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The effect of cooking, autoclaving and germination on the nutritional quality of faba beans

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The nutritive value of raw, cooked, autoclaved and germinated faba bean was evaluated. Heat processing and germination, resulted in significant reduction in stachyose, tannins, phytic acid, vicine, trypsin inhibitor and haemagglutinin activity. Germination was more effective in reducing stachyose than heat processing. Heat processing was more effective in reducing the tannins, trypsin inhibitor and haemagglutinin activity. Heat processing and germination did not affect the total essential amino acids. Heat processing increased the contents of leucine, threonine and histidine. Sulphur containing amino acids were the first limiting amino acids, while valine was the second limiting one. The in-vitro protein digestibility and PER value of faba bean were improved by heat processing and germination. Pyridoxine, pantothenic acid and riboflavin were more stable to heat processing than niacin and thiamine. The retention of B-group vitamins in germinated faba bean was higher than in heat treated faba bean. There was a slight change in the mineral content by the heat processing with the exception of K and Ca. Germinated faba bean showed noticeable decreases in the contents of Na, K, Cu, Mn and Mg and increases in Zn and Fe.

INTRODUCTION

Faba bean (*Vicia faba*) is a high protein crop grown in Europe, Africa and Asia, used to feed both animals and humans. In Egypt, faba bean is one of the most common legumes consumed in the stewed form called Medammis and also as the germinated and blanched form called Nabet (El-Shimi, 1980). The nutritive value of faba bean has been limited due to the presence of tannins, phytic acid, trypsin inhibitor and haemagglutinin activity. In addition to that its consumption might lead to a hemolytic anemia disease called Favism (Bottini, 1973). The factors in the bean that have been implicated as the causative agents of the disease are vicine and convicine (Mager *et al.*, 1969).

Many researchers have reported that the nutritive value of many legumes was enhanced by heat processing and germination (Chen, 1970; Hsu *et al.* 1980; Ziena, 1989; Mansour & El-Adawy, 1994). The traditional method for preparing Medammis in Egypt is by simmering the beans for about 12 h with low heat. However, the long cooking time reduces the nutritive value of legumes (El-Mahdy, 1974; Kon & Sanshuck, 1981; Youssef *et al.*, 1986; Ziena, 1989).

Therefore, the present study was conducted to evaluate the nutritive value of cooked faba bean by boiling for a short time (45 min) as well as by autoclaving (30 min). The effect of germination on nutritive quality of faba bean was also studied.

MATERIALS AND METHODS

Materials

Faba beans were obtained from the local market of Alexandria, Egypt. The seeds were cleaned by hand to remove foreign materials.

Preparation of samples

Heat processing

Cooking treatment. Faba beans seeds were soaked in distilled water (1 : 20, w/v) for 12 h at room temperature (~25°C). The soaked seeds were strained off and rinsed three times with distilled water. The rinsed soaked seeds were cooked in tap water (3 ml/g dry seeds) on a hot plate until they became soft when felt between the fingers (45 min).

Autoclaving treatment. The rinsed soaked faba beans were placed in a conical flask. After adding tap water (2 ml/g dry seeds) the mixture was autoclaved at 121°C for 30 min (about 50% of the seeds were soft when felt between the fingers).

Germination treatment

Faba bean seeds were sterilised by soaking in ethanol for 1 min. The seeds were soaked in distilled water for 12 h at room temperature (~25°C). The soaked seeds were kept between thick layers of cotton cloth and allowed to germinate in the dark at room temperature for 3 days. The germinated seeds were rinsed with distilled water. Cooking, autoclaving and germination treatments were replicated three times. The cooked, autoclaved and germinated seeds were mashed and dried at 50°C overnight in an electric draught oven. Raw and processed faba beans were ground to pass through a 60 mesh sieve then kept in the cold for analysis.

Analytical method

Moisture content (method No. 14.004), crude oil (method No. 7.056), crude protein N × 6·25 (method No. 2.057) and total ash (method No. 14.006) were determined according to the method of AOAC (1980). Non-protein nitrogen was determined by the method of Bhatty and Finlayson (1973). Reducing sugars (as glucose) were determined in 70% ethanol extracts by the method of Dubois *et al.* (1956). Total carbohydrate was determined by Schoorl's method after hydrolysis for 3 h with 2·5% HCl.

Raffinose and stachyose were determined according to Tanaka *et al.* (1975) using TLC methods. Tannins were determined according to the method of Khokhar and Chauhan (1986). Phytic acid was determined according to the method of Wheeler and Ferrel (1971). Trypsin inhibitor activity was determined as described by Kakade *et al.* (1974). The method of Hegazy and Marquardt (1983) was used for determination of vicine and convicine. Haemagglutinin activity was measured as described by Liener (1955).

Amino acids were determined using a Mikrotechna AAA 881 automatic amino acid analyser according to the method described by Moore and Stein (1963). Hydrolysis of the proteins were performed in the presence of 6M HCl at 110°C for 24 h in a nitrogen atmosphere. Sulphur-containing amino acids were determined after performic acid oxidation. Tryptophan was chemically determined by the method of Miller (1967). Amino acids of faba bean products were compared with FAO/WHO/UNU (1985) reference pattern.

The in-vitro protein digestibility was determined as described by Salgó *et al.* (1984) by measuring the decrease in pH during digestion with trypsin and pancreatin. Chemical scores of amino acids were calculated using the FAO/WHO (1973) reference pattern. Protein efficiency ratio (PER) was calculated from the following equation: PER = –0·468 + 0·454 (leucine) – 0·105 (tyrosine) according to Alsmeyer *et al.* (1974).

B-group vitamins were determined by microbiological methods as described by György and Pearson (1967).

Sodium, potassium and calcium were determined after nitric acid digestion by flame photometer Microelements (Cu, Zn, Fe, Mn, Mg) were determined after dry-ashing by a Perkin Elmer Model 403 atomic absorption spectrophotometer.

Data of chemical composition, antinutritional factors and in-vitro protein digestibility were recorded as means and standard deviation of triplicate measurements and were analysed using a Statistical Analysis System (SAS, 1985). Differences between treatments at 5% level were considered significant.

RESULTS AND DISCUSSION

Table 1 shows that the differences in crude protein, reducing sugar, ash and crude oil contents between raw and heat-treated faba bean by either cooking or autoclaving were not significant ($P \geq 0.05$). However, non-protein nitrogen was significantly ($P \leq 0.05$) decreased by cooking and autoclaving. Germination of faba bean showed a slight increase ($P \geq 0.05$) in crude protein and NPN as compared to the raw faba bean. This increase is mainly due to the consumption of the other beans components and degradation of the high molecules of the protein to simple peptides during germination process. The decreases in total carbohydrate and reducing sugar contents could be attributed to their consumption as a source of energy for the germination process. Also, non-significant ($P \geq 0.05$) decreases in ash and oil contents were observed by germination. These results are in good agreement with those reported by Lee and Karunanithy (1990).

Table 2 represents the analysis of the oligosaccharides in faba bean that are known to cause flatulence. Raffinose was absent, but stachyose showed a very low content (1·8%) as compared to that found by Mansour and El-Adawy (1994) in fenugreek seeds. Stachyose was significantly ($P \leq 0.05$) decreased by heat treatments whereas germination caused complete elimination. Our results are in good agreement with those reported by Mansour and El-Adawy (1994).

Tannins and phytic acid of heated faba beans were reduced ($P \leq 0.05$) by 55–60% and 31–41%, respectively. Similar results were obtained by Beal and Mehta (1985) and Ziena (1989). Germination was less effective than heat treatments in reducing tannins while it was more effective in reducing phytic acid. Therefore, it improves the nutritional quality of the beans.

Raw faba bean contained considerable quantities of vicine and convicine (0·68% and 0·27%, respectively). Pitz *et al.* (1981) analysed the whole seed of 242 faba bean cultivars and reported a range of 0·44–0·82% vicine and 0·13–0·64% convicine. Our findings are in the reported range of Pitz *et al.* (1981). Both heat treatments and germination showed significant ($P \leq 0.05$) decreases in vicine content. However, non-significant ($P \geq 0.05$) reduction in convicine was observed after cooking and germination. Similar results were reported by Hegazy and Marquardt (1983) and El-Adawy (1986).

Trypsin inhibitor activity in faba bean was significantly ($P \leq 0.05$) reduced by heat treatments and germination. Autoclaving was more effective ($P \geq 0.05$) in reducing trypsin inhibitor activity than cooking. Ziena (1989) reported that the inhibition of trypsin inhibitor

Table 1. Chemical composition (g/100 g) of raw and processed faba bean (on a dry weight basis) (means ± SD, $n = 3$)[a]

Treatments	Crude protein	Non-protein nitrogen	Carbohydrate	Reducing sugar	Ash	Crude oil
Raw	29·2ab ± 0·36	0·7ab ± 0·02	44·1ab ± 0·72	7·2a ± 0·26	4·2a ± 0·17	1·1a ± 0·06
Cooking	29·0ab ± 0·44	0·5c ± 0·03	45·9a ± 0·85	6·0ab ± 0·10	3·8a ± 0·10	1·0a ± 0·04
Autoclaving	27·5b ± 0·53	0·6c ± 0·04	45·0a ± 0·44	6·9a ± 0·17	4·0a ± 0·17	1·0a ± 0·05
Germination	30·5a ± 0·55	0·8a ± 0·02	41·1b ± 0·70	4·2b ± 0·20	4·0a ± 0·20	0·9a ± 0·02

[a]Means in the same column with different following letters are significantly different at the 5% level.

Table 2. Antinutritive materials (g/100 g) of raw and processed faba bean (on a dry weight basis) (means ± SD, $n = 3$)[a]

Treatments	Raffinose	Stachyose	Tannins	Phytic acid	Vicine	Convicine	Trypsin inhibitor[b]	Haemagglutinin activity[c]
Raw	0·0a ± 0·0	1·81a ± 0·13	1·45a ± 0·11	0·39a ± 0·07	0·68a ± 0·05	0·27a ± 0·04	8·13a ± 0·28	3·85a ± 0·13
Cooking	0·0a ± 0·0	0·96c ± 0·04	0·65c ± 0·03	0·27b ± 0·03	0·44b ± 0·02	0·18ab ± 0·02	2·32c ± 0·10	0·0c ± 0·0
Autoclaving	0·0a ± 0·0	1·43b ± 0·09	0·58c ± 0·04	0·23b ± 0·04	0·41b ± 0·03	0·16b ± 0·02	1·27c ± 0·06	0·0c ± 0·0
Germination	0·0a ± 0·0	0·0d ± 0·0	1·03b ± 0·08	0·18b ± 0·02	0·49b ± 0·04	0·19ab ± 0·01	5·54b ± 0·12	0·77b ± 0·04

[a]Means in the same column with different following letters are significantly different at the 5% level.
[b]Unit/mg protein.
[c]Haemagglutinin unit/mg flour.

was significantly dependent upon both heat temperature and time of exposure.

Haemagglutinin activity was completely eliminated by heat treatment, while germination showed 80% reduction. Dhurandhar and Chang (1990) reported that cooking of navy and red kidney beans for 10 min at 100°C was sufficient to inactivate all haemagglutinin activity. El-Adawy (1986) reported that the haemagglutinin content in faba beans decreased by about 86% after 3 days of the germination.

Data in Table 3 indicates that the amino acid composition of raw faba bean was similar to those reported by Ziena (1989). Lysine and leucine together were the major essential amino acids in raw and processed faba bean. Lysine formed 16·8–18·2% and leucine 17·9–19·2% of the total essential amino acids. Heat-

Table 3. Amino acid profile of raw and processed faba bean (g/16 g N) as compared to FAO/WHO/UNU (1985) pattern

Amino acid	Faba bean				Child 10–12 years	Adult
	Raw	Cooked	Autoclaved	Germinated		
Isoleucine	3·3	3·2	3·2	3·2	2·8	1·3
Leucine	7·2	7·8	7·5	7·5	4·4	1·9
Lysine	7·3	6·8	7·0	7·0	4·4	1·6
Cystine	1·3	1·2	1·1	1·2	—	—
Methionine	1·1	1·0	1·0	1·1	—	—
Total sulphur amino acids	2·4	2·2	2·1	2·3	2·2	1·7
Tyrosine	3·6	3·9	3·5	3·3	—	—
Phenylalanine	4·2	4·2	4·3	4·2	—	—
Total aromatic amino acids	7·8	8·1	7·8	7·5	2·2	1·9
Threonine	4·1	4·4	4·4	4·0	2·8	0·9
Tryptophan	1·1	1·1	1·1	1·2	0·9	0·5
Valine	3·7	3·6	3·6	3·6	2·5	1·3
Histidine	3·2	3·3	3·4	3·8	1·9	1·6
Total essential amino acids	40·1	40·5	40·1	40·1	24·1	12·7
Arginine	10·7	10·3	10·6	10·6	—	—
Aspartic acid	12·9	12·5	12·8	13·8	—	—
Glutamic acid	15·8	16·6	16·2	15·7	—	—
Serine	5·8	5·6	5·8	5·5	—	—
Proline	4·9	4·8	5·1	5·2	—	—
Glycine	4·7	4·9	4·6	4·5	—	—
Alanine	5·1	4·8	4·8	4·6	—	—
Total non-essential amino acids	59·9	59·5	59·9	59·9	—	—

treatments and germination did not affect the total essential amino acids. Ziena (1989) found that cooking with low heat for 12 h resulted in significant declines in most essential amino acids except lysine. It is interesting to note that faba beans cooked by boiling for a short time had higher contents of leucine, tyrosine, threonine and histidine as compared to raw faba beans. However, cooking for a short time decreased sulphur-containing amino acids by about 8%, while tryptophan was not affected. These results differed from those reported by Ziena (1989) who found that cooking with low heat for a long time reduced sulphur-containing amino acids and tryptophan by 60% and 40%, respectively.

On the basis of FAO/WHO/UNU (1985) requirements, the raw and processed faba beans contain more essential amino acids than the standard pattern.

Table 4 shows that the in-vitro protein digestibility was improved ($P \leq 0.05$) by heat treatments and germination. This improvement may be attributed to the denaturation of protein or destruction of the trypsin inhibitor or reduction of tannins and phytic acid (Table 2). These results agree well with those reported by Mansour *et al.* (1993) and Mansour and El-Adawy (1994). Although sulphur-containing amino acids and valine were considered the first and second limiting amino acids, respectively, it could be seen that the contents of these acids were equal to or higher than that of the FAO/WHO/UNU (1985) pattern. Also PER was improved by heat treatments and germination. These results agree well with those reported by Ziena (1989).

Tables 5 and 6 indicate that raw faba bean contains low levels of B-group vitamins as compared to soybean meal (Rutkowski, 1971). However, our results are in good agreement with those reported by Aherne and Lewis (1978) for faba bean. The stability of B-group vitamins to heat treatments was arranged in the following decreasing order: pyridoxine, pantothenic acid, riboflavin, thiamine and niacin. Similar results were obtained by Ang *et al.* (1975), DeRitter (1982) and Lu *et al.* (1984).

On the other hand, autoclaved faba bean had a higher content and retention of B-group vitamins than cooked faba bean. These results agree well with the findings of Kilgore and Sistrunk (1981) and Uzogara *et al.* (1991) who reported that pressure cooking of cowpeas using various solutions, generally increased levels and retention of thiamine, riboflavin and niacin as compared to cooking at atmospheric pressure.

Germinated faba bean had higher contents and retentions of riboflavin and pyridoxine than raw seeds. Similar observations were found by Hsu *et al.* (1980) and Chen (1970) who reported that the contents of riboflavin, niacin and retinol in soya bean increased after germination. The retentions of niacin, pantothenic acid and thiamine were 90%, 81% and 56%, respectively. Generally, the retention of B-group vitamins in germinated faba bean was higher than in heat-treated seeds.

Table 7 indicates that mineral contents of raw faba bean were higher than those reported by Mansour and El-Adawy (1994) for fenugreek seeds with the exception of Zn and Fe. There was a slight change in the mineral content by the heat treatments with the exception of K which decreased by 37% due to the cooking process but Ca increased by 40%. Germinated faba bean showed noticeable decreases in the contents of Na, K, Cu, Mn and Mg. These decreases might be attributed to the leaching of such minerals into soaking water. El-Shimi (1980) found that Na and K levels in faba beans were decreased as germination proceeded. Germinated faba bean had higher Zn and Fe contents than the raw sample. These results are in reasonably good agreement with those reported by Lee and Karunanithy (1990)

Table 4. In-vitro protein digestibility (IVPD), limiting amino acids and PER value of raw and processed faba bean (means ± SD, $n = 3$)[a]

Treatments	IVPD (%)	Limiting amino acids (%)				PER
		ILe	Met + Cys[b]	Try	Val[c]	
Raw	64·6c ± 1·23	81	65[d]	99	72	2·4
Cooking	71·2b ± 1·18	78	59[d]	99	69	2·7
Autoclaving	73·7a ± 1·37	79	57[d]	NL[e]	70	2·6
Germination	72·2ab ± 1·25	80	63[d]	NL[e]	71	2·6

[a]Means in the same column with different following letters are significantly different at the 5% level.
[b]First limiting amino acid.
[c]Second limiting amino acid.
[d]Chemical score.
[e]Not limiting.

Table 5. B-group vitamins (μg/100 g) of raw and processed faba bean (on a dry weight basis) (means ± SD, $n = 3$)

Treatments	Thiamine	Riboflavin	Niacin	Pyridoxine	Pantothenic acid
Raw	640 ± 9·17	190 ± 2·64	2000 ± 26·46	230 ± 3·61	270 ± 3·46
Cooking	160 ± 4·36	110 ± 2·67	120 ± 3·61	200 ± 4·58	160 ± 4·36
Autoclaving	210 ± 3·61	130 ± 3·00	140 ± 2·63	230 ± 3·53	180 ± 3·61
Germination	360 ± 3·46	230 ± 4·58	1800 ± 21·79	290 ± 4·32	220 ± 1·73

Table 6. Percentage retention of B-group vitamins in raw and processed faba bean (means ± SD, $n = 3$)

Treatments	Thiamine	Riboflavin	Niacin	Pyridoxine	Pantothenic acid
Raw	100 ± 0·0	100 ± 0·0	100 ± 0·0	100 ± 0·0	100 ± 0·0
Cooking	25·0 ± 1·00	57·9 ± 2·08	6·0 ± 0·12	87·0 ± 1·71	59·3 ± 2·25
Autoclaving	32·8 ± 1·00	68·4 ± 1·07	7·0 ± 0·06	100 ± 2·72	66·7 ± 1·75
Germination	56·3 ± 1·27	121·1 ± 3·43	90·0 ± 1·94	126·1 ± 3·15	81·5 ± 1·67

Table 7. Minerals (mg/100 g) of raw and processed faba bean (on a dry weight basis)

Treatments	Na	Ca	K	Cu	Zn	Fe	Mn	Mg
Raw	297	220	748	2·5	11·7	6·6	2·3	281
Cooking	292	208	468	2·1	11·0	6·1	2·3	270
Autoclaving	297	198	474	2·1	11·7	6·1	2·3	286
Germination	281	220	297	2·3	11·2	6·4	2·1	242

who stated that the loss of divalent metals (Ca, Fe, and Zn) was low during germination due to their binding to protein and, also, the formation of a phytate–cation–protein complex.

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