Assessment of the technological quality characters and chemical composition for some Egyptian Faba bean germplasm

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ABSTRACT

Increasing the yield and nutritional value of faba beans is one of the main objectives of the common bean cultivar improvement programs due to its contribution to terminate protein deficiency malnutrition in developing countries and raising the income level of smallholder farmers. In this study, the technological quality of bean seeds from twenty-four genotypes were evaluated (twenty germplasm and four improved cultivars (Misr 1, Giza 429, Giza 716, Giza 843). The results showed a significant diversity in the Egyptian bean germplasm in their quality traits compared to the control cultivars and indicated that the genotypes had a high hydration coefficient that ranged between (98.6-112.4%). While most of the genotypes for cotyledons to hull ratio met the commercial criteria that ranged between (7.41-6.41%). Twenty genotypes had the highest total soluble solids (6.90-11.78%) and were superior to the control cultivars. The seeds chemical composition analysis showed that the genotypes differed in their composition such as protein (26.65 to 30.72 %), carbohydrate (58.00 to 62.25%), tannin (70.67 to 157.45%), phenols (35.23-51.02 %), and moisture (9.15 to 10.45%).

Keywords: Faba bean (Vicia faba L.) Germplasm Technological characters Chemical composition

Graphical Abstract

1. Introduction

Faba bean (Vicia faba L.) is one of the most important cultivated and consumed leguminous crops. From a nutritional and economic point of view, it ranks fourth in the world after dry beans, dry peas and chickpeas.1,2 This crop has gained increasing interest in recent years. It is mainly grown all over the world due to its high content of nutrients, and thus it is used in both food and forage.3-5 It's importance as a food crop and forage lies in its high content of high-quality proteins
which is necessary for a balanced diet as well as its high content of vitamins, minerals and carbohydrates rich in lysine, making it one of the best solutions to malnutrition, especially in developing countries and source of income for smallholder farmers. From an environmental point of view, when introduced into an intercropping system with cereals, it contributes to the fixation of nitrogen from the soil, improving soil fertility, and thus increasing crop yield. It is an excellent component of crop cycles, something that has been largely ignored in modern crops, at a time when there is an urgent need to reduce the impact of chemical fertilizers on the environment, and to minimize the emissions of unwanted grasses.

In Egypt, faba beans (Vicia faba L.) constitute one of the oldest major food crops that were cultivated by the Egyptians nearly 5,000 years ago, and the population relied on them to provide them with sufficient dietary protein. Nearly 75 percent of the daily per capita consumption of protein in Egypt is of vegetable source, mostly from cereals and beans. Egyptians consume about 14 grams per capita per day of beans, which is about 3 grams of protein. The pathogens (fungal and viral diseases) are one of the main obstacles that have affected plant growth and have contributed significantly to causing significant yield loss in terms of quantity and quality. The yield loss due to diseases is estimated to be around (25-80%) and the protein content decrease is about 4%. However, some control efforts are available to reduce these pathogens. The analysis of variance for protein content and tannin content revealed significant differences among genotypes. Their results indicated a wide genetic variability for all variables in the material under study.

Increasing crop yields or preserving productivity at acceptable levels has become a primary objective of breeding and improvement programs, but the mechanization of farming and agribusiness model has found new demands on improvement programs, comprising technological quality of the cereals traded. Consequently, the testing of technological quality traits such as the cookability of the seeds, the percentage of whole seeds, the total soluble solids of the seeds, the protein content and the hydration coefficient before and after cooking, became a requirement for the inclusion of bean品质 traits. The analysis of variance for protein content and tannin content revealed significant differences among genotypes. Their results indicated a wide genetic variability for all variables in the material under study. The chemical composition of seeds of 11 field grown faba bean cultivars in two cultivation periods was evaluated. It was found that the variation among genotypes was always highly significant and most cultivars exhibited a consistent rank in protein concentration.

2. Experimental

2.1. Materials and Methods

Twenty-four faba bean genotypes of Vicia faba L were used in this study. Seeds were obtained from the Bahtim Research Station, Kalyopia, Egypt and four improved varieties (Misr 1, Giza 429, Giza 716 and Giza 843) were used as controls from Legumes Crops Department, Field Crops Research Institute, ARC, Egypt. The experiments were arranged in a randomized complete block design with three replications during two growing seasons.

Table 1. Faba bean varieties and landraces collected from Middle and Upper Egypt to characterize during growth seasons.

| Serial No. | Source    | Code   | Origin                              | Location         |
|------------|-----------|--------|-------------------------------------|------------------|
| 1          | Bahtim    | 63     | 35 km N of Idifu by El Sabaya village | Qena             |
| 2          | Bahtim    | 97     | Armant local market                 | Qena             |
| 3          | Bahtim    | 153    | Benifeex - Near Sindia              | Assiut           |
| 4          | Bahtim    | 165    | Beni – Rafi                         | Assiut           |
| 5          | Bahtim    | 172    | Qena                               | Qena             |
| 6          | Bahtim    | 173    | Qena                               | Qena             |
| 7          | Bahtim    | 193    | 4 km W of Qena on the road to Dandara temple | Qena         |
| 8          | Bahtim    | 233    | 14 km E of Nag Hammadi             | Qena             |
| 9          | Bahtim    | 243    | Nag Hammadi                        | Qena             |
| 10         | Bahtim    | 250    | 20 km NW of Nag Hammadi             | Qena             |
| 11         | Bahtim    | 276    | El Balyana                         | Sohag            |
| 12         | Bahtim    | 290    | El Mar Sara-Dakhla                 | New valley       |
| 13         | Bahtim    | 298    | 21 km N of Girga                   | Sohag            |
| 14         | Bahtim    | 305    | 19 km N of Sohag                   | Sohag            |
| 15         | Bahtim    | 307    | 25 km N of Sohag                   | Sohag            |
| 16         | Bahtim    | 332    | Ezbat El Haga – El Kharga          | Sohag            |
| 17         | Bahtim    | 485    | 3 km S of Bemi Mazar               | Minia            |
| 18         | Bahtim    | 514    | 11 km S of Ihnasya El Madina        | Benisuef         |
| 19         | Bahtim    | 637    | 3 km of El Fayoum (El Karadina)     | Fayoum           |
| 20         | Bahtim    | 233    | El Abbada (Tameia)                 | Fayoum           |
| 21         | Giza      | Misr 1 | Giza 3 X 123 A/45/76               | Egypt            |
| 22         | Giza      | Giza 429 | Individual selection from Giza 402 | Egypt            |
| 23         | Giza      | Giza 716 | 461/842/83 X 503/453/83          | Egypt            |
| 24         | Giza      | Giza 843 | 561/2076/85 Sakka X 461/845/83     | Egypt            |
2.2 Technological characteristics

Seeds of genotypes were bulked from three replication to determine the following technological characteristics. The samples seeds were dried at 130°C for 1 hr.\textsuperscript{21}

2.2.1 Soaking stage

The seeds were soaked and cooked.\textsuperscript{22} Briefly, ten grams of dry seeds from each genotype were soaked in tap water for 24 hr at room temperature. The following measurements were determined in soaked seeds.

- Hydration coefficient of seeds before cooking (H.C.B.):
  \[
  H.C.B = \frac{(W_2 - W_1)}{W_1} \times 100
  \]
  where, \( W_1 \) = weight of dry seeds (g); and \( W_2 \) = weight of soaked seeds (g).

- Cotyledons to hull ratio (C/H ratio):
  The soaked seeds was separated manually into cotyledons and hull. Every separation was dried at 40°C over night, then it was weighted. The percent for each content was calculated.

2.2.2. Cooking stage

Other samples (10 g seeds/each) of dry seeds from each genotype were placed in glass tube (100 cm\(^3\)) containing enough water (50 cm\(^3\)) for each. The tubes were put in oven for 24 hr at 100°C. The following measurements were determined in cooked seeds.\textsuperscript{22}

- Hydration coefficient after cooking (H.C.A.):
  The measurements were recorded according the following formulas:
  \[
  H.C.A = \frac{(W_2 - W_1)}{W_1} \times 100
  \]
  where, \( W_1 \) = weight of dry seeds (g); and \( W_2 \) = weight of cooked seeds (g).

- Total soluble solids of the seeds (T.S.S.):
  The solution containing soluble material was poured into a porcelain pot placed in an oven at 60°C over night until all water was evaporated. The pot was weighted before and after putting and the T.S.S. was calculated as follow:
  \[
  T.S.S. = \frac{(W_3 - W_2)}{W_1} \times 100
  \]
  where, \( W_1 \) = initial weight of seeds; \( W_2 \) = weight of empty pot; and \( W_3 \) = weight of pot after drying.

- Seed cookability (Stewing):
  The ability of cooked seeds was measured by means of using the normal press of fingers and comparing between the cooked seeds for their hardness (Stewing).

2.3. Statistical Analyses

Statistical analysis of the obtained data was carried out for analysis of variance using computer Statistical program MSTAT-C.\textsuperscript{23} Means were compared by the L.S.D. values at 5% level.

3. Results

3.1 Technological characteristics

3.1.1 Hydration coefficient before cooking (H.C.B %)

Hydration coefficient before cooking of faba bean genotypes under study are summarized in table (2). H.C.B was the highest in genotype 10 at 112.4% than control varieties, followed by genotypes 1-20 at 98.6-108.4% which are approximately nearby and equaled those found in control cultivars (Misr 1 and Gize 716). The highest values of H.C.B. due
to lack genotypes of hard seeds. It displayed a higher H.C. and required short cooking times. Some researchers have found an association between higher HC and shorter cooking times,24-25 while others have not.26-27 The lowest H.C. may be related to low seed coat permeability. Differences in hydration capacity among varieties may be associated with differences in seed coat hardness, porosity, elasticity, cotyledon adherence, and colloidal properties across seeds from different varieties (Fig. 1).28

![H.C.B. %](image1)

**Fig. 1.** Hydration coefficient before cooking (H.C.B %) for 24 Faba bean genotypes.

### 3.1.2 Cotyledons %

Cotyledons % values of faba bean seeds genotypes under study were obtained and the highest values for genotypes 9 (88.30%) and 20 (88.0%) while the lowest value was found in genotypes 6 and 2 (84.8 and 85.0%, respectively). The cotyledons of the other genotypes ranged from 84.8 to 88.3% (Fig. 2).

![Cotyledons %](image2)

**Fig. 2.** Cotyledons percentage for 24 Faba bean genotypes.

### 3.1.3 Hulls %

Data in Table 2 showed that the hulls% was significant between genotypes. The highest value for genotypes 6 (15.2%) and 2 (14.9%) whereas, genotypes 9 and Giza 843 had the lowest values (11.7 and 11.9%, respectively). Hulls% content of the other genotypes ranged from 11.7 to 15.2% (Fig. 3).
3.1.4 Cotyledons to hulls ratio (C./H. ratio).

Results in Table 2 show the Cotyledons to hulls ratio of faba beans for the genotypes under investigation. Presented results indicated that the genotypes 3 and 20 gave the highest values (8.14 and 7.55%, respectively), while genotype 6 and 2 gave the lowest values (5.58 and 5.71%, respectively). Whereas, most of the other genotypes conformed to commercial standards (7.41-6.41%). A low cotyledons to hulls ratio is a desirable character, as a high cotyledons to hulls ratio affects the supposed stimulus of chewing and decreases consumer acceptance (Fig. 4).²⁹

3.1.5 Hydration coefficient after cooking (H.C.A %)

Data present in Table 2 show the hydration coefficient after cooking of the tested faba bean seeds. The highest value was recorded for genotypes 11, 20 and 9 (199.7, 197.3 and 195.9%, respectively), whereas the lowest value was found for genotype 6 (145.6%). H.C.A % in the other genotypes under study ranged from 145.6 to 199.7% (Fig. 5).
Fig. 5. Hydration coefficient after cooking (H.C.A %) for 24 Faba bean genotypes

3.1.6 Total soluble solids (T.S.S. %)

Total soluble solids content was highest in genotypes 1 to 17 (Table 2). T.S.S. in these genotypes exceeded those found currently in the market. T.S.S. is an important character in determining soup quality of cooked beans and consumer studies indicate a preference for viscous soup after cooking, which should favor the new varieties with similar or higher soluble solid content compared to current varieties (Fig. 6).30

Fig. 6. Total soluble solids (T.S.S. %) for 24 Faba bean genotypes.

3.1.7 Seed cookability (Stewing) %

Stewing % in these genotypes equaled or exceeded those found in control cultivars. Especially, genotypes 10, 11, and 17 had the highest stewing and were superior to control cultivars, while genotypes 6, 8, and 18 had the shortest stewing at 60 – 70%. The highest stewing is suitable for bean cultivars, because it means maintaining energy and resources.31 In addition, beans that require very long stewing to become delicious may have lower nutritional qualities as protein, vitamin, and mineral contents.32-33 Lastly, the development of fast-cooking bean cultivars conforms requirements of consumer.29 The presence of hard seeds is linked to the “hard to cook” phenomenon which defines the condition in which seeds take longer to soften through cooking or do not soften even after extended cooking in boiling water (Fig. 7).34
Table 2. Technological characters of some faba bean genotypes

| Genotypes | H.C.B. % | Cotyledons % | Hulls % | C./H. ratio | H.C.A. % | T.S.S. % | Stewing % |
|-----------|----------|--------------|---------|-------------|----------|----------|-----------|
| 1         | 104.2    | 86.9         | 13.1    | 6.64        | 158.4    | 9.94     | 75        |
| 2         | 104.1    | 85.0         | 14.9    | 5.71        | 155.2    | 10.9     | 85        |
| 3         | 100.6    | 86.9         | 13.1    | 8.14        | 181.7    | 9.64     | 80        |
| 4         | 103.7    | 86.9         | 13.1    | 6.64        | 186.9    | 9.74     | 85        |
| 5         | 103.4    | 86.8         | 13.2    | 6.58        | 183.7    | 10.69    | 90        |
| 6         | 100.1    | 84.8         | 15.2    | 5.58        | 145.6    | 10.54    | 60        |
| 7         | 100.7    | 87.2         | 12.8    | 6.82        | 187.0    | 9.03     | 85        |
| 8         | 99.5     | 86.2         | 13.8    | 6.25        | 168.4    | 9.525    | 60        |
| 9         | 106.5    | 88.3         | 11.7    | 7.55        | 195.9    | 10.31    | 95        |
| 10        | 112.4    | 87.1         | 12.9    | 6.75        | 190.7    | 10.18    | 100       |
| 11        | 104.2    | 87.2         | 12.8    | 6.82        | 199.7    | 11.78    | 100       |
| 12        | 98.6     | 87.4         | 12.6    | 6.94        | 189.2    | 9.58     | 90        |
| 13        | 104.4    | 87.2         | 12.8    | 6.82        | 192.1    | 10.34    | 75        |
| 14        | 104.4    | 87.4         | 12.6    | 6.94        | 187.0    | 9.62     | 95        |
| 15        | 99.8     | 87.3         | 12.7    | 6.88        | 189.2    | 10.68    | 95        |
| 16        | 108.8    | 86.2         | 13.8    | 6.21        | 188.8    | 10.88    | 95        |
| 17        | 107.1    | 87.1         | 12.9    | 6.75        | 192.3    | 10.79    | 100       |
| 18        | 108.1    | 86.7         | 13.3    | 6.52        | 157.1    | 7.785    | 70        |
| 19        | 104.5    | 87.5         | 12.5    | 7.00        | 177.5    | 7.755    | 85        |
| 20        | 102.6    | 88.00        | 12.0    | 7.34        | 197.3    | 6.90     | 95        |
| Misr1     | 107.1    | 87.7         | 12.3    | 7.13        | 186.4    | 6.88     | 95        |
| Giza 429  | 61.9     | 86.8         | 13.2    | 6.58        | 178.7    | 8.14     | 70        |
| Giza 716  | 107.5    | 86.5         | 13.5    | 6.41        | 188.0    | 7.32     | 85        |
| Giza 843  | 74.5     | 88.1         | 11.9    | 7.41        | 187.9    | 6.335    | 100       |
| LSD 5%    | 1.18     | 1.35         | 1.33    | 1.61        | 6.13     | 0.74     | 12.1      |

3.2 Seed chemical composition

The gross seed chemical composition analysis (on dry matter basis) of 24 faba bean genotypes under study is given in Table 3. All genotypes differed significantly in all seed chemical characters.

Moisture content ranged from 9.15 to 10.45% the highest value was recorded by line No. 6, while the lowest one for Misr 1. Results in Table 3 show the crude protein content of faba bean genotypes under investigation. Presented results indicated that line 20 was the highest in protein content (30.72%), while line 5 gave the lowest value (26.65%). However, protein content behaved a similar trend of 29.82, 29.70 and 29.70% for lines 19, 17 and 18, respectively. Seed crude fat content values of faba bean genotypes under study are presented in Table 3. Results showed that the highest values of fat content were obtained for line 9 (2.05%) and line 19 (2.04%), while the lowest value was found in line 7 (1.93%). Data present in Table 3 show the ash content of the tested faba bean seeds. The highest ash content was recorded for faba bean variety Giza 429 (3.35%), whereas the lowest ash content was found for faba bean seeds of line 11 (3.00%). Carbohydrates contents of faba bean genotypes under study are presented in Table 3. Results indicated that the line 5 (62.25%) showed
the highest value, however the lowest carbohydrate content was obtained in seeds of line 20 (58.00%). Carbohydrate content for seeds of the other genotypes ranged between the previously mentioned limits, i.e. the highest and the lowest values.

Data in Table 3 show that the tannin content was highly significant by difference between genotypes. The highest value was in seed of Giza 716 (157.45 mg/100g), whereas line 5 had the lowest content (70.67 mg/100g). Total tannin content of the rest of the genotypes ranged between these two limits. Seed phenols content values of faba bean genotypes under study are presented in Table 3. Results indicated that the highest value of phenols content was obtained for line 3 (51.02 mg/100g) while the lowest value was found in line 11 (35.23 mg/100g).

### Table 3. Chemical composition analysis of some faba bean germplasm

| Characters Studied | Moisture % | Crude protein % | Crude fat % | Ash % | Total Carbohydrate % | Tannins % | Phenols % |
|--------------------|------------|-----------------|-------------|-------|-----------------------|-----------|-----------|
| Genotypes         |            |                 |             |       |                       |           |           |
| 1                  | 10.2       | 29.63           | 1.96        | 3.20  | 59.22                 | 91.74     | 45.10     |
| 2                  | 10.6       | 29.25           | 1.99        | 3.30  | 59.47                 | 61.99     | 44.50     |
| 3                  | 10.25      | 26.70           | 1.97        | 3.35  | 62.18                 | 78.10     | 51.02     |
| 4                  | 10.05      | 27.45           | 1.97        | 3.25  | 61.33                 | 76.86     | 42.20     |
| 5                  | 9.65       | 26.65           | 1.95        | 3.60  | 62.25                 | 70.67     | 36.22     |
| 6                  | 10.45      | 29.31           | 1.97        | 3.25  | 60.47                 | 105.4     | 39.56     |
| 7                  | 9.9        | 27.70           | 1.93        | 3.15  | 61.22                 | 122.7     | 36.08     |
| 8                  | 9.9        | 28.26           | 1.97        | 3.25  | 60.51                 | 111.6     | 38.43     |
| 9                  | 9.8        | 26.80           | 2.05        | 3.20  | 61.95                 | 96.70     | 39.18     |
| 10                 | 9.8        | 26.75           | 1.98        | 3.30  | 61.97                 | 136.4     | 28.68     |
| 11                 | 9.45       | 27.33           | 1.97        | 3.00  | 61.70                 | 85.54     | 35.23     |
| 12                 | 9.3        | 27.89           | 1.95        | 3.25  | 60.92                 | 124.0     | 43.94     |
| 13                 | 10.2       | 28.47           | 2.02        | 3.10  | 60.42                 | 147.5     | 43.06     |
| 14                 | 10         | 28.51           | 1.95        | 3.20  | 60.33                 | 121.5     | 41.54     |
| 15                 | 10         | 28.35           | 2.04        | 3.10  | 60.51                 | 100.4     | 49.47     |
| 16                 | 10.05      | 28.50           | 1.95        | 3.20  | 60.35                 | 131.4     | 40.84     |
| 17                 | 9.85       | 29.70           | 2.10        | 3.15  | 59.05                 | 147.5     | 46.55     |
| 18                 | 10.4       | 29.70           | 1.97        | 3.25  | 59.08                 | 150.0     | 36.47     |
| 19                 | 9.5        | 29.82           | 2.04        | 3.20  | 58.94                 | 114.1     | 40.15     |
| 20                 | 10.05      | 30.72           | 1.99        | 3.30  | 58.00                 | 106.6     | 40.69     |
| Giza 429           | 9.15       | 27.67           | 1.96        | 3.25  | 60.12                 | 107.9     | 41.01     |
| Giza 716           | 10.4       | 29.23           | 1.98        | 3.35  | 59.44                 | 127.7     | 45.69     |
| Giza 843           | 9.5        | 27.26           | 1.97        | 3.20  | 61.58                 | 157.4     | 44.31     |
| LSD 5%             | 0.24       | 4.25            | 0.09        | 0.21  | 4.16                  | 25.28     | 5.91      |

4. Discussions

The data presented in this study on the technological characteristics and chemical composition of the genotypes under the study are in agreement with many studies that dealt with the different technological characteristics of the faba bean cultivars. For instance, a slight variation between varieties for hulls to seed ratio which was found in the range of 11.4 and 14.51% stewing percentage ranged from 20 to 90%. Also, the hydration coefficient of the dried seeds ranged between 93.95 and 116.55. Hull percentage ranged from 10.75-13.74%. The ratio between cotyledon and hull showed an opposite trend of hull percentage. The percentage of stewed faba bean seeds ranged from 50 to 100% when the autoclaving method was used, while it ranged from 30 to 100 % due to the oven method. The analysis of variance for all studied chemical and technological characters such as (C/H ratio, stewing % and TSS %) revealed significant differences among genotypes for all characters. Significant variations were found for most physical and cooking properties such as, density, imbibed water after soaking %, imbibed water after cooking %, cotyledons %, seed coat % and total soluble solids % in six faba bean cultivars with their F1 crosses.

Seed proteins are deficient in some amino acids that are essential for humans and other mono-gastric animals, so, the most economic approach is through breeding programs to develop promising genotypes with high yield, quality and good agronomic performance. Protein content of faba bean seeds depended on cultivars and oscillated from 23.9 to 29.8%. These results indicated wide genetic variability for all variables in the material under study. Beside to these genotypes are suitable for Faba bean breeding programs to improve Faba seed quality and fulfill consumer's requirements. This work can confirm the previous data that clarify the importance of science in the world.35-67

5. Conclusion

The data presented in this study on the technological characteristics of the genotypes under study are in agreement with many studies that dealt with the different technological characteristics of the faba bean cultivars. For example, hydration coefficients in all of the genotypes had values ranging from 98.6-112.4% equalled and/or exceeded those found in control cultivars. With regard to the property of the Cotyledons to hull ratio, the decrease is a desirable trait and most genotypes
meet consumer standards. Only genotypes 3 and 20 gave the highest values (8.14 and 7.55%, respectively). Hydration coefficient after cooking (H.C.A %) was superior with germplasm as 9, 11, 13, 17 and 20 compared with other germplasm and check varieties. Whereas, most of the other genotypes ranged from (7.41-6.41%). The total soluble solids character was the highest in all of the genotypes, ranging from 6.90-11.78% and were superior to control cultivars (6.33-8.14%). Finally, genotypes 6, 8, and 18 displayed the shortest percentage of seed cookability, ranging from 60 -70%, while the highest was observed in most of genotypes, ranging from (75-100%) and conforming to the needs of consumers. The seeds chemical composition analysis showed that the genotypes differed in their composition as follows: protein (from 26.65 to 30.72%), carbohydrate (from 58.00 to 62.25%), crude fat (from 1.93 to 2.05%), ash (from 3.00 to 3.35 %), tannin (from 70.67 to 157.45%), phenols (35.23-51.02 %), and moisture (9.15 to 10.45%). Based on the above results, these genotypes are suitable for the Faba bean breeding program to improve Faba seed quality and fulfill consumer's requirements.

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