Plant Foods for Human Nutrition **41**: 89–100, 1991.

Nutrient composition and anti-nutritional factors in selected vegetable soybean (*Glycine Max* [L.] Merr.)*

ALI I. MOHAMED, TADESSE MEBRAHTU & M. RANGAPPA
Cooperative State Research Service (CSRS), Virginia State University, P.O. Box 285, Petersburg, VA 23803, USA

Received 15 June 1990; accepted 20 July 1990

Key words: soybean (*Glycine max.* [L.] Merr.), vegetable, protein content, trypsin inhibitors, phytate and minerals, genetic variation

Abstract. The genetic variation in the nutrient composition and anti-nutritional factors of 17 vegetable soybean genotypes were determined and a wide variation in protein %, total phosphorus (TP_i) and available phosphorus (AP) was found among these genotypes. Variations in Ca, K, Fe, Mn, and Cu were also documented. Variation was also found for trypsin inhibitor (TI) activity and Phytate (PA) content. A highly significant and negative correlation ($r = -0.533$, $P < 0.01$) was observed between TI and total protein. Strong positive correlation ($r = 0.90$) was also found between TP_i and AP. Several genotypes (Sooty, Emperor, Wilson-5, PI 416771, PI 417322) showed good nutritional potential and can be used in the breeding program. High protein %, TP_i, and minerals are desirable qualities for vegetable-type soybeans that make it as food with high nutrient density. Studies on the nutritional evaluation of immature vegetable type soybean seeds at different reproductive stages are also underway.

Introduction

Consumers across the United States concerned with health and physical fitness are exploring alternative vegetable crops that can be incorporated into their diets. Legume seeds are important suppliers of protein in diets. They are also important sources for oils and carbohydrates. It is the relative proportions of these constituents that largely determine the nutritional quality of the seeds [38], e.g. a large content of both protein and oil is desirable. However, it has been documented that protein and oil are negatively correlated [14, 20, 21, 24].

Although the soybean (*Glycine max* L.) has high protein content and is used as an alternative to animal protein. However, the nutritive value of

Agricultural Research Station Journal Article Series No. 172. The use of any trade name varieties, and/or vendors does not imply the exclusion of other products or vendors that may also be suitable.

soybean protein is poor due to deficiency of the sulfur-containing amino acids, particularly methionine [9, 25]. Protease inhibitors are the anti-nutritional factors found in soybean [15, 35]. It has been reported that when animals were fed heat-treated soybean, better growth and maximum protein efficiency ratio (PER) were found [6, 16].

Phytic acid (PA), myo-inositol 1, 2, 3, 4, 5, 6 hexaphosphate, is the storage form of phosphorus (P_i) in soybean seeds [5, 8, 36, 37]. The PA binds with nutritionally-important metals, especially zinc (Zn), calcium (Ca), manganese (Mn), and magnesium (Mg), and forms a phytate-metal complex that possibly contributes to nutritional deficiencies in nonruminant animals. The growing interest in soybean as a source of protein has spurred an interest in its PA content. Several studies have shown significant varietal differences in the accumulation of PA in soybean seeds [34, 36]. If significant variation in seed PA and minerals exist among the vegetable soybean genotypes, a breeding program aimed at reducing PA and increasing the availability of minerals of the vegetable soybean seed should be feasible.

Vegetable-type soybeans are already popular as a food in the Orient, where the incidence of heart disease is low [1]. Also it has been reported that vegetable-type soybeans are superior to grain-type varieties in flavor, texture, cooking [23], and low in trypsin inhibitor (TI) activity [12]. Little is known about the nutritional quality of vegetable soybean and no study has been reported on genetic variations in TI and PA among vegetable soybean genotypes.

The present study was conducted to evaluate the nutritional quality of the selected vegetable soybean. The variations in protein, total phosphorus, available phosphorus, and minerals were determined. Also, the variation in anti-nutritional factors, namely TI and PA was investigated.

Materials and methods

Seventeen vegetable soybans genotypes, 6 cultivars (Ware, Emperor, Sango, Kingston, Sooty, and Wilson-5), and 11 plant introductions (PIs 416982, 416771, 417288, 417322, 417052, 417213, 417310, 423759, 423852, 222397 and 171437) were selected based on seed size, maturity group and seed availability during the experiment [28]. Conventional tillage practices were used along with 227 Kg ha^{-1} P and K fertilizers, which followed soil test recommendations. Three replications of each entry were planted in four row plots, in a randomized complete block design, on May 30, 1988; at the Randolph Research Farm, Virginia State University, Petersburg, Va. Each four-row plot was 4 m long and 3.60 m wide, with spacing of 90 cm between rows. A seeding rate of 23 seeds per meter was used. At physiological maturity (R8) [10] each entry was evaluated by harvesting the two center rows of each plot. The harvested materials were threshed and samples of seed were taken, ground in a centrifugal grinding mill, and passed through a 0.5 mm pore size screen. The oil was extracted with hexane using a Goldfish apparatus, and the defatted samples were used to determine total protein, trypsin inhibitor activity, total phosphorus, phytate, and minerals (Ca, Fe, Mn, K, and Cu). Total protein was analyzed by the Kjeldahl method [2].

Determination of trypsin inhibitors activity

Trypsin inhibitor activity was determined according to the method of Kakade *et al.* [22] using 2-N-Benzoyl-DL arginine p-nitroanilide as substrate. One trypsin unit corresponds to an increase of 0.01 absorbance at 410 nm/10 ml of the reaction mixture under the conditions defined by Kakade *et al.* [22]. Trypsin inhibitor activity is defined as the number of trypsin units inhibited.

Determination of phytate and total phosphorus

Extraction of phytate was done according to the procedure of Camire and Clydesdale [4] and modified by Mohamed *et al.* [29]. The phytate was purified on an anion exchange resin (Dowex $- 1 \times 8$ Cl^-) to remove inorganic phosphorus and di, tri and tetra phosphate of inositol. The phytate was eluted from the anion exchange using 1 *M* NaCl. The eluent was used to determine phytate as described by Mohamed *et al.* [29].

Chromogenic solution was used to determine total phosphorus in digested vegetable soybean samples, as described by Hafez *et al.* [18].

Determination of Ca, K, Fe, Mn, and Cu

Vegetable soybean meal was digested using peroxymonosulfuric acid as described in Hach *et al.* [13]. The digested samples were diluted to 100 ml using deionized distilled water. Atomic Absorption Spectrophotometer model 357 (instrumentation laboratory, Wilmington, MA) was used to determine these minerals, as described by Sotera and Stux [40].

The data from the chemical analyses were statistically analyzed, and the means were separated using the least significant differences (LSD) test at the 5% level of significance. Simple linear correlations were also calculated using the MSTAT statistical package.

Results and discussion

Analysis of variance of crude protein (CP), trypsin inhibitor activity (TI), phytate (PA), total phosphorus (TP_i), available phosphorus (AP_i) and minerals of selected vegetable soybean genotypes are reported in Table 1. Highly significant differences for all variables were documented.

As shown in Table 2, variations in the CP, and PA contents, and in TI activity were found among the selected vegetable soybean genotypes. The mean CP content of the tested genotypes was 43.32%; the values ranged from 36.92 for PI 222397 small-sized seeds to 47.87% for Sooty small-sized seed (Table 2). Both Sooty and Wilson-5 from MG IV had the highest % CP and PIs 222397 and 423759 from MG VI had the lowest. No significant difference in CP was found between small and large-sized seeds. However, based on maturity group a significant variation in CP was found among the three MGs used in the study. MG IV had the highest % CP (45.14%), while MG VI (41.11%) was the lowest. The high value of CP observed in MG IV may be explained on the basis that vegetative growth is still active in this maturity group during flowering. The active growth may provide high energy through the period of seed development which can be diverted toward protein synthesis. At the MG V and MG VI, vegetative growth is ceased after the initiation of reproductive stage which may limit the amount of energy that can be diverted to protein. The protein value reported here is higher than that reported from some other varieties of vegetable soybean and grain type soybean [7, 9, 11, 14] and that may be due to environmental factors and/or varietal differences [11, 42]. However, the mean % CP observed in this study was in the same range as the mean % CP grain soybean which has been analyzed in our laboratory. The mean % CP of vegetable soybean varieties (45.14%) was significantly ($P < 0.05$) higher than the mean % CP that was calculated for the PIs (43.32%).

Significant differences in TI activity was observed among tested vegetable soybean genotypes (Table 2). TI activity among the tested genotypes ranged from 24.71 for PI 416777 from MG VI to 47.06 TI units/mg meal for PI 222397 from MG VI. The grand mean of TI activity (30.39 units/mg meal) for tested genotypes was lower than that reported by Hafez [14] but similar to that reported by Gupta and Deodhar [12]. Vegetable soybean cultivars had relatively higher TI activity (31.50 units/mg meal) than that of PIs (26.99 units/mg meal). The small-sized seeds showed significantly ($P < 0.05$) higher grand mean of TI activity (31.85 units/mg meal) than did large-sized seeds (29.09 units/mg meal). Among the maturity groups, the TI activity was 31.50, 27.27, and 32.72 units/mg meal for MG IV, V, and VI, respectively. A highly significant ($P < 0.01$) and negative correlation ($r = -0.533$) was

Table 1. Analysis of variance of total protein, trypsin inhibitors activity, phytate, total phosphorus, Ca, K, Fe, Cu and Mn of selected vegetable soybeans

Source of Variation	Mean square										
	df[a]	CP[b]	TI[c]	TP_i[d]	AP_i[e]	PA[f]	Ca	K	Fe	Cu	Mn
Replications	2	34.81**	12.45**	7.65**	4.87**	17.28**	1870.79**	443.19**	32.61**	4.98**	0.126**
Genotypes	16	2.53**	75.70**	46.93**	283.66**	108.62**	986738.88**	1259.56**	494.42**	283.66**	915.08**
Error	32	0.26	0.26	0.12	0.07	0.17	12.54	2.20	1.63	0.07	0.35

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
[a] Degree of freedom. [b] Crude protein. [c] Trypsin inhibitors. [d] Total phosphorus. [e] Available phosphorus. [f] Phytate.

Table 2. Percentage crude protein (16% nitrogen), trypsin inhibitors activity and phytate content of selected vegetable soybeans

Genotypes	MG[a]	Seed size	CP[b] (g/100 gm meal)	TI[c] (units/mg meal)	PA[d] (mg/g meal)
Ware	IV	Lg	43.49	32.43	29.27
Emperor	IV	Lg	46.50	32.68	21.91
Sango	IV	Lg	38.35	34.85	35.45
Kingston	IV	Sm	46.78	31.34	40.05
Sooty	IV	Sm	47.87	29.37	30.95
Wilson-5	IV	Sm	47.83	28.30	38.36
PI 416982	V	Lg	44.81	31.59	25.01
PI 417288	V	Lg	42.18	27.71	31.80
PI 417322	V	Lg	45.83	27.50	32.16
PI 417052	V	Sm	41.18	27.50	40.67
PI 423759	V	Sm	38.94	33.55	26.03
PI 416771	V	Sm	46.76	24.71	18.80
PI 417213	VI	Lg	42.73	30.79	32.89
PI 417310	VI	Lg	43.88	28.70	33.35
PI 423852	VI	Sm	40.22	25.08	30.49
PI 222397	VI	Sm	36.92	47.06	35.60
PI 171437	VI	Sm	41.79	29.69	29.26
CV %			1.18	1.63	1.30
LSD (< 0.05)			0.85	0.85	0.24

[a] Maturity group. [b] Crude protein. [c] Trypsin inhibitors. [d] Phytate.

observed between protein and TI activity. This study indicated that by selecting for higher protein lower TI activity will be expected and higher protein digestibility will be achieved [16, 17]. Variation in TI activity in grain-type soybean has been investigated [15, 29, 32, 33, 39]. The inheritance of different classes of trypsin inhibitor in vegetable soybean is under study.

The data of PA, TP_i and AP_i of 17 vegetable soybean genotypes are reported in Tables 2 and 3. Extensive variation in the concentration of PA was observed among genotypes. The phytate content for the genotypes ranged from 18.8 for PI 416771 small-sized seeds from MG V to 40.67 mg/gm meal for PI 416052 small-sized seeds from MG V. The mean PA content of vegetable soybean (31.69 mg/gm meal) was higher than that reported for grain soybean [3, 4, 34, 36]. The mean of PA for cultivars (32.52 mg/gm meal) was significantly ($P < 0.05$) higher than that reported for PIs (30.66 mg/gm meal). The mean of PA content for small-sized seeds (32.47 mg/gm meal) was significantly ($P < 0.05$) higher than the mean of large-sized seeds (30.28 mg/gm meal) genotypes. The mean of PA content for MG V (29.08 mg/gm meal) was significantly ($p < 0.05$) lower than that calculated for MG IV and VI (32.67, 32.36 mg/gm meal respectively).

It was also observed that these selected genotypes differ significantly in

Table 3. Total phosphorus, available phosphorus, Ca, Fe, Mn, K, and Cu of selected vegetable soybeans

Genotype	MG[a]	Seed size	TP[b] (mg/g meal)	AP_i[c] (mg/g meal)	Ca (μg/g meal)	K (μg/g meal)	Fe (μg/g meal)	Cu (μg/g meal)	Mn (μg/g meal)
Ware	IV	Lg	18.78	10.55	2817.8	178.4	48.1	34.1	28.2
Emperor	IV	Lg	12.77	6.61	2113.0	124.1	46.2	49.2	22.2
Sango	IV	Lg	28.33	18.36	1676.1	85.9	26.5	8.8	5.7
Kingston	IV	Sm	20.34	8.98	2413.7	101.6	40.5	32.1	5.9
Sooty	IV	Sm	23.63	14.92	2782.7	128.5	55.7	35.1	10.4
Wilson-5	IV	Sm	21.60	10.81	1326.9	98.9	50.8	36.1	7.8
PI 416982	V	Lg	19.20	12.16	2546.8	134.0	42.3	26.4	10.5
PI 417288	V	Lg	19.69	10.74	1475.8	104.9	51.2	35.5	3.9
PI 417322	V	Lg	24.38	15.00	1477.2	108.2	35.0	51.2	68.4
PI 416771	V	Sm	16.06	10.77	3262.9	131.8	79.0	39.4	28.8
PI 417052	V	Sm	15.22	3.78	1954.3	100.8	67.5	33.5	6.3
PI 423759	V	Sm	21.04	13.72	2743.9	129.9	44.9	33.7	43.5
PI 417213	VI	Lg	27.14	17.79	2502.4	118.1	34.3	21.8	9.0
PI 417310	VI	Lg	20.66	11.12	2468.5	113.8	42.8	36.6	5.5
PI 423852	VI	Sm	20.24	11.57	2918.6	112.8	40.1	26.0	8.6
PI 222397	VI	Sm	22.13	12.38	2829.4	111.5	32.1	34.8	4.3
PI 171437	VI	Sm	22.68	14.58	2310.3	113.0	43.8	31.3	7.3
CV %			1.68	2.38	0.15	1.26	2.79	0.85	0.75
LSD			0.58	0.11	5.89	0.86	2.1	20.15	0.20

[a] Maturity group. [b] Total phosphorus. [c] Available phosphorus.

TP_i. The mean of TP_i was 20.82 mg/gm meal. The cultivar Sango from MG IV and PI 417213 from MG VI had the highest TP_i and Emperor from MG IV, and PI 417052, from MG V had the lowest. In general, there was no significant variation in the mean of TP_i of cultivars (20.91 mg/gm meal) and PIs (20.74 mg/gm meal). However, significant differences between small and large-sized seed were found. MG VI had a higher mean of TP_i (22.57 mg/gm meal) followed by MG IV, and MG V (20.91, 19.27 mg/gm meal, respectively). The mean of TP_i for vegetable-type soybeans was higher than that reported in the literature for grain-type soybeans [34]. A moderately significant positive correlation ($r = 0.383$) was observed between TP^i and PA. This correlation coefficient observed in our study was lower than that reported by Raboy *et al.* [34] which may be due to varietal differences, environmental conditions and/or type and amount of fertilizer applied during the course of the study [42]. The data also showed wide variation in AP_i among selected genotypes. The mean of AP_i was 11.97 mg/gm meal and values ranged from 3.78 mg/gm meal for PI 417052 from MG V to 18.36 mg/gm meal for Sango from MG IV. Higher significant ($P < 0.05$) AP_i for large-sized seed (12.66 mg/gm meal) than small-sized seeds (11.23 mg/gm meal) was observed. MG IV had higher AP_i than MG VI and MG V (13.48 vs 11.69 and 11.03, respectively). Strong positive correlation ($r = 0.90$) was found between TP_i and AP. The effects of food processing on phytate and other phosphorus compounds have been a subject of investigation [18, 27, 31, 37, 41]. Cooking decreases both water soluble and acid-extractable phytate in legumes [26] and causes only small changes in the ratio of phytate phosphorus/total phosphorus. Reddy *et al.* [37] did not observe any breakdown of phytate during cooking of black bean seeds. However, Hafez *et al.* [18] reported 50% reduction in phytate content of soybean seed exposed to microwave heating treatment. It has been noticed that overheating soybean seeds by microwave treatment caused reduction in the quality of soybean protein. From this discussion, it can be concluded that reducing phytate content through breeding is the best method to improve the bioavailability of minerals in diets containing vegetable soybean or soymeal.

Significant differences were observed among the genotypes for all tested minerals (Table 3). Variation in Ca content was found with a grand mean of 2330.6 μg/gm meal, and ranged from 1326.9 μg/gm meal for Wilson-5 to 3262.9 μg/gm meal for PI 416771. The mean Ca content of the cultivars (2188.33 μg/gm meal) was lower than that calculated for PIs (2408.19 μg/gm meal). The mean of Ca content of small-sized seeds (2453.0 μg/gm meal) was significantly ($P < 0.05$) higher than that for large-sized seeds (2221.8 μg/gm meal). Calcium content was also affected by Maturity group. Maturity group VI showed a higher mean of Ca (2605.8 23 μg/gm meal) than that for

MG V and MG IV (2243.5, 2186.9 μg/gm meal, respectively). The mean of Ca content of vegetable soybean observed in this study is comparable to those values reported for grain soybean [34]. Given that American diet typically is lower in Ca than the recommended dietary allowances [30], the high Ca content of vegetable soybean recommends it as a food with high nutrient density.

A wide variation in K was observed in vegetable soybean, especially more between cultivars than that between PIs. The K content ranged from 85.9 μg/gm meal for Sango to 178.4 μg/gm meal for Ware with a mean of 116.8 μg/gm meal. The mean of K for large-sized seed (120.0 μg/gm meal) was greater than that for small-sized seed (114.5 μg/gm meal). MG IV and V showed higher mean K than MG VI. Moderate variations in Fe content are recorded in Table 3. Iron ranged from 26.5 μg/gm meal for Sango to 79.0 μg/gm meal for PI 416771, with a mean of 45.8 μg/gm meal. Mean Fe for small-sized seeds (51.8 μg/gm meal) was significantly greater than for large-sized seeds (40.4 μg/gm meal); also the mean of Fe of MG V was significantly higher than that of MG IV and MG VI. Variation in Cu also was found; the lowest value was recorded for Sango at 8.8 μg/gm meal. Most of the other genotypes had significantly ($P < 0.01$) higher values which ranged from 21.8 μg/gm meal for PI 417213 to 51.2 μg/gm meal) for PI 417322. The mean Cu for small-sized seeds (39.4 μg/gm meal) was significantly ($P < 0.05$) higher than did large-sized seeds (30.96 μg/gm meal). However, no significant difference in Cu content was found among maturity groups. Manganese (Mn) showed a wider variation among genotypes than the other selected elements. The mean of Mn was 16.3 μg/gm meal and values from 3.9 μg/gm meal for PI 417288 to 68.4 μg/gm meal for PI 417322. Large-sized seeds showed higher Mn concentration than did small-sized ones. According to maturity, MG V had an exceptionally higher mean at 26.9 μg/gm meal. Contrarily, MG VI had a very low mean of 6.9 μg/gm meal.

Moderately significant negative correlation ($r = -0.459$**, -0.524**, and -0.389**) were found between PA and Ca, K, and Mn respectively (Table 4). Also, a highly significant negative correlation ($r = -0.750$**) was found between TP_i and Cu, and significant and negative correlations ($r = -0.540$** and -0.644**) were also found between both Fe and Cu and AP. Among the tested minerals, a moderately positive correlation ($r = 0.596$**) was found between Ca and K. Similarly significant positive correlations ($r = 0.339$** and 0.567**) were found between K and Cu and Fe and Cu. The high content of protein, TP_i, Ca, Fe, and Mn in vegetable soybean is recommended it as a food with high nutrient density. The forgoing discussion shows that great variations exist among the tested

Table 4. Simple Linear Correlation coefficients among chemical composition of selected vegetable soybean genotypes

Chemical composition	Chemical composition								
	TI[a]	PA[b]	TP_i[c]	AP_i[d]	Ca	K	Fe	Cu	Mn
CP[e]	−0.533**	−0.154[NS]	−0.264[NS]	−0.209[NS]	−0.103[NS]	0.192[NS]	0.439**	0.315*	0.171[NS]
TI		0.243*	0.214[NS]	0.126[NS]	0.123[NS]	0.016**	−0.463**	−0.007[NS]	−0.183[NS]
PA			0.383**	−0.047[NS]	−0.459**	−0.524**	−0.276*	−0.298*	−0.384**
TP_i				0.900**	−0.189[NS]	−0.283*	−0.627**	−0.752**	−0.026**
AP_i					0.013[NS]	−0.051[NS]	−0.542**	−0.664**	0.136[NS]
Ca						0.586**	0.221[NS]	0.095[NS]	0.032[NS]
K							0.263**	0.339*	0.310*
Fe								0.569**	0.042[NS]
Cu									−0.205[NS]

NS, *, ** Not significantly different or significantly different from zero at the 0.05 and 0.01 probability levels, respectively.
[a] Trypsin inhibitors. [b] Phytate. [c] Total phosphorus. [d] Available phosphorus. [e] Crude protein.

soybean genotypes for CP, TP_i, Ti activity, PA, AP_i, and selected minerals. Genotypes Sooty, Emperor, Wilson-5, PI 416771, PI 417322 possessed good nutritional quality and they can be used in the breeding program.

In conclusion, through hybridization and selection, the gene(s) responsible for the desirable nutritional quality observed in these genotypes could be incorporated into other genotypes which possess the desirable agronomic traits. Eventually, develop a superior cultivar for consumer use. Studies on the nutritional quality of immature seeds of vegetable-type soybean at different reproductive stages to determine the best stage that can be used for human consumption are underway.

References

1. Anonymous (1980) Effect of legume seeds on serum cholesterol. Nutr Rev 38: 159–160
2. AOAC (1980) Official Method of Analysis, 13th edn, pp. 14, 15. Washington D.C.: Association of Official Analytical Chemists
3. de Boland AR, Garner GB, O'Dell BL (1985) Identification and properties of phytate in cereal grains and oilseed products. J Agric Food Chem 23: 1186–1189
4. Camire AL, Clydesdale FM (1982) Analysis of phytic acid in foods by HPLC. J Food Sci 47: 575–578
5. Cheryan M (1980) Phytic acid interaction in food system. CRC Crit Rev Food Sci Nutri 13: 297–335
6. Collins JL, Beaty BF (1980) Heat inactivation of trypsin inhibitors in fresh green soybean and physiologial responses of rats fed the beans. J Food Sci 45: 542–546
7. Deodhar AD, Lal MS, Sharmor YK, Mehta SK (1973) Chemical composition of vegetable type varieties of soybean. Ind J Nutr Diet 10: 134–138
8. Erdman JW (1979) Oilseed phytate: Nutritional implication. J Amer Oil Chem Soc 56: 736–741
9. Evans RJ, Bandemer SL (1976) Nutritive value of legume seed proteins. J Agric Food Chem 15: 439–443
10. Fehr WR, Coviness CE, Burrmood DT, Pennington JS (1971) Stage development description of soybean, Glycine max. (L.) Merr. Crop Sci 11: 929–930
11. Gupta YP, Grover HL, Kapoor AC (1978) Preliminary studies on the quality characters of soybeans. Curr Agric 2: 39–43
12. Gupta AK, Deodhar AD (1975) Variation in trypsin inhibitor activity in soybean (Glycine max). Ind J Nutr Diet 12: 81–84
13. Hach CC, Brayton SV, Kopenlone AB (1985) A powerful Kjeldahl nitrogen method using peroxymonosulfuric acid. J Agric Food Chem 33(6): 1117–1123
14. Hafez YS (1983) Nutrient composition of different varieties and strains of soybean. Nutr Report Int 28(6): 1197–1206
15. Hafez YS, Mohamed AI (1983) Presence of non-protein trypsin inhibitor in soy and winged beans. J Food Sci 48: 75–76
16. Hafez YS, Mohamed AI, Hewedy FM, Singh G (1985) Effects of microwave heating on solubility, digestibility and metabolism of soy protein. J Food Sci 50: 415–417 & 324
17. Hafez YS, Mohamed AI, Singh G, Hewedy FM (1985) Effects of gamma irradiation on proteins and fatty acid composition of soybean. J Food Sci 50(5): 1271–1274
18. Hafez YS, Mohamed AI, Perera PAJ, Singh G, Hussein AS (1989) Effects of microwave heating and gamma irradiation on phytate and phospholipid contents of soybean (Glycine max L.). J Food Sci 54(4): 958–962
19. Hymowitz T, Handdy HH (1972) Inheritance of trypsin inhibitor variant in seed protein of soy beans. Crop Sci 12: 197–198
20. Johnson GR, Harper JM, O'Dean LA (1978) Nutritional evaluation of full-fat soybean flour produced by day heat. J Food Sci 43: 1350–1351

21. Jones GD, Lutz JA (1971) Yield of wheat and soybeans and oils and protein content of soybean as affected by fertility treatments and deep placement of limestone. Agron J 63: 931–934
22. KaKade ML, Simon N, Linear IE (1969) An evaluation of natural vs. synthetic substrate for measuring the anti-tryptic activity of soybean samples. Cereal Chem 46: 518–526
23. Kapoor M, Gupta AK, Deodhar AD (1977) Sensory evaluation of vegetable cutlets prepared from soybeans (vegetable and grain type) and potatoes. Curr Agric 1: 49–52
24. Krivoruchco D, Kana H, Sambucetti ME, Sanahuja JC (1979) Maturation time and some seed composition characters affecting nutritive value in soybeans varieties. Cereal Chem 56: 217–219
25. Krober OA, Cartter JL (1978) Relation of methionine content to protein levels in soybeans. Cereal Chem 55: 320–323
26. Kumar KG, Venkatamaraman LV, Jaya TT, Krishnamaurthy KS (1978) Cooking characteristics of some germinated legumes: changes in phytins, Ca^{++}, Mg^{++}, and pectin. J Food Sci 43: 85–88
27. Lolas GM, Markakis P (1975) Phytic acid and other phosphorus compounds of beans (*Phaseolus vulgaris* L.). J Agric Food Chem 23: 13–15
28. Mebrahtu T, Mohamed AI, Rangappa M (1989) Greenpod yield and architectural traits of selected vegetable soybean genotypes. Soybean Genetic Newsletter 16: 208–210
29. Mohamed AI, Perera PAJ, Hafez YS (1986) New chromophore for phytic acid determination. Cereal Chem 63: 475–476
30. NAS (1989) National Academy of Science, National Research Council, Recommended Dietary Allowances, 10th edition
31. Nayini NR, Markakis P (1983) Effects of fermentation time on the inositol phosphates of bread. J Food Sci 48: 262–263
32. Orf JH, Hymowitz T (1979) Inheritance of the absence of the kunitz trypsin inhibitor in seed protein of soybeans. Crop Sci 19: 107–109
33. Orf JH, Hymowitz T (1977) Inheritance of a second trypsin inhibitor variant in seed protein of soybeans. Crop Sci 17: 811–813
34. Raboy V, Dickinson DB, Below FE (1984) Variation in seed total phosphorus, phytic acid, zinc, calcium, magnesium and protein among lines of Glycine max. and Glycine Soja. Crop Sci 24: 431–434
35. Rackis TJ, McGhee JE, Booth AN (1975) Biological threshold levels of soybean trypsin inhibitors by rat bioassay. Cereal Chem 52: 85–92
36. Reddy NR, Sathe SK, Salunkhe DK (1982) Phytate in legumes and cereals. Adv Food Res 28: 1–92
37. Reddy NR, Blakrisham CV, Salunkhe DK (1978) Phytate phosphorus and minerals changes during germination and cooking of black bean (Phaseolus mongo L.) seeds. J Food Sci 43: 540–543
38. Sgarbeiri VC (1982) Physical, chemical and nutritional properties of common bean (phaseolus) protein. Adv Food Res 28: 93–166
39. Singh L, Wilson CM, Handdy HH (1969) Genetic differences in soybean trypsin inhibitors separated by disc electrophoresis. Crop Sci 9: 489–491
40. Sotera JJ, Stux Rl (1979) Standard conditions for flame operation, Atomic absorption methods manual, vol. 1. Instrumentation Laboratory Inc. Analytical Instrument Division, Wilmington, MA
41. Sutardi L, Buckle A (1985) Phytic changes in soybeans fermented by traditional inoculum and six strains of Rhizopus Oligospus. J Appl Bacteriol 58: 539–543
42. Weiss MG, Weber CR, Williams LE, Probst AH (1959) Correlation of agronomic characters and temperature with seed composition characters in soybeans as influenced by variety and time of planting. Agron J 44: 289–297