

# Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes

A.E. Mubarak

Home Economics Department, Faculty of Specific Education, Menofiya University, Ashmoon City, Egypt

Received 1 August 2003; received in revised form 8 January 2004; accepted 8 January 2004

## Abstract

The effects of some domestic traditional processes, such as dehulling, soaking, germination, boiling, autoclaving and microwave cooking, on the nutritional composition and antinutritional factors of mung bean seeds were studied. Germination and cooking processes caused significant ( $p < 0.05$ ) decreases in fat, carbohydrate fractions, antinutritional factors and total ash contents. All processes decreased the concentrations of lysine, tryptophan, threonine and sulfur-containing amino acids. However, all treatments were higher in total aromatic amino acids, leucine, isoleucine and valine contents than the FAO/WHO reference. Dehulling, soaking and germination processes were less effective than cooking processes in reducing trypsin inhibitor, tannins and hemagglutinin activity contents. Also, germination was more effective in reducing phytic acid, stachyose and raffinose. Germination resulted in a greater retention of all minerals compared to other processes. In vitro protein digestibility and protein efficiency ratio were improved by all processes. The chemical score and limiting amino acids of mung bean subjected to the various processes varied considerably, depending on the type of process.

© 2004 Elsevier Ltd. All rights reserved.

**Keywords:** Mung bean; Antinutritional factors; Nutritional composition; Home traditional processes

## 1. Introduction

In Egypt, mung bean (*Phaseolus aureus*) has been introduced recently by the Ministry of Agriculture. Mung bean is an excellent source of protein (27%), and its essential amino acid composition compares favourably with that of soybean, kidney bean and FAO/WHO reference protein (El-Adawy, 1996; Fan & Sosulski, 1974; Thompson, Hung, Wang, Rapser, & Gade, 1976). However, antinutritional factors limit the food applications of mung bean. Therefore, dehulling of the seeds before milling has been used to overcome this problem (El-Adawy, 1996; Thompson et al., 1976).

Generally, legumes have been reported to have low nutritive value due to low amounts of sulfur-containing amino acids, low protein digestibility and presence of antinutritional factors. Cooking is usually done before the use of legumes in a human diet. This improves the

protein quality by destruction or inactivation of the heat-labile antinutritional factors (Chau, Cheung, & Wong, 1997; Wang, Lewis, Brennan, & Westby, 1997; Vijayakumari, Siddhuraju, Pugalenti, & Janardhanan, 1998). However, cooking causes considerable losses in soluble solids, especially vitamins and minerals (Barrampama & Simard, 1995). Increasing the time and temperature of processing has been reported to reduce the nutritive value and available lysine of legumes (Kon & Sanshuck, 1981). Germination also enhances the nutritive value of legumes by inducing the formation of enzymes that eliminate or reduce the antinutritional and indigestible factors in legumes (Bau, Villanme, Nicolos, & Mejean, 1997). The chemical composition and oligo-saccharides of raw and germinated mung bean seeds were reviewed by El-Beltagy (1996).

Therefore, the aim of the present work was to study the effects of some domestic traditional processes, such

as soaking, dehulling, boiling, autoclaving, microwave cooking and germination on the nutritional composition and nutritive value of mung bean seeds.

## 2. Materials and methods

### 2.1. Materials

Mung bean seeds (*P. aureus*), Variety Giza-1 (VC. 2010), were obtained from the Agriculture Research Center, Seed Department, Giza, Egypt. The seeds were cleaned by hand to remove the foreign materials and ground into 60-mesh (British Standard Screen) flour, using a household flourmill (Braun, Germany).

### 2.2. Processing

#### 2.2.1. Soaking

The whole mung bean seeds were soaked in distilled water (1:10, w/v) for 12 h at room temperature (~25 °C).

#### 2.2.2. Dehulling

Hulls were removed manually after soaking the mung bean seeds for 12 h in distilled water (1:10, w/v) according to El-Beltagy (1996).

#### 2.2.3. Germination

Mung beans were sterilized by soaking in ethanol for 1 min. The seeds were soaked in distilled water (1:10, w/v) for 12 h at room temperature (~25 °C), then kept between thick layers of cotton cloth and allowed to germinate in the dark for three days. Germinated seeds were frozen for 12 h to stop the germination process. After thawing at room temperature, the seeds were dried in an electric air draught oven (VEB MLW Medizinische, Gerate, Berlin, Germany) at 50 °C for 20 h.

### 2.3. Cooking treatments

#### 2.3.1. General

Mung bean seeds were soaked in distilled water (1:10, w/v) for 12 h at room temperature (~25 °C). The soaked seeds were drained and rinsed three times with 600 ml distilled water, then cooked by the methods described below.

#### 2.3.2. Boiling

Rinsed soaked seeds were cooked in tap water (100 °C) in the ratio of 1:10 (w/v) on a hot plate until they became soft when felt between the fingers (90 min).

#### 2.3.3. Autoclaving

Rinsed soaked seeds were autoclaved at 15 atmospheric pressure (121 °C) in tap water (1:10, w/v) for (35 min).

#### 2.3.4. Microwave cooking

Rinsed soaked seeds were placed in a Birex pot with tap water (1:10, w/v), then cooked in a microwave oven (Goldstar, Model ER-50540, 2450 MHz, Egypt) (on high) for 15 min (about 50% of the seeds were soft when felt between the fingers). The cooked seeds were dried in an electric air draught oven (VEB MLW Medizinische, Gerate, Berlin, Germany) at 50 °C for 20 h.

Germination, soaking, dehulling and cooking processes were replicated three times. Raw and processed mung bean seeds were ground in an electric mill (Braun, Model 1021, Germany) to pass through a 60 mesh (British standard screen) sieve.

### 2.4. Analytical methods

#### 2.4.1. Chemical composition

Moisture (14.004), fat (14.018), ash (14.006), crude fibre (14.020) and protein (Nx6.25) (14.026) were determined as described by AOAC (1990).

#### 2.4.2. Carbohydrate fractions

Stachyose and raffinose were determined according to Tanaka, Thananunkul, Lee, and Chichester (1975) using thin-layer chromatography. The content of reducing sugars was determined in the 70% ethanol extracts by the phenol-sulphuric acid method used by Dubois, Gilles, Hamilton, Rebers, and Smith (1956). Starch content was determined as reducing sugars after complete acid hydrolysis.

#### 2.4.3. Minerals

Minerals were determined after wet-ashing by concentrated nitric acid and perchloric acid (1:1, v/v). Na, K and Ca were determined by flame photometry (Corning 410, England), while Mg, Mn and Fe were determined using an atomic absorption spectrophotometer (Perkin-Elmer, Model 2380, USA). Phosphorus was estimated photometrically via the phosphorus molybdate complex described by Taussky and Shorr (1953).

#### 2.4.4. Amino acids

Amino acids were determined using a Mikrotechna AAA881 automatic amino acid analyzer (Model 118/119 CL, Czech Republic) according to the method of Moore and Stein (1963). Hydrolysis of the samples was performed in the presence of 6 M HCl at 110 °C for 24 h under a nitrogen atmosphere. Sulfur-containing amino acids were determined after performic acid oxidation. Tryptophan was chemically determined by the method of Miller (1967).

#### 2.4.5. Antinutritional factors

Total tannins were determined colorimetrically as described in AOAC (1990). Phytic acid was determined according to the method of Wheeler and Ferrel (1971).

Trypsin inhibitor activity was determined according to the method of Kakade, Simons, and Liener (1969) using benzoyl-DL-arginine-*P*-nitroanalide hydrochloride as the substrate. Hemagglutinin activity was estimated according to the method of Liener and Hill (1953).

#### 2.4.6. *In Vitro* protein digestibility

*In Vitro* protein digestibility (IVPD) was determined as described by Salgo, Granzler, and Jecsai (1984), measuring the change in the sample solution pH after incubation at 37 °C with trypsin–pancreatin enzyme mixture for 10 min.

#### 2.4.7. Biological values

Biological values of raw and treated mung bean seeds flour were determined on the basis of amino acid profile. Chemical score of amino acids was calculated using the FAO/WHO (1973) reference pattern. Essential amino acid index (EAAI) was calculated according to Oser (1959), using the amino acid composition of whole egg protein published by Hidvegi and Bekes (1984). Protein efficiency ratio (PER) was estimated using the regression equation proposed by Alsmeyer, Cunningham, and Happich (1974):  $PER = -0.468 + 0.454 (\text{leucine}) - 0.105 (\text{tyrosine})$ .

#### 2.5. Statistical analysis

Results are expressed as the mean values of three separate determinations, except for the minerals and amino acid contents, which were determined in duplicate. Data were statistically analyzed using analysis of variance and least significant difference using SAS

(1985). Significant differences were determined at the  $p < 0.05$  level.

### 3. Results and discussion

#### 3.1. Chemical composition

Chemical compositions of raw and processed mung bean seeds are presented in Table 1. No significant ( $p > 0.05$ ) differences in total protein or total carbohydrate contents were observed among cooking processes of mung bean seeds. These observations are in agreement with those reported by Bau et al. (1997) for soy beans. Cooking treatments significantly ( $p < 0.05$ ) decreased the fat and ash contents. These decreases might be attributed to their diffusion into the cooking water. Germination of mung bean seeds resulted in a significant ( $p < 0.05$ ) increase in crude protein compared to the cooked mung bean seeds. This increase was mainly due to the use of seed components during the germination process. However, germination significantly ( $p < 0.05$ ) decreased the fat and total carbohydrate contents. These decreases could be attributed to their use as an energy source to start germination. Ash was significantly ( $p < 0.05$ ) decreased by all processes. These results are in agreement with those reported by El-Beltagy (1996) for germinated mung bean seeds and El-Adawy (2002) for germinated chickpea.

#### 3.2. Carbohydrate fractions

Table 2 shows the carbohydrate fractions of raw and processed mung bean seeds. Stachyose and raffinose

Table 1  
Effect of some traditional domestic processes on the chemical composition of mung bean seeds (g/100 g dry weight basis)

Components	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking
Crude protein	27.5 <sup>b</sup>	27.6 <sup>b</sup>	27.0 <sup>c</sup>	30.0 <sup>a</sup>	26.80 <sup>c</sup>	26.6 <sup>c</sup>	26.7 <sup>c</sup>
Crude fat	1.85 <sup>a</sup>	1.82 <sup>a</sup>	1.83 <sup>a</sup>	1.45 <sup>b</sup>	1.82 <sup>a</sup>	1.82 <sup>a</sup>	1.81 <sup>a</sup>
Crude fibre	4.63 <sup>a</sup>	4.10 <sup>b</sup>	4.45 <sup>a,b</sup>	4.40 <sup>a,b</sup>	4.50 <sup>a</sup>	4.61 <sup>a</sup>	4.64 <sup>a</sup>
Ash	3.76 <sup>a</sup>	3.60 <sup>b</sup>	3.32 <sup>c</sup>	3.55 <sup>b</sup>	3.55 <sup>b</sup>	3.54 <sup>b</sup>	3.65 <sup>b</sup>
Total carbohydrate <sup>A</sup>	62.3 <sup>b</sup>	62.9 <sup>ab</sup>	63.4 <sup>a</sup>	61.7 <sup>c</sup>	63.3 <sup>a</sup>	63.4 <sup>a</sup>	63.2 <sup>a</sup>
Moisture	9.75 <sup>b</sup>	10.10 <sup>b</sup>	10.50 <sup>b</sup>	11.10 <sup>a</sup>	10.13 <sup>b</sup>	10.15 <sup>b</sup>	10.10 <sup>b</sup>

<sup>a-c</sup> Means in the same row with different letters are significantly ( $p < 0.05$ ) different.

<sup>A</sup> By difference.

Table 2  
Effect of some traditional domestic processes on the carbohydrate fractions of mung bean seeds (g/100 g dry weight basis)

Carbohydrate fractions	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking
Reducing sugars	4.85 <sup>a</sup>	4.42 <sup>a,b</sup>	3.81 <sup>b</sup>	3.10 <sup>c</sup>	3.21 <sup>c</sup>	3.32 <sup>b,c</sup>	3.34 <sup>b</sup>
Raffinose	0.41 <sup>a</sup>	0.29 <sup>b</sup>	0.30 <sup>a</sup>	0.0 <sup>d</sup>	0.21 <sup>c</sup>	0.23 <sup>c</sup>	0.27 <sup>b,c</sup>
Stachyose	1.49 <sup>a</sup>	1.25 <sup>b</sup>	1.23 <sup>b</sup>	0.0 <sup>d</sup>	1.12 <sup>c</sup>	1.05 <sup>c</sup>	1.04 <sup>c</sup>
Starch	54.88 <sup>a</sup>	54.81 <sup>a</sup>	54.71 <sup>a</sup>	50.10 <sup>b</sup>	54.61 <sup>a</sup>	54.63 <sup>a</sup>	54.55 <sup>a</sup>

<sup>a-d</sup> Means in the same row with different letters are significantly ( $p < 0.05$ ) different.

were completely eliminated by germination. Germination significantly ( $p < 0.05$ ) reduced the levels of reducing sugars and starch by 36.1%, 8.78%, respectively. These reductions could have been due to the hydrolysis of these components by hydrolytic enzymes to monosaccharides, which are used as an energy source during germination. Similar results were reported by Bau et al. (1997) for soy bean sprouts. Reducing sugars, stachyose and raffinose, were significantly ( $p < 0.05$ ) reduced after cooking processes. These reductions are mainly due to their diffusion into cooking water. Germination was more effective in the reduction of oligosaccharides (stachyose and raffinose) than cooking treatments. The reduction in starch observed after cooking treatments was not significant ( $p > 0.05$ ).

### 3.3. Minerals

Mineral contents of raw and processed mung bean seeds are presented in Table 3. The minerals leached from the mung bean seeds into the water at different rates during cooking treatments. However, dehulled and soaking resulted in the greatest retention of all minerals. Haytowitz and Matthews (1983) reported that cooking in boiling water caused a great loss of K (24%) and Fe (8%). Longe (1983) reported losses of 22% Mg from mature cowpeas when cooked by autoclaving. Salama and Ragab (1997) reported that kidney beans, cooked by conventional and microwave methods, had different retention rates of minerals. Germinated mung bean seeds showed slight increases of K, Ca, P, Mg, Fe and Mn. These results agree with those reported by Khalil (2001) for guar and faba bean. The loss of divalent metals was due to their binding to protein and also to the formation of a phytate-cation protein complex. While cooking under pressure (autoclaving) gave the lowest reduction in the elements Na, Mg and Fe, this may be attributed to cooking by steam only. Generally, the decrease in mineral contents may be due to leaching out during cooking processes. These data agree well with the report of Mansour and El-Adawy (1994) on boiled fenugreek seeds.

### 3.4. Amino acids

Table 4 shows the amino acid composition of raw and treated mung bean seeds. Mung bean protein was rich in essential amino acids such as total aromatic amino acids, leucine, isoleucine and valine, compared with the FAO/WHO (1973) reference. However, threonine, total sulfur amino acids, lysine and tryptophan were slightly deficient in mung bean protein compared with the reference pattern. Dehulling and germination processes caused a slight increase in total essential amino acids, but there were only slight decreases by other processes. All processes decreased the concentrations of isoleucine, tryptophan (except germination) and total sulfur amino acids (except dehulling and germination). Soaked and cooked processes of mung bean seeds were slightly decreased in lysine (except dehulled and germinated). These results confirmed those reported by Ziena (1989), who found that cooking reduced the sulfur-containing amino acids and tryptophan. All processes increased the concentration of leucine (except soaked process). The leucine/isoleucine ratios of all processed mung bean seeds were typical, of the ideal ratio suggested by FAO/WHO (1973). Deosthale, Mohan, and Rao (1970) showed that excess leucine in foods interfered with the utilization of isoleucine and lysine.

### 3.5. Antinutritional factors

The antinutritional factors of raw and processed mung bean seeds are shown in Table 5. Trypsin inhibitor activity and hemagglutinin were significantly ( $p < 0.05$ ) decreased by soaking and dehulling processes, were completely destroyed by cooking processes and were drastically reduced by germination. Khalil and Mansour (1995) reported that boiling and autoclaving of faba bean seeds completely eliminated hemagglutinin activity. El-Beltagy (1996) reported that the hemagglutinin activity of mung bean seeds decreased by about 84.4% after three days of germination. Tannins and phytic acid in mung bean seeds were significantly ( $p < 0.05$ ) reduced by germination and cooking processes. Similar results were obtained by Vijayakumari et al. (1998) for Vigna

Table 3  
Effect of some traditional domestic processes on the mineral contents of mung bean seeds (mg/100 g dry weight basis)

Element	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking
Na	12.00	10.20	9.60	11.60	8.20	8.95	8.10
K	3.62	2.90	2.35	3.95	2.90	2.88	2.80
Ca	84.00	80.00	81.00	88.50	75.00	80.00	78.00
P	391	385	381	406	368	370	365
Mg	55.60	54.30	49.90	56.6	44.00	48.00	47.80
Fe	9.70	8.60	8.40	9.65	7.90	8.10	8.00
Mn	1.70	1.50	1.40	1.70	1.30	1.55	1.40

Average of two determinations.

Table 4  
Effect of some traditional domestic processes on the amino acid contents of mung bean seeds (g/16 g N)

Amino acid	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking	FAO/WHO (1973)
Tyrosine	3.27	3.27	3.11	3.28	3.23	3.14	3.20	
Phenylalanine	5.66	5.68	5.60	5.70	5.67	5.69	5.65	
Total aromatic amino acid	8.93	8.95	8.71	8.98	8.90	8.83	8.85	6.00
Threonine	3.15	3.19	3.10	3.20	3.20	3.17	3.18	4.00
Cystine	0.75	0.76	0.64	0.77	0.76	0.65	0.75	
Methionine	1.92	1.92	1.70	1.95	1.83	1.85	1.80	
Total sulfur amino acids	2.67	2.68	2.34	2.72	2.59	2.50	2.55	3.50
Leucine	8.36	8.40	8.25	8.53	8.44	8.50	8.43	7.00
Isoleucine	4.74	4.70	4.64	4.70	4.40	4.30	4.37	4.00
Lysine	4.19	4.21	4.15	4.26	4.05	4.00	4.02	5.50
Valine	5.20	5.21	5.23	5.20	5.20	5.30	5.18	5.00
Tryptophan	0.97	0.97	0.95	1.00	0.89	0.94	0.88	1.00
Total essential amino acid	38.2	38.3	37.3	38.6	37.7	37.4	37.5	36.0
Aspartic acid	13.5	13.5	13.8	13.5	13.8	13.8	13.9	–
Glutamic acid	21.7	21.6	21.6	21.5	21.8	21.7	21.8	–
Proline	4.23	4.22	4.35	4.20	4.36	4.26	4.37	–
Serine	4.95	4.95	4.96	4.80	4.90	4.86	4.96	–
Glycine	4.26	4.25	4.35	4.20	4.40	4.38	4.47	–
Alanine	4.35	4.33	4.53	4.41	4.58	4.50	4.66	–
Arginine	6.33	6.33	6.50	6.35	6.00	6.52	5.92	–
Histidine	2.49	2.50	2.58	2.42	2.54	2.54	2.55	–
Total non-essential amino acids	61.8	61.7	62.7	61.4	62.3	62.6	62.5	–
Leucine/ isoleucine ratio	1.76: 1	1.78: 1	1.77:1	1.81:1	1.91:1	1.97:1	1.92:1	1.8:1

Table 5  
Effect of some traditional domestic processes on the antinutritional factors of mung bean seeds (dry weight basis)

Antinutritional factor	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking
Trypsin inhibitor (TIU <sup>A</sup> /mg protein)	15.8 <sup>a</sup>	14.6 <sup>b</sup>	13.3 <sup>c</sup>	12.3 <sup>d</sup>	0.00 <sup>e</sup>	0.00 <sup>e</sup>	0.00 <sup>e</sup>
% Reduction	–	7.59	15.8	22.4	100	100	100
Heamagglutinin activity (HU <sup>B</sup> /g sample)	2670 <sup>a</sup>	1800 <sup>b</sup>	1360 <sup>c</sup>	560 <sup>d</sup>	0.00 <sup>e</sup>	0.00 <sup>e</sup>	0.00 <sup>e</sup>
% Reduction	–	32.6	49.1	79.0	100	100	100
Tannins (mg/g sample)	3.30 <sup>a</sup>	2.20 <sup>b</sup>	2.00 <sup>c</sup>	1.90 <sup>d</sup>	1.80 <sup>e</sup>	1.60 <sup>f</sup>	1.25 <sup>g</sup>
% Reduction	–	33.3	39.4	66.7	45.5	51.5	62.1
Phytic acid (mg/gm sample)	5.80 <sup>a</sup>	4.60 <sup>b</sup>	4.30 <sup>c</sup>	4.03 <sup>d</sup>	4.25 <sup>e</sup>	4.41 <sup>bc</sup>	4.29 <sup>c</sup>
% Reduction	–	20.7	26.7	30.5	25.86	24.0	26.0

<sup>a–e</sup> Means in the same row with different letters are significantly ( $p < 0.05$ ) different.

<sup>A</sup> TIU: Trypsin inhibitor units.

<sup>B</sup> HU: Hemagglutinin units.

aconitifolia and *Vigna sinensis*. Dehulling and soaking processes were less effective than germination and cooking processes in reducing phytic acid and tannins. The higher reduction of tannin could have been due to the tannin activity during germination. These results agree well with those reported by El-Adawy (2002) for germinated chickpea.

### 3.6. *In vitro* protein digestibility and biological value

*In vitro* protein digestibility and biological values of raw and processed mung bean seeds are presented in Table 6. All processes improved the IVPD. IVPD of mung bean seeds were significantly ( $p < 0.05$ ) higher

after germination and autoclaving than after the other processes. The improvement in digestibility may be attributed to denaturation of protein, destruction of the trypsin inhibitor or reduction of tannins and phytic acid. El-Beltagy (1996) found that germination improved the IVPD of mung bean seeds.

Protein efficiency ratio (PER) was improved slightly by germination and cooking processes. There was a slight improvement in EAAI by germination, while cooking and soaking processes lowered the EAAI. This lowering is attributed to the reduction of some essential amino acids during cooking processes. Lysine and sulfur-containing amino acids were the first and second limiting amino acids, respectively, in raw, dehulled,

Table 6  
Effect of some traditional domestic processes on in vitro protein digestibility (IVPD) and protein quality of mung bean seeds

Property	Raw	Dehulling	Soaking	Germination	Boiling	Autoclaving	Microwave cooking
In-vitro protein digestibility (%)	80.2 <sup>c</sup>	84.3 <sup>d</sup>	87.4 <sup>c</sup>	89.1 <sup>a</sup>	87.8 <sup>c</sup>	88.7 <sup>a</sup>	88.2 <sup>b</sup>
Protein efficiency ratio (PER)	4.29	4.30	4.24	4.37	4.32	4.35	4.32
Essential amino acid index (EAAI) (%)	67.8	67.9	65.6	68.9	65.9	65.7	65.6
Chemical score (CS) (%)	76.2	76.5	66.9	77.5	73.6	71.4	73.1
First limiting amino acid	Lysine	Lysine	Cys + Meth	Lysine	Lysine	Cys + Meth	Cys + Meth
	76.2	76.5	66.9	77.5	73.6	71.4	72.9
Second limiting amino acid	Cys + Meth	Cys + Meth	Lysine	Cys + Meth	Cys + Meth	Lysine	Lysine
	76.3	76.6	75.5	77.7	74.0	72.7	73.1

<sup>a-c</sup> Means in the same row with different letters are significantly ( $p < 0.05$ ) different.

germinated and boiled mung bean seeds. However, the first and second limiting amino acids were sulfur-containing amino acids and lysine, respectively, in soaked, autoclaved and microwave cooked mung bean seeds. Chemical score was slightly affected by germination or dehulling, but was decreased by other processes. Therefore, the chemical score and limiting amino acids of mung bean varied considerably, depending on process.

#### 4. Conclusions

As shown in this study, dehulling, soaking, germination, cooking, autoclaving and microwave cooking affected the chemical composition, antinutritional factors and nutritional quality of mung bean seeds. However, dehulling and soaking processes caused smaller losses in minerals than cooking processes. All processes improved the IVPD and protein efficiency ratio of mung bean seeds. Therefore, microwave and autoclaving cooking are recommended for mung bean seed preparation in households and restaurants, not only for improving the nutritional quality, but also for lowering the cooking time.

#### References

- Alsmeyer, R. H., Cunningham, A. E., & Happich, M. L. (1974). Equations predicts PER from amino acid analysis. *Food Technology*, 28, 34–40.
- AOAC (1990). *Official methods of analysis* (15th ed.). Washington, DC: Association of Official Analytical Chemists.
- Barampama, Z., & Simard, R. E. (1995). Effect of soaking, cooking and fermentation on composition, in vitro starch digestibility and nutritive value of common beans. *Plant Food for Human Nutrition*, 48, 349–365.
- Bau, H. M., Villanme, C., Nicolos, J. P., & Mejean, L. (1997). Effect of germination on chemical composition, biochemical constituents and antinutritional factors of soy bean (*Glycine max*) seeds. *Journal of the Science of Food Agriculture*, 73, 1–9.
- Chau, C. F., Cheung, P. C., & Wong, Y. S. (1997). Effect of cooking on content of amino acids and antinutrients in three Chinese indigenous legume seeds. *Journal of the Science of Food Agriculture*, 75, 447–452.
- Deosthale, Y. G., Mohan, V. S., & Rao, K. V. (1970). Varietal deficiencies in protein lysine and leucine content of gram sorghum. *Journal of Agricultural and Food Chemistry*, 18, 644–646.
- Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, 28, 350–356.
- El-Adawy, T. A. (1996). Chemical, nutritional and functional properties of mung bean protein isolate and concentrate. *Menufiya Journal of Agricultural Research*, 21(3), 657–672.
- El-Adawy, T. A. (2002). Nutritional composition and antinutritional factors of chickpeas (*Cicer arietinum L.*) undergoing different cooking methods and germination. *Plant Food for Human Nutrition*, 57, 83–97.
- El-Beltagy, A. (1996). Effect of home traditional methods on quality aspected of some legumes. MS Thesis, Faculty of Agriculture, Menofiya University, Shibin El-Kom, Egypt.
- Fan, T. Y., & Sosulski, F. W. (1974). Dispersibility and isolation of protein from legume flours. *Canadian Institute of Food Science and Technology Journal*, 7, 256–261.
- FAO/WHO (1973). Energy and protein requirements. Report of FAO Nutritional Meeting Series No 52. Rome : FAO.
- Haytowitz, D. B., & Matthews, R. H. (1983). Effect of cooking on nutritive retention of legumes. *Cereal Food World*, 28, 326–364.
- Hidvegi, M., & Bekes, F. (1984). Mathematical modeling of protein quality from amino acid composition. In R. Lasztity & M. Hidvegi (Eds.), *Processing of the international association of the cereal chemistry symposium* (pp. 205–286). Budapest: Akademiai Kiado.
- Kakade, M. L., Simons, N., & Liener, I. E. (1969). An evaluation of natural vs. synthetic substrates for measuring the antitryptic activity of soy bean samples. *Cereal Chemistry*, 46, 518–528.
- Khalil, M. M. (2001). Effect of soaking, germination, autoclaving and cooking on chemical and biological value of guar compared with faba bean. *Nahrung/Food*, 45, 246–250.
- Khalil, A. H., & Mansour, E. H. (1995). The effect of cooking, autoclaving and germination on the nutritional quality of faba beans. *Food Chemistry*, 54, 177–182.
- Kon, S., & Sanshuck, D. W. (1981). Phytate content and its effect on cooking quality of beans. *Journal of Food Processing and Preservation*, 5, 169–178.
- Liener, I. F., & Hill, E. G. (1953). The effect of heat treatment on the nutritive value and hemagglutinating activity of soy bean oil meal. *Journal of Nutrition*, 49, 609–620.
- Longe, O. G. (1983). Varietal differences in chemical characteristics related to cooking quality of cowpea. *Journal of Food Processing and Preservation*, 7, 143–150.

- Mansour, E. H., & El-Adawy (1994). Nutritional potential and functional properties of heat treated and germinated fenugreek seeds. *Lebensm Wiss. U. Technol.*, 27, 568–572.
- Miller, E. L. (1967). Determination of the tryptophan content in feeding stuffs with particular reference to cereals. *Journal of the Science of Food Agriculture*, 18, 381–386.
- Moore, S., & Stein, W. H. (1963). Chromatographic determination of amino acids by the use of automatic recording equipment. In S. P. Colowick & N. O. Kaplan (Eds.), *Methods in enzymology* (Vol. 6, pp. 815–860). New York: Academic Press.
- Oser, B. L. (1959). An integrated essential amino acid index for predicting the biological value of proteins. In A. A. Albanese (Ed.), *Protein and amino acid nutrition* (pp. 295–311). New York: Academic Press.
- Salama, A. M., & Ragab, G. H. (1997). Composition of conventional and microwave cooking of kidney beans and carrot in relation to chemical composition, nutritive value and sensory characteristics. *Journal of Home Ec-Menoufiay Univiversity*, 7, 213–225.
- Salgo, A., Granzler, K., & Jecsei, J. (1984). Simple enzymatic methods for predication of plant protein digestibility. In R. Lasztity & M. Hidvegi (Eds.), *Processing of the international association of the cereal chemistry symposium* (pp. 311–321). Budapest: Akademiai Kiado.
- SAS (1985). *SAS users Guide: statistics version* (5th ed.). Cary, NC: SAS Institute Inc.
- Tanaka, M., Thananunkul, D., Lee, T. C., & Chichester, C. O. (1975). A simplified method for the quantitative determination of sucrose, raffinose and stachyose in legume seeds. *Journal of Food Science*, 40, 1087–1088.
- Tausky, H. H., & Shorr, E. (1953). A microcolorimetric method for the determination of inorganic phosphorus. *Journal of Biological Chemistry*, 202, 675–682.
- Thompson, I. U., Hung, L., Wang, N., Rapser, V., & Gade, H. (1976). Preparation of mung bean flour and its application in bread making. *Canadi Institute of Food Science and Technology Journal*, 9, 1–7.
- Vijayakumari, P., Siddhuraju, P., Pugalenti, M., & Janardhanan, K. (1998). Effect of soaking and heat processing on the levels of antinutrients and digestible proteins in seeds of vigna sinensis. *Food Chemistry*, 63, 259–264.
- Wang, N., Lewis, M. J., Brennan, J. G., & Westby, A. (1997). Effect of processing methods on nutrients and anti-nutritional factors in cowpea. *Food Chemistry*, 58, 59–68.
- Wheeler, E. I., & Ferrel, R. E. (1971). A method for phytic acid determination in wheat and wheat fractions. *Cereal Chemistry*, 48, 312–316.
- Ziena, H.M.S. (1989). Hard-to-cook phenomenon in relation to physical, chemical and biological properties of faba beans (*Vicia Faba L.*) PhD Thesis, Faculty of Agriculture, Alexandria University, Alexandria, Egypt.