 min. Sample seeds were withdrawn at 15 and 30-min intervals.

[b]Values in parentheses refer to percent polyphenol reduction. From *Barroga et al., 1985a.*

Table 7. Changes in polyphenol content of mung bean seeds during germination

germination (h)	*polyphenol content (mg of catechin/g)*	*polyphenol reduction (%)*
0	3.16	
24	2.44	22.8
48	2.01	36.4
72	2.20	30.4
96	2.25	28.2
120	2.96	6.4

[a]Average of three replicates analyzed by Prussian blue assay. Fifty seeds of Paga-sa 1 were placed in filter-lined petri dishes and allowed to germinate in the dark at 25°C.

From Barroga et al., 1985a.

The above results indicate that although condensed tannins decrease *in vitro* protein digestibility of mungbean, simple pre-cooking and cooking treatments such as soaking, with minimal intake of broth, roasting, germination for sprouts, and the use of mechanically dehulled seeds and varieties containing low levels of tannins could minimize their adverse effects.

Flatulence Factor

Flatulence in experimental animals and in man has been shown to be induced by oliqosaccharides of the raffinose family (Calloway, 1973). These oligosaccharides are galactosy-sucrose derivatives with 1,2 and 3 galactosyl varieties attached to sucrose: (α-D-Gal-(1-6)n-α-D-glu (1-2)-β-D-fruc), where n=0, sucrose, 1, raffinose: 2, stachyose and 3, verbascose. Unlike trypsin inhibitors, oligosaccharides are heat-stable and, hence, cooking by boiling or roasting will not be able to remove them.

Mung bean seeds had been reported to contain 0.87% raffinose and 1.16% stachyose (Gupta and Wagle, 1980); Noel (1985) obtained 0.22% and 1.03%, respectively, for raffinose and stachyose in mung bean seeds. Sozulski *et al.* (1982) detected a high level of verbascose at 1.83%. These values are much lower than those reported for cowpea and soybean (Akpapunam and Markakis, 1979; Mendoza *et al.*, 1980; Sosulski *et al.*, 1982). These flatulence factors disappear upon germination of mung bean. In sprouts, only traces of raffinose and stachyose were observed (IPB Report 1985; Barroga *et al., 1987). Similar* results were obtained Gupta and Wagle (1980) and Novel (1985). The effectiveness of germination in the removal of oligosaccharides has also bee shown in other legumes such as red kidney (*Phaseolus vulgaris*), Gloria pink (*Phaseolus vulgaris* cv Gloria) and black eye beans (*Vigna sinensis*) (Labaneiah and Luh, 1981).

Phytohemagglutinins and Trypsin Inhibitors

Phytohemagglutinins or lectins are substances which agglutinate red blood cells. Physiologically, it is hypothesized that hemagglutinins bind with specific receptor sites on the intestinal wall causing non-specific interference with the absorption of nutrients (Liener, 1974). Raw seeds of mung bean have of hemagglutinating activity (Beltran *et al.*, 1983; Barroga *et al.*, 1987) which are specific only to bovine and rabbit red blood cells but not to human blood type A and O cells (Barroga *et al.*, 1987). Germination effectively removes hemagglutinins; 12 hour and 24 hour sprouts are already devoid of hemagglutinating activity.

Trypsin inhibitors are considered anti-nutritional because of their ability to inhibit the action of the enzyme trypsin found in the digestive tract of man and animals and which could result in lower digestion and utilization of food and, thus slower growth. The trypsin inhibitor activity (TIA) of mung bean ranges from eight to 10 units/mg protein (see Table 8) which is comparable to values for cowpea and lower than those reported for soybean (IPB, 1981). Del Rosario *et al.*, (1980) reported similar trends; values could not be compared with those reported herein because of difference in units used. Cooking mung bean by boiling for 30 minutes results in 98% reduction of TIA while roasting results in 20% residual TIA (IPB, 1981). Beltran reported a 70% destruction of TIA in mung bean boiling. The residual TIA could represent the heat-stable tyrpsin inhibitor such as tannins. Germination decreases trypsin inhibitor activity by 23% after 24 hr. and 54% after 72 hours, (Noel, 1985).

Table 8. Trypsin inhibitor activity of mung bean and cowpea

Variety/Acc.	*Trypsin Inhibitor Units/mg sample*
Mung bean	
Pag-asa 1	9.5
Pag-asa 2	10.0
CES 55	8.2
CES 87	8.0
Acc. 225	9.0
Acc. 293	9.0
Cowpea	
UPL Cp1	9.0
UPL Cp2	7.6
UPL Cp3	8.30
Acc. 141	15.97

[a]Determined using the method of Kakade et al (1973)
(From IPB, 1981).

Alkaloids, Phytic Acid and Saponins

Alkaloids, a chemically heterogenous group of basic substances which contain nitrogen in a heterocyclic ring have varying physiological action, such as antihemorrhagic, narcotic, tranquilizer etc. (Robinson, 1975). Analysis of four varieties of mung bean seeds revealed the absence of alkaloids (Barroga *et al.*, 1987).

On the other hand, phytic acid which is phytate form will bind mineral and protein and, thus, could decrease mineral availability, was found to be low in mung bean flour (5.12-6.5 mg/kg) and was among those with low values (Kumar *et al., 1978; El*kowics and Sozulski, 1982).

Saponins, like phytate, can complex with minerals and can cause growth depression due to reduced food intake and lower availability of minerals. Mung bean flour contains 0.8 hemolyzing activity (HA)/mg much lower than the 12.8 HA/mg activity of cowpea and navy bean which could have adverse effects on the nutritive value of these legumes (Elkowics and Sozulski, 1982).

Acceptability of Mung Bean

Acceptability in terms of eating and cooking qualities (taste, texture, aroma and appearance) is a major characteristic that ultimately determines the market price, acceptance and utilization of a cultivar. Unlike rice and corn, the sensory characteristics of consumer-preferred mung bean have not yet been studied. We have recently started work on this with Dr. Linda Mabesa of the Institute of Food Science and Technology.

in addition to the sensory characteristics, the presence of "patol" or hard seeds limits the acceptability of a cultivar. Some anti-nutritional factors such as flatulence factors and tannins also lower the acceptability of a cultivar since they affect the intake and taste of the product.

Hard Seeds or "Patol"

Hard seeds in mung bean occur from 0 to 3.8% with Pag-asa 2 having the highest level among 4 varieties tested (Rodriguez and Mendoza, 1988). The consistently high percentage of "patol" seeds found in Pag-asa 2 and much less or none in others indicators that this is a varietal characteristic (see Table 9). Uncooked normal and hard seeds are hard to distinguish from one another. After boiling the hard seeds could be sorted from cooked soft normal seeds. The hard seeds are brownnish, wrinkled, twice as hard as the normal seeds (6.91 kg vs 3.64 kg), and with thicker (0.290 mm) seed coats than normal (0166 mm).

Chemical analysis of whole normal and hard seeds indicated that hard seeds had 9 to 25% higher fiber content (%) (Table 10) than normal. This was also evident when the hulls were analyzed. Hard seed hulls had 11% higher fiber content than normal (Table 11). Further analysis of the fiber components revealed that the hard seeds had seven times more lignin and 23% higher silica than the normal in

Table 9. Occurrence of hard seeds in different varieties of mung bean

Sample	*Seed coat color*	*Hard seeds (%)*
Pag-asa 1	green	0
Pag-asa 2	yellow	3.8
Pag-asa 3	yellow	0.4
CES 87	green	0
A	yellow	2.46
B	yellow	1.54
C	yellow	0.58
D	yellow	3.24

Samples A-D of unknown genotypes or variety were obtained from different stores in the town of Los Banos.

(From Rodriguez and Mendoza, 1987)

their hulls (Table 12). Both normal and hard seeds had similar content of pectic substances in their seed coats. These results indicate that the high lignin and silica content may account for the hardness of some mung bean seeds as well as their impermeability to water.

Table 10. Proximate composition of normal and hard mature seeds of several mung bean varieties

Variety	*Moisture (%)*	*Fat (%)*	*Protein (% N x 6.25)*	*Total Ash (%)*	*Fiber (%)*	*NFE (%)*
CES 87 (N)	7.22	1.46	21.21	4.12	5.07	60.92
Pag-asa 1 (N)	7.29	1.19	22.84	3.98	4.51	60.19
Pag-asa 2 (N)	7.24	1.06	24.96	3.56	4.15	59.03
Pag-asa 3 (N)	7.12	1.12	23.42	3.64	4.56	60.14
Pag-asa 2 (H)	7.14	1.12	24.78	3.44	5.48	58.04
Mixed variety (H)	7.56	1.21	20.46	3.56	5.61	61.60

N – normal; H hard
(From Rodriguez and Mendoza, 1988)

Table 11. Proximate analysis of mungbean hulls of Pag-asa 2 (dry weight basis)

Sample Hulls from	*Protein (% N x 6.25)*	*Fat (%)*	*Fiber (%)*	*Ash (%)*	*NFE (%)*
Hard seeds	8.00	2.37	35.11	4.11	50.41
Normal seeds (Boiled)	8.64	2.40	31.12	4.02	53.82

(From Rodriguez and Mendoza, 1988)

Table 12. Fiber components of mung bean hulls of Pag-asa 2 (dry weight basis)

Sample	*ADF (%)*	*Lignin (%)*	*Silica (%)*
Hard seeds	43.11	10.50	40.63
Normal (Boiled)	40.36	1.24	31.38

ADF, Acid detergent fiber.
(From Rodriguez and Mendoza, 1988)

In hard soybeans, the high contents of crude fiber and calcium and the solidness of the seed coat structure were believed to be responsible for the resistance to water absorption (Saio, 1976). The presence of hard seeds in soybean lots used in processing traditional Japanese food has been blamed for the low yield of produts by Japanese processors (Saio, 1976). Hard seeds have also been reported for cowpea (Sefa-Dedeh *et al.*, 1979), black beans (Molina *et al.*, 1976; Varriano-Marston and Jackson, 1981; Jackson and Varriano-Marston, 1981) and some yellow peas (Werker *et al.*, 1978).

Beany Flavor

Although raw mature seeds of mung bean contain low levels of lipoxygenase, prolonged incubation and germination result in the development of beany off-flavor (Del Rosario *et al.*, 1980). This off-flavor becomes noticeable after 72 hours of germination (Noel, 1985). In studying the possibility of preparing beverage from "sotanghon" washing, del Rosario and Maldo (1982) noted that washing obtained from hot water grinding of mung bean at 75°C got the best score for odor and general acceptability compared to washing obtained at lower temperatures. Presumably there was more effective in activation of lipoxygenase at higher temperature.

This beany flavor problem in mung bean has gained the attention of Japanese scientists who have started work on obtaining mung bean mutants devoid of lipoxygenase (K. Kitamura, pers. comm.). Lipoxygenase is the enzyme primarily involved in the conversion of polyunsaturated fatty acids to a aldehydes and alcohol which contribute to the off-and beany flavor of legume seeds and other products.

Effects of Major Constituents – Protein and Starch

The major processed food product obtained from mung bean is "sotanghon" which is crystalline opaque-white when raw and transparent, slippery and elastic when cooked. Sotanghon is made from mung bean starch. The unique properties of sotanghon have been attributed to the high (40%) amylose content of starch in mung bean (Sin-I, 1974). Partial substitution of mung bean starch with corn, cassava or sweet potato starches up to 15% did not significantly affect the quality of the cooked sotanghon but resulted in cooking losses (Sin-I, 1974). A related study dealt with the effect of additives such as alum, sodium tripolyphosphate, urea and noodle improper on physicochemical properties of starch from mung bean as well as from cassava and corn (Sabiniano, 1985).

The functional properties of mung bean flour and protein isolate such as nitrogen solubility, water and fat absorption, gelation capacity, whippability and foam stability were found to be excellent (Coffman and Garcia, 1977; del Rosario and Flores, 1981;). These results indicate the good potential of mung bean's application in various food products.

Efforts to Improve Mung Bean's Nutritional Quality

Genetic variability has been observed in several characters of mung bean, including protein and methionine contents (Yohe and Poehlman, 1972). Protein content recorded for 313 strains ranged from 19.1 to 28.3% protein (dry weight basis) while methionine was from 0.55 to 1.78% (as% protein). Similar ranges were obtained at the Asian Vegetable Research and Development Center (AVRDC). Further studies showed that environmental conditions affect mung bean protein content, thus, the potential for improving mung bean protein content by traditional breeding approach was deemed not promising.

In view of this, AVRDC has embarked on a project which involves interspecific hybridization of mung bean with methionine-rich blackgram (*Vigna mungo*) (AVRDC, 1980). initial results showed that some of the seeds of the F progency of an interspecific cross had high contents of methionine similar to blackgram. A similar cross produced at the Department of Genetics of the Haryana Agricultural University, Hissar, India, had lower flatulence factor, trypsin inhibitor and hemaglugtinin activity than its parents (Gupta and Wagle, 1978).

At the Institute of Plant Breeding (IPB), the successful interspecific hybridization of mung bean with *Vigna umbellata* or rice bean was reported in 1979 (Laurel and Ramirez, 1980). Although IPB does not have a program on improving mung bean protein content and quality, per se, its promising varieties are routinely analyzed chemically to ensure that the protein content is not lower than the check varieties. Perhaps, as a consequence, it is to be noted that the protein content of the varieties released in the past ten years has increased by 3-4%.

Acknowledgment

Biochemical and chemical studies of mung bean done in our laboratory were supported by the Institute of Plant Breeding through grants from the Philippine government.

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