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Estimation of Bioactive Components and Technological Properties in Some Faba Bean Varieties

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ABSTRACT

Six faba bean varieties, namely Sakha 1, Sakha 4, Giza 3, Giza 716, NA 112, and Santa Mora, were evaluated for the physicochemical, phytochemical, and technological properties as well as the impact of some technological processes, i.e., soaking, germination, and cooking on phytochemical and vicine contents of such varieties. Results revealed that Santa Mora variety had a higher kernel weight and dimensions (length and width). Likewise, Giza 716 had the highest lightness and yellowness values, while NA 112 had the highest redness values. The NA 112 and Giza 716 varieties had the highest protein content, and Sakha 4 had a higher crude fibers content. The highest potassium and phosphorus contents were in Giza 716 and Sakha 1, respectively. The NA 112 variety was the highest content of iron and zinc. Santa Mora had the highest phenolic content, followed by NA 112. The content of anthocyanins, and flavonoids were significantly varied among the tested varieties. Pyrogallol possessed the highest phenolic compound in such faba bean varieties, and the highest content was in Giza 716 and Santa Mora. Catechin was the highest flavonoid compound, and the varieties contained the highest values were Sakha 1 and Santa Mora. Santa Mora had the highest content of L-DOPA (L-3,4-dihydroxyphenyl-L-alanine), while Sakha 1 had the highest total vicine. The phytochemical compounds, L-DOPA and total vicine decreased in all varieties after different processing methods and cooking processes revealed a high loss in such components. Overall, data showed that the Giza 716 and Sakha 4 had the highest cookability and overall acceptability.

Keywords: Faba bean varieties, Physicochemical, Phytochemicals, Technological parameters and processing methods, Cooking quality, Sensory characteristics.

1. Introduction

The quality component has been taken into consideration in plant breeding research, due to rising demand for a healthy, and balanced diet by consumers. Broad bean, or faba bean (*Vicia faba* L.), is a winter-grown crop belonging to the Fabaceae family. It is one of the oldest and most consumed crops in the world due to its nutritional value and medicinal effects. The top producers of faba beans are China, Ethiopia, Egypt, India, and Afghanistan (Rahate *et al.*, 2021 and Topal and Bozoğlu, 2016). In 2021, Egypt produced around 170,000 Tons (Bulletin of Food Balance Sheet, 2021). It is one of the most favored cuisines, and is a common daily breakfast food in Egypt. It was the first consumed by the ancient Egyptians thousands of years ago, and their varieties components are varied depending on their origin, morphological and quality characteristics (Abdel-Sattar *et al.*, 2021 and Mekky *et al.*, 2020). It is one of the most inexpensive protein plant sources with a longer shelf life.

The mature seeds are used for human consumption in Egypt and are considered a rich source of protein, carbohydrates and dietary fibers. Moreover, faba beans accumulate a large amount of L-DOPA (L-3,4-dihydroxyphenylalanine), which is a precursor of dopamine. Dopamine is an essential component for learning, mood, sleeping, and the brain, and can be potentially used for managing Parkinson's disease. The number of Parkinson's disease patients was between 4.10 and 4.60 million in

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2005; that figure will be doubled to 8.70 and 9.30 million by 2030 (Dorsey *et al.*, 2007 and Singh *et al.*, 2013). Likewise, faba bean contains vicine and convicine (type of pyrimidine glycosides), which are strong oxidants and harmful to humans that have a gene mutation for the glucose-6-phosphate dehydrogenase (G6PD) deficiency. The hydrolysis compounds of vicine and convicine cause oxidation of glutathione (GHS), and their reduced form cannot be done, which is altering several functions of red blood cells, that are responsible of haemolytic anemia (favism) in the G6PD-deficient individuals. G6PD generates the NADPH, which is necessary for the glutathione reductase function (the enzyme that reduce oxidised glutathion). Favism can quickly destroy up to 80% of circulating red blood cells, and it is one of the key explanations for faba bean seeds that are forbidden to be used by people with favism (Ali and Shakir, 2023 and Diegues *et al.*, 2022). Consumption of faba beans is frequently linked to G6PD insufficiency in the Middle East, the Far East, and the Mediterranean region. The G6PD deficiency in females is uncommon or rare, while male children between the ages of 2-5y account for 66-75% of instances with severe favism. Besides, the breeding, selection of faba bean varieties, and use of different processing methods could be assessed in reducing or eliminating vicine and convicine. Fresh, frozen, or incompletely cooked faba beans are the main typically the cause of favism (Duc *et al.*, 1989). The reduction in vicine and convicine in faba bean after processing may be caused by the leach out of it into the soaking water under the effect of the concentration gradient (Hendawey and Younes, 2013).

Faba bean has a wide range of bioactive substances, including condensed tannins, flavonoids, and total phenolics, that has antioxidant and antimicrobial properties. Moreover, the bioactive compounds may help in managing the risk of some diseases like hypertension, and cancer (Badjona *et al.*, 2023).

Faba bean seed processing methods, like soaking, germination, dehulling, cooking, microwave heating, extrusion, enzyme treatment, etc., are the most common processing methods used and have produced fruitful outcomes, promoting human consumption and usage of broad beans in a variety of innovative foods. The seeds could be used in various ways, *e.g*., green (fresh) and cooked seeds. The most popular dishes are medamis (stewed faba bean), falafel (deep-fried faba bean cotyledon paste), nabet soup (germinated faba bean seeds), and bissara (faba bean cotyledon) (Rahate *et al.*, 2021 and Singh *et al.*, 2013). The nutrient-rich components in various foods may become easier to digest with lower antinutritional characteristics through different processing techniques (Dhull *et al.*, 2022).

Thus, the current study set out to estimate the physicochemical, phytochemical, technological characteristics (soaking, germination, and cooking), and sensorial acceptability of six faba bean varieties.

2. Materials and Methods

2.1. Materials

Dry brown-beige-colored faba bean (*Vicea faba* L.) varieties [Sakha 1, Sakha 4, Giza 3, and Giza 716], and two dry purple-colored varieties (NA 112 and Santa Mora), have been got from the Department of Food Legumes Research, Field Crops Research Institute, ARC, Egypt (Figure 1). DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid, catechin, catechol, pancreatin, and pepsin enzymes were obtained from the Sigma-Aldrich Chemical Company, Saint Louis, USA. The Folin-Ciocalteu-phenol reagent was purchased from LOBA-Chemie, India, and the other chemicals were all analytically graded.

2.2. Methods

Seeds were manually freed from broken seeds, dust, stones, and foreign materials. For whole meal powder, seeds were milled using a high-speed grinder (MDY-2000, China), packed in polyethylene bags and then kept at -18°C for additional analysis.

2.2.1. Physical characteristics of faba beans

The physical characteristics [the weight of 100 kernels or seeds, density, seed dimensions (length, width, and thickness), imbibed water percentage after soaking, seed parts, and color parameters) of faba bean varieties were determined using AACC (2002). Seed dimensions were measured for each seed variety using a Vernier Caliper. Seed hundred weight was determined using a digital balance and expressed as a hundred kernels weight in grams. Seeds volume was estimated using the water

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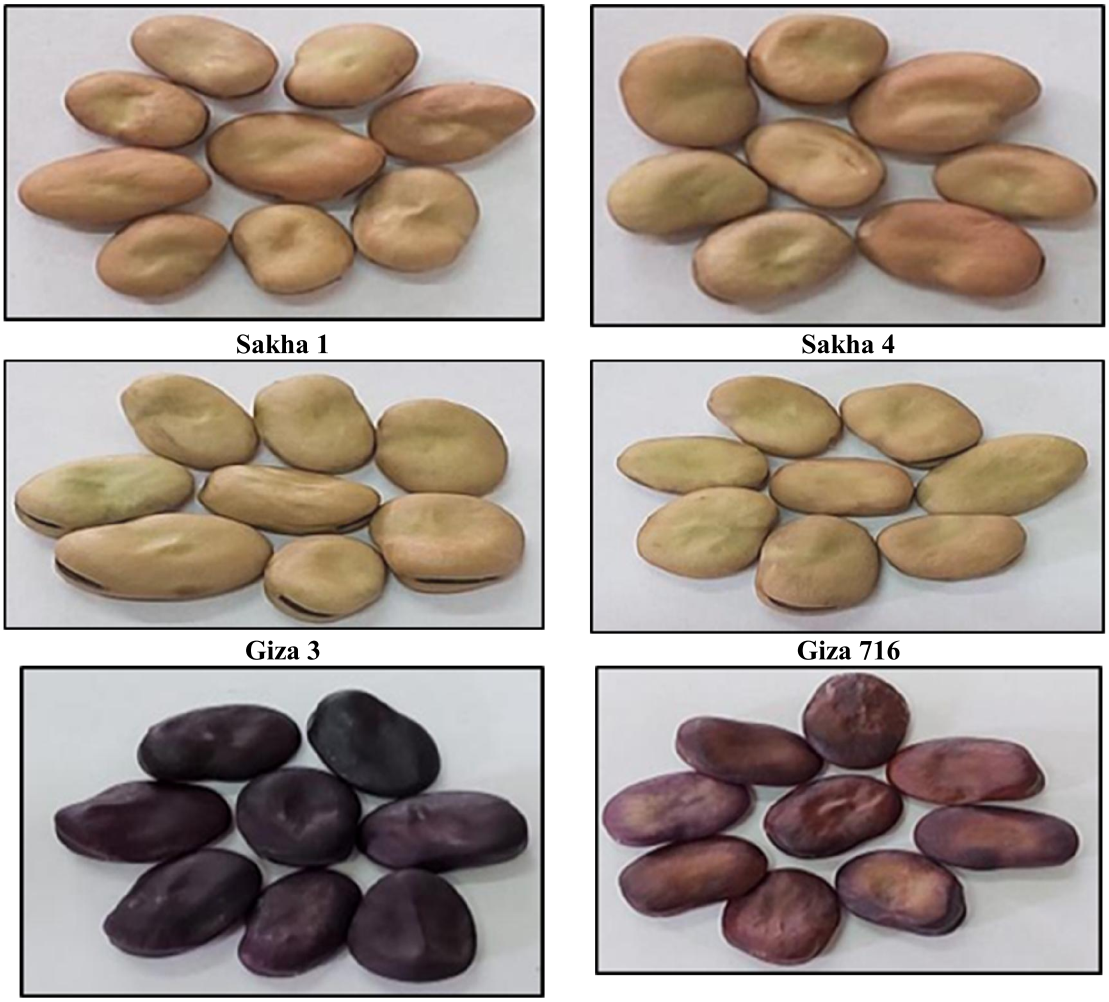
displacement method, and seed density (g/cm^3) was calculated using the weight and volume ratio results.



Sakha 1 **Sakha 4**

Giza 3 **Giza 716**

NA 112 **Santa Mora**

Fig. 1: Photos of the tested faba bean varieties

For the seed parts (cotyledons and the seeds coat or hull), ten seeds were weighed, and soaked for 12 hours in 100 ml of water at ~25ºC. The soaked seeds were weighted to calculate the imbibed water percentage after soaking (the mass gained by seeds after soaking to the mass before soaking). Then seeds were manually dehulled to obtain coats and cotyledons, and then dried at 60°C for 12 hours, weighted to calculate the percentages of the seed coat and the cotyledons, and their ratio. The external or raw seed coat color parameters were exhibited in terms of lightness (L*), redness (a*), and yellowness (b*) (hand-held chromameter, model: CR 400, Konica Minolta, Japan). The color of the exterior seed coat was assessed, and all measurements were carried out from averages of three determinations.

2.2.2. Faba bean processing methods

The faba beans were subjected to some processing methods (soaking, germination and cooking). The previous soaked seeds (for 12 hours at ~25ºC), were divided into two groups; the first was just soaked, and the second group was germinated for 72 hours at 25±5°C. The cooked seeds (stewed) were taken after cooking experiments (in technological characteristics section) for sensory and cooking quality evaluation. The different processed seeds were dried at 45±5°C, packed in polyethylene bags, and kept at the freezer for bioactive compounds analysis.

2.2.3. Chemical analysis

2.2.3.1. Proximate analysis

Using the AOAC (2019) methods, the moisture, protein, ash, crude fibers and fat content of faba bean seeds were investigated in whole meal powder. Protein, ash, fats, and crude fibers have been eliminated from 100 g of samples in order to calculate the carbohydrates content. Mineral contents (potassium, iron, zinc, and calcium) were determined (Agilent Technologies Microwave Plasma Atomic Emission Spectrometers, Model: 4210 MP-AES, USA) following the procedure described in the AOAC (2019). The Trough and Mayer (1929) method was used to determine the total phosphorus content.

2.3. Phytochemical analysis

2.3.1. Total Phenolic determination

The Folin-Ciocalteu method was used to determine the total phenolic, a two gram of sample was mixed with 20 ml of methanol (80%), shaken for two hours, filtrated, and the color was developed by adding 0.250 ml of sample extract to 0.250 ml of Folin-Ciocalteu phenol reagent, 0.50 ml of Na_2CO_3 solution (7.50%), and 4 ml of distilled water (Singleton and Rossi, 1965). The reaction mixture was kept in the dark for 30 min, the absorbance was measured at 725 nm using a Jenway spectrophotometer (Model-6715-UV/Vis, Cole-Parmer Ltd, Staffordshire, UK), and samples were calculated as mg/100g of gallic acid equivalent.

2.3.2. Total flavonoids determination

0.40 ml of the previous extract was combined with 4 ml of H_2O, and 0.30 ml of 5% $NaNO_2$ then was added to determine the total flavonoids (Zhishen *et al.*, 1999). 10% $AlCl_3$ (0.30 ml) was added after five minutes. Two ml of 1 M NaOH were added shortly after the six-minute, and H_2O was used to complete the volume to 10 ml. After that, samples were measured at 510 nm, and samples were calculated as mg/100g of catechin equivalent.

2.3.3. Tannins determination

The tannins were determined using the vanillin/HCl method, by mixing sample extract with equal volumes of 2% vanillin in methanol with 8% methanol/HCl and kept at room temperature for 20 min, then measured at 500 nm, and samples were presented as mg/100g of catechin equivalent (Price *et al.*, 1978).

2.3.4. Phenolic acids and flavonoids compound identification using HPLC

High-performance liquid chromatography analysis (HPLC) was used for the identification of phenolic acids and flavonoids compounds in raw faba bean by an Agilent-1200-chromatograph (Agilent Technologies Inc., USA) composed of column C18 Zorbax ODS with particle size 5µm, 4.60 mm x 250mm (Goupy *et al*., 1999 and Mattila *et al*., 2000, receptively). A UV detector calibrated to detect phenolic acids at 280 nm and flavonoids at 330 nm and the mobile phase was composed of methanol and acetonitrile (flowed at a rate of 1 ml/min). The chromatographic peaks were identified by comparing the retention times with those of known standard reference materials, and calculated using the retention time and peak area. Samples were expressed as mg/100g on dry weight based on the data analysis performed by the instrument software.

2.3.5. Total anthocyanin determination

A spectrophotometric pH differential methodology, was operated to determine the total anthocyanin concentration in samples (Lee *et al.*, 2005). The anthocyanin pigments reversibly change color with a change in pH (pH 1.0 and pH 4.5), and the absorbance of the pigments was measured at 520 and 700nm. The anthocyanins content was expressed as mg of cyanidin-3-glucoside equivalents in 100 g using the following equation:

$$\text{Total anthocyanins content (mg/100 g of dried sample)} = A \times MW \times DF \times 1000/(\mathcal{E} \times 1)$$

where A= the absorbance [$(A_{520} - A_{700})$ pH 1.0 – $(A_{520}-A_{700})$ pH 4.5]; MW= molecular weight for cyanidin-3-glucoside (449.20 g/mol); DF= the dilution factor of the samples; $\mathcal{E}$= the molar extinction coefficient of cyanidin-3-glucoside (26900); and 1= the path length in cm.

2.3.6. DPPH free radical scavenging activity

The antioxidant activity of the previous sample extract was measured using its radical scavenging activity after reacting with DPPH free radicals. Sample extract (0.10 ml) was added to 3.90 ml of DPPH solution (2.40 mg of DPPH in 100 ml of methanol). The reaction mixture was vigorously shaken and allowed to stand for 30 minutes in a dark place and measured at 515 nm (Brand-Williams *et al.*, 1995). The DPPH radical scavenging percentage (antioxidant activity) was calculated following the next equation:

$$Radical\ scavenging\ (\%) = [(A0 - A1)/\ A0]\ x\ 100$$

A0 was the absorbance of the control reaction (containing all reagents except the test extract), and A1 was the absorbance in the presence of the tested extracts after 30 min.

2.3.7. L-DOPA determination

The method of L-DOPA determination was based on the reaction of L-DOPA with $NaNO_2$ in an acidic medium to form an unstable yellow solution, that was converted to a stabilized red solution by the addition of sodium hydroxide (1 N), and measured at 470 nm (Arnow, 1937). The samples were presented as mg/100 g of catechol.

2.3.8. Total vicine determination

Total vicine was determined by suspending 2.0 g of sample in 60 ml of 4% meta-phosphoric acid, blended for 5 minutes in a Moulinex supper blender (Moulinex, Egypt), then centrifuged at 4000 xg for 15 min (Collier, 1976). The supernatant was diluted with HCl (0.10 N), and measured at 273.50 nm. The content of total vicine was presented as mg/g using the following equation:

$$\text{Total vicine (mg/g)} = (\text{Absorbance x } 322) / (13.60 \times 10^3)$$

where 322 = molecular weight of vicine and 13.60 x 10^3 = molar absorption of pure vicine.

2.4. Technological characteristics

2.4.1. Imbibed water and hydration coefficient after soaking

Imbibed water (water absorption) and hydration coefficient after soaking (previous soaked faba beans for seed parts) were measured using the method of AACC (2002). The weight of the soaked seeds was recorded. The imbibed water, and hydration coefficient of soaked beans were calculated using the weight measurements of faba bean seeds before and after soaking and expressed as follows:

$$\text{Imbibed water (\%)} = [(\text{Weight of soaked seeds} - \text{Weight of seeds before soaking}) / \text{Weight of seeds before soaking}] \times 100$$

$$\text{Hydration coefficient (\%)} = [(\text{Weight of soaked seeds} / \text{Weight of seeds before soaking})] \times 100$$

2.4.2. Cooking quality

The cooking quality characteristics, including imbibed water, stewing, and total soluble solids (total water-soluble solids) percentages, were measured (AACC, 2002). Ten seeds were weighed and stewed with 100 ml of water in an oven for 12 hours at 100°C until complete stewing. The imbibed water percentage of the cooked faba bean was measured by weighing the seeds before and after cooking, and exhibited as a percentage of the original sample weight. By pressing and comparing the firmness of the cooked seeds, the ability of the faba beans to be soft was used to calculate the stewing (cookability) percentage. Total soluble solids, or water-soluble solids, were determined by drying the cooking water containing water-soluble materials at 100ºC in an oven until a constant weight was reached and then weighed. The following equations were used to calculate the imbibed water, stewing (cookability), and water-soluble solids percentages:

$$\text{Imbibed water (\%)} = [(\text{Weight of cooked seeds} - \text{Weight of seeds before cooking})/\text{Weight of seeds before cooking}] \times 100$$

Stewing (%) = [(Initial number of seeds −Number of non stewed seeds)/(Initial number of seeds) x 100]

$$\text{Total soluble solids (\%)} = \text{Weight of residue (g)} \ / \ \text{Initial weight of seeds (g)} \ \text{x} \ 100$$

2.4.3. Sensory evaluation

Following Larmond's (1977) method, the stewed faba bean seeds (following the same procedure as cooking process) were examined for sensory evaluation, and organoleptically scored using a nine-hedonic scale for their sensory attributes, i.e., color, texture, taste, odor and overall acceptability by ten well-trained panelists from the Food Technology Research Institute, ARC, Egypt.

2.5. Statistical analysis

Costat statistical software was used to conduct the statistical analysis. The averages and standard deviations of the collected data were statistically determined (Steel *et al.*, 1997). The Duncan's new-multiple range tests were used after a one-way analysis of variance (ANOVA) at $p<0.05$ to evaluate the obtained data as well as mean differences between samples.

3. Results and Discussion

3.1. Physical properties

Table 1 shows the physical properties of faba bean varieties. The highest 100 kernel weight value (161.39 g) was observed in the Santa Mora variety, while Giza 3 had the lowest (85.31 g). Lu *et al.* (2018) found that the weight of 100 kernels of dry faba bean seeds varied among 32.26 and 126.31 g, and this may be referred to the differences in varieties.

In terms of density, the data demonstrated that the density values were non-significant ($p>0.05$) different between all varieties.

Concerning seed dimensions (length, width, and thickness), the data indicated that the Santa Mora variety had the highest value in length, and width (21.69 and 15.30 mm, respectively). On the other hand, non-significant ($p>0.05$) differences were detected in seed thickness values among all varieties. Abd Allah *et al.* (1988) reported that the length, width, and thickness values of faba beans were 16.50, 11.00, and 7 mm, respectively.

Regarding L^* values, data pointed out that there were a significant differences among varieties, and this may be due to the differences in phytochemical contents in the seed coat, and Giza 716 possessed the highest value. The redness and the yellowness values differed from 5.56-15.13 and 1.98-29.77, respectively. NA 112 had the highest a^* value, while Giza 716 had the highest b^* value. The results for color parameters are partially close to those of Abdel-Aleem *et al.* (2019). De Cillis *et al.* (2019) stated that total phenols were negatively correlated with L^* values. Karatas *et al.*, (2017) and Siah *et al.* (2019) observed that the condensed tannins and phenolic compounds in faba beans give the seeds the exist coat color.

3.2. Proximate chemical composition

Table 2 summarizes the proximate chemical composition of different faba bean varieties. All faba bean varieties had a higher protein content, and NA 112 faba bean had the highest protein content, followed by Giza 716 (27.63 and 27.16%, respectively). A comparison of six varieties of faba bean indicated non significant differences among samples in fat content (1.75-1.86%) and ash content (3.03-3.48%), while crude fibers content showed significant differences. Sakha 4 had a higher crude fibers content (7.31%) in comparison to other varieties, while NA 112 had the lowest value (5.90%). The carbohydrate content of the varieties is not significantly different (60.74-62.21%). Giza 716 and Sakha 1 had the highest potassium content (1595.82 and 1540.58 mg/100 g, respectively). Sakha 1 was the highest variety in phosphorus (401.82 mg/100g), while NA 112 was the highest in iron and zinc (5.76 and 3.96 mg/100g, respectively), and this may be attributed to the variation in genetic and environmental factors. The results for proximate chemical composition are partially close to those of

Table 1: Physical characteristics of faba bean varieties.

Varieties	100-kernels weight (g)	Density (g/cm^3)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Color parameters		
						*L**	*a**	*b**
Sakha 1	98.02^{b}±3.75	1.19^{a}±0.03	16.46^{b}±0.73	12.44^{b}±0.36	6.33^{a}±0.35	49.28^{c}±0.85	9.73^{d}±0.94	26.89^{c}±0.85
Sakha 4	94.50^{b}±5.23	1.16^{a}±0.05	16.71^{b}±0.07	12.33^{b}±0.46	6.41^{a}±0.51	46.57^{d}±0.59	11.91^{c}±0.31	24.69^{d}±0.41
Giza 3	85.31^{c}±0.85	1.20^{a}±0.04	16.32^{b}±0.39	12.35^{b}±0.42	6.17^{a}±0.11	52.86^{b}±1.77	6.81^{e}±0.37	28.05^{b}±0.64
Giza 716	97.01^{b}±0.87	1.17^{a}±0.05	16.27^{b}±0.17	12.09^{b}±0.27	6.37^{a}±0.41	64.76^{a}±0.39	5.56^{f}±0.25	29.77^{a}±0.26
NA 112	98.68^{b}±0.12	1.16^{a}±0.06	15.85^{b}±0.53	11.88^{b}±0.50	6.32^{a}±0.14	24.83^{f}±0.38	15.13^{a}±0.32	4.40^{e}±0.11
Santa Mora	161.39^{a}±2.23	1.14^{a}±0.02	21.69^{a}±0.59	15.30^{a}±0.23	6.28^{a}±0.08	27.44^{e}±1.10	12.99^{b}±0.24	1.98^{f}±0.09

*L**= lightness, *a**= redness, and *b** = yellowness. Data are presented as means (n=3)± SD, and different letters in the same column are significantly different at p≤ 0.05.

Table 2: Proximate chemical composition of raw faba bean varieties (%)*.

Varieties	**Sakha 1**	**Sakha 4**	**Giza 3**	**Giza 716**	**NA 112**	**Santa Mora**
Moisture	9.27^{c}±0.06	9.62^{ab}±0.13	9.85^{a}±0.09	9.72^{a}±0.17	9.43^{bc}±0.19	9.87^{a}±0.15
Protein*	26.97^{ab}±0.42	26.51^{b}±0.53	26.64^{ab}±0.13	27.16^{ab}±0.54	27.63^{a}±0.36	26.86^{ab}±0.37
Fat*	1.83^{a}±0.07	1.76^{a}±0.06	1.86^{a}±0.07	1.83^{a}±0.06	1.75^{a}±0.19	1.77^{a}±0.09
Ash*	3.03^{b}±0.35	3.43^{a}±0.05	3.09^{b}±0.03	3.48^{a}±0.11	3.16^{ab}±0.21	3.45^{a}±0.04
Crude fiber*	6.99^{b}±0.23	7.31^{a}±0.17	6.20^{cd}±0.10	6.79^{b}±0.15	5.90^{d}±0.12	6.25^{c}±0.24
Carbohydrates*	61.18^{a}±1.57	60.99^{a}±0.71	62.21^{a}±0.33	60.74^{a}±0.84	61.56^{a}±0.83	61.67^{a}±0.60
Minerals (mg/100g)*						
Potassium	1540.58^{b}±3.67	1236.70^{e}±13.56	1202.67^{f}±12.0	1595.82^{a}±6.63	1264.90^{d}±1.09	1431.96^{c}±10.51
Phosphorus	401.82^{a}±1.57	375.84^{b}±1.53	363.55^{c}±4.29	362.52^{c}±5.56	312.08^{e}±3.09	340.80^{d}±8.70
Iron	5.00^{b}±0.45	4.51^{b}±0.06	3.19^{c}±0.07	4.93^{b}±0.86	5.76^{a}±0.06	5.03^{b}±0.03
Zinc	3.66^{a}±0.21	3.81^{a}±0.61	2.66^{b}±0.03	3.62^{a}±0.29	3.96^{a}±0.77	3.41^{ab}±0.04

*% on dry weight basis. Data are presented as means (n=3)± SD and different letters in the same row are significantly different at p≤ 0.05.

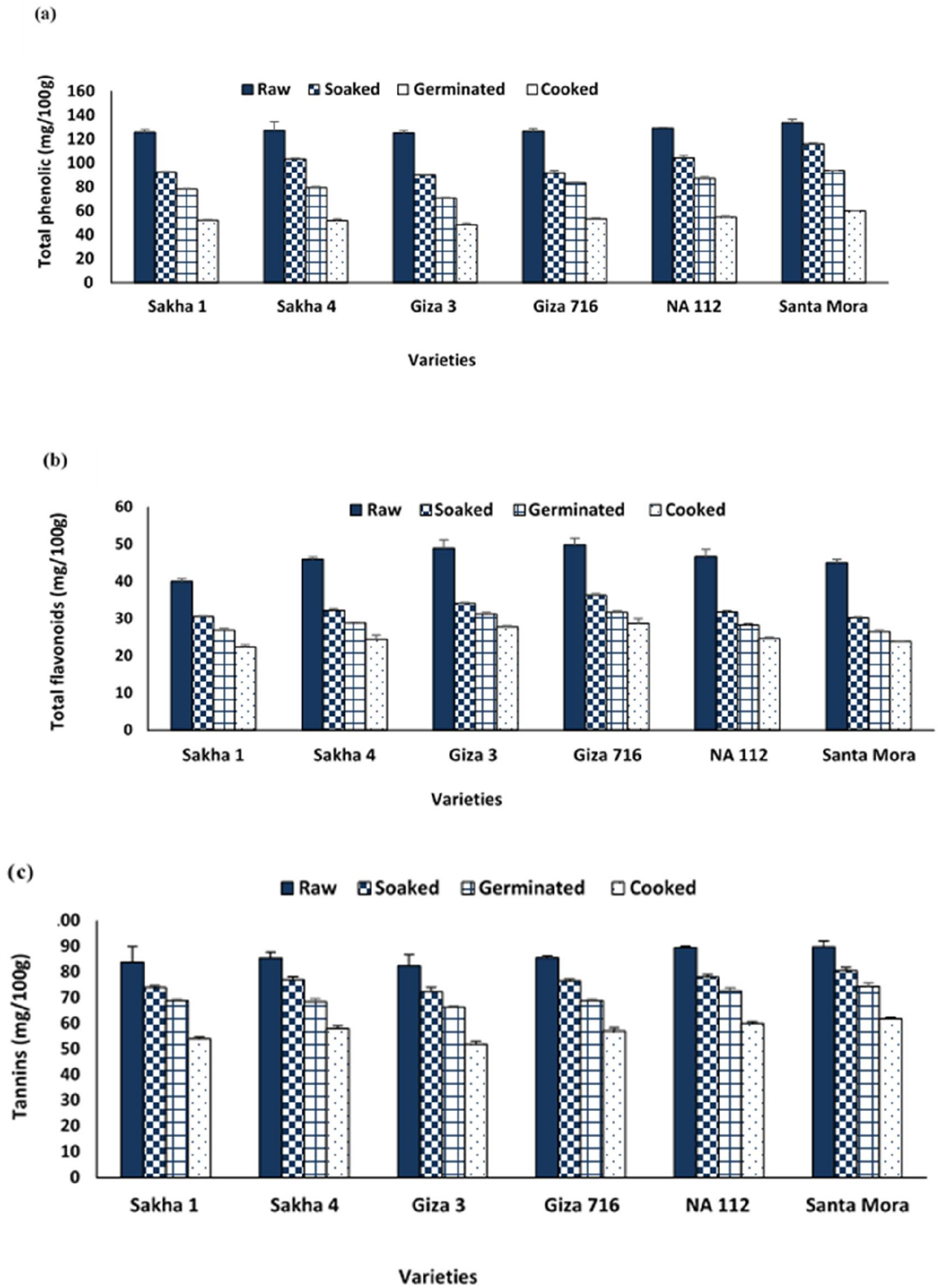
Coda *et al.* (2015) who analyzed the nutritional composition of faba beans. Faba bean contains between 20 and 41% protein; and this is due to the variation in faba bean varieties, genotype, planting site, and season (Rahate *et al.*, 2021). Yassen *et al.* (2022) found that different faba bean varieties and genotypes varied in chemical composition and contained 24.60-30.68% of protein, 1.54-2.70% of fat, and 1.38-4.16% of ash. Regarding the USDA (2019), the raw faba bean seeds contain 26.12% protein, 1.53% fats, 3.08 ash, 58.29% carbohydrates, 1062.0 potassium, 421.0 phosphorus, 6.70 iron, and 3.14 mg/100g zinc. Baloch *et al.* (2014) observed that potassium, phosphorus, iron, and zinc of different faba bean varieties ranged between 450.0 and 1930.0, 124.0 and 489.0, 2.97 and 9.63, and 1.04 and 4.93 mg/100 g, respectively.

3.3. Phytochemicals and antioxidant activity of the fab bean varieties

The phytochemical contents (total phenolic, total flavonoids, tannins, and anthocyanin) and antioxidant activity of six faba bean varieties before and after different processing methods are shown in Figure 2. Regarding the theory that phenolic compounds have free-radical properties and faba bean varied in phenolic content, the highest total phenolic content in raw seeds was in Santa Mora (133.54 mg/100g as gallic acid), followed by NA 112 (129.23 mg/100g as gallic acid), while the lowest was for Giza 3 (125.17 mg/100g). The results indicated significant differences in flavonoids content between different varieties. The highest flavonoids content was in Giza 716 (49.83 mg/100g as catechin), while the lowest content was in Sakha 1 (40.00 mg/100g as catechin). There were non-significant ($p>0.05$) differences among varieties in the tannins content. The anthocyanins content in different varieties is significantly different ($p<0.05$), and the highest value was 9.25 mg/100g in Santa Mora, followed by NA 112 (8.18 mg/100g). Regarding antioxidant activity, the results revealed that faba bean varieties contain 44.62-55.18% antioxidant activity as DPPH.

Osman *et al.* (2020) and Choi *et al.* (2023) observed significant correlations among total phenols, tannins content, and antioxidant activity levels. According to Kwon *et al.* (2018) and Shetty *et al.* (2001), L-DOPA helps to prevent oxidative damage to the seeds because it has antioxidant properties. Johnson *et al.*, (2020) found that different colored faba bean varieties have 21.0 to 65.0 mg/100g of tannins. Baginsky *et al.* (2013) reported that different seed coat colors (including brown, beige, red, violet, and black) in different varieties affect the tannin content of faba bean seeds, and it is influenced by genotype and environmental conditions.

However, the phytochemical content decreased after different processing methods, and the rates of losses varied depending on the type of process. Likewise, the major influence on phytochemicals and antioxidant activity was observed during the cooking process (the loss ranged from 57.70-61.38%, 42.49-47.19%, 31.28-35.58%, 82.39-85.35%, and 67.92-70.87% for total phenolic, flavonoids, tannins, anthocyanins, and antioxidant activity, respectively). Kumari (2023) and Osman *et al.*, (2012) observed that traditional techniques including soaking, germination, dehulling, cooking or boiling, and roasting have an impact on bioactive compounds. Ramakrishna *et al.* (2006) observed that the decrease in polyphenol compounds during soaking and boiling processes may be due to leaching out into soaking or cooking water along the concentration gradient. The decrease in polyphenol content, and antioxidant activity during the germination process may be caused by the polyphenol oxidase-based enzymatic hydrolysis (Singh *et al.*, 2014). According to Xu and Chang (2009), anthocyanins are heat-sensitive; their breakdown during thermal treatments may be the cause of their loss. Besides, cooking process was related to a lesser antioxidant activity due to the decrease in phytochemicals. Various thermal processing techniques, including roasting, cooking, and extrusion, have been employed in an attempt to enhance the use of faba beans by minimizing their antinutritional characteristics (Liu *et al.*, 2017).


(a)
Raw
Soaked
Germinated
Cooked
Total phenolic (mg/100g)
160
140
120
100
80
60
40
20
0
Sakha 1
Sakha 4
Giza 3
Giza 716
NA 112
Santa Mora
Varieties
(b)
Raw
Soaked
Germinated
Cooked
Total flavonoids (mg/100g)
60
50
40
30
20
10
0
Sakha 1
Sakha 4
Giza 3
Giza 716
NA 112
Santa Mora
Varieties
(c)
Raw
Soaked
Germinated
Cooked
Tannins (mg/100g)
.00
90
80
70
60
50
40
30
20
10
0
Sakha 1
Sakha 4
Giza 3
Giza 716
NA 112
Santa Mora
Varieties

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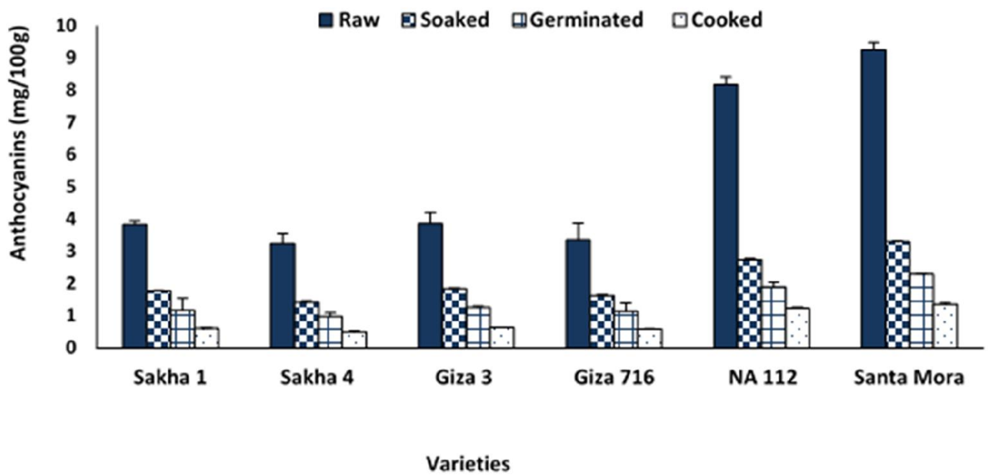
(d)



(e)

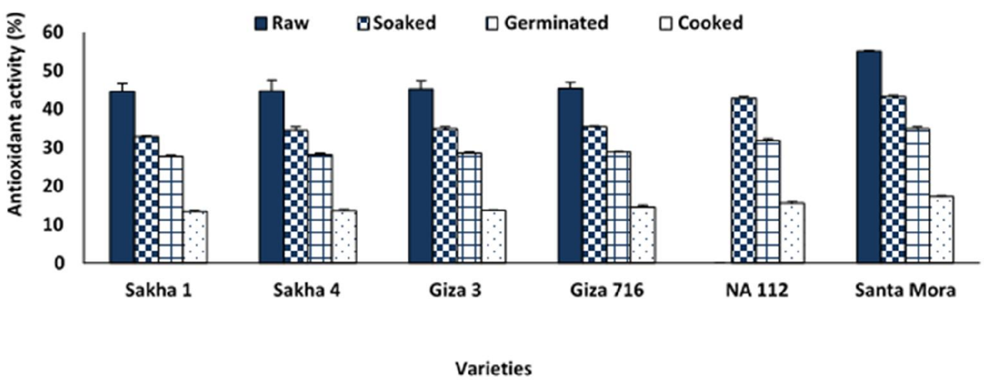


Fig. 2: Phytochemicals content [total phenolic as gallic acid equivalent (a), flavonoids as catechin equivalent (b), tannins as catechin equivalent (c), anthocyanins (d)], and antioxidant activity percentage (radical scavenging percentage) as DPPH (e) of faba bean varieties before and after different processing (on dry weight basis). Data are presented as means (n=3) ± SD.

3.4. Phenolic acids and flavonoids compound identified in faba bean varieties

Table 3 presents the identified phenolic and flavonoid compounds in faba bean varieties (whole meal) using HPLC. The results cleared that pyrogallol was the highest among all phenolic acid compounds, and Giza 716 had the highest content, followed by Santa Mora and Sakha 1 (7.86, 5.91, and 5.08 mg/100g, respectively). Meanwhile, the NA 112 variety had the highest content of caffeic acid (7.79 mg/100g). Besides, ellagic acid ranged between 1.82 and 4.72 mg/100g, and Santa Mora had the highest content, followed by NA 112. Likewise, for flavonoid compounds, catechin was the predominant compound among all flavonoid compounds and varied from 2.63 to 8.50 mg/100g. Sakha 1 and Santa Mora varieties had the highest catechin content, while Giza 716 had the lowest value. Naringin was the second highest flavonoid compound in all faba bean varieties (ranging between 2.30 and 4.84 mg/100g), and Giza 716 had the highest content, followed by Giza 3. The results for identifying the phenolic acids and flavonoids follow those found by Amarowicz and Shahidi (2018). Kwon *et al.* (2018) and Badjona *et al.* (2023) identified several bioactive phytochemicals in faba bean, including caffeic acid, ferulic acid, vanillic acid, quercetin, apigenin, luteolin, and kaempferol. Badjona *et al.*

(2023) and Bibi *et al.* (2022) observed that the presence and concentration of phenolic and flavonoid compounds in plants varied depending on the environment (e.g., soil composition and climate factors), and genetic factors. The faba bean growing location may have a negligible impact on their content of phenolic acids.

Table 3: Identification of phenolic acid and flavonoid compounds in raw faba bean (mg/100g).

Compounds	Sakha 1	Sakha 4	Giza 3	Giza 716	NA 112	Santa Mora
			Phenolic acid compounds			
Pyrogallol	5.08	2.31	4.76	7.86	2.21	5.91
Gallic acid	0.83	0.81	0.78	0.57	0.63	0.54
***p*-Hydroxybenzoic acid**	2.63	1.14	1.63	2.95	1.53	1.10
4-Aminobenzoic acid	0.83	1.45	1.61	0.94	0.92	0.67
Catechol	1.59	2.77	1.90	1.95	2.45	1.74
Caffeic acid	2.80	4.69	2.70	5.48	7.79	2.44
Vanillic	2.18	3.66	2.30	2.80	3.38	1.70
Caffeine	3.79	4.45	4.50	4.70	5.57	3.14
Ferulic acid	1.77	1.33	1.10	1.49	0.96	2.18
Benzoic acid	2.84	4.33	3.37	2.58	2.10	3.89
Ellagic	2.93	2.28	1.82	2.12	3.01	4.72
Coumarin	1.10	1.76	1.38	1.06	1.04	1.04
			Flavonoid compounds			
Catechin	8.50	7.21	6.51	2.63	5.52	8.28
Rutin	0.51	0.61	0.67	0.51	0.66	0.62
Kaempferol	0.14	0.54	0.38	0.34	0.22	0.52
Apigenin	0.42	0.51	0.24	0.15	0.15	0.23
Naringenin	0.32	1.20	0.64	0.69	0.67	0.58
Quercitrin	0.43	0.893	0.96	0.80	0.90	1.03
Quercetin	0.65	0.56	1.28	0.55	0.82	0.56
Naringin	2.30	2.49	3.97	4.84	2.61	2.66
Apigenin-7-*O*-glucoside	0.49	0.67	0.54	0.66	0.32	0.27
Rosmarinic acid	0.70	1.30	0.62	0.62	0.76	0.54

3.5. Total vicine and L-DOPA before and after different technological processing

Figure 3 presents the total vicine and L-DOPA content in faba beans before and after processing methods. Total vicine in raw faba bean was non-significantly ($p>0.05$) different between faba bean varieties and varied between 10.27 and 11.09 mg/g, and Sakha 1 had the highest total vicine content (11.09 mg/g), while NA 112 was the lowest (10.27 mg/g). Concerning the processing methods, the total vicine significantly decreased in all faba beans varieties. The cooking treatment had the highest loss (29.41-42.38%), and Sakha 1 was the highest. Etemadi *et al.* (2018) mentioned that faba beans accumulate a large amount of L-3,4-dihydroxyphenyl-L-alanine (L-DOPA), and cooking process reduces its amount by around 50%. Hendawey and Younes (2013) found that some Egyptian faba bean varieties contain 8.55 to 13.98 mg/g of total vicine. Abd Allah *et al.* (1988) observed that raw faba bean seeds contain 16.98 mg/g of total vicine, while soaked faba bean contains 12.15 mg/g on the dry weight. Duc *et al.* (1989) observed that fully cooked faba beans usually reduce the incidence of favism.

In terms of L-DOPA in raw faba beans of the current study, it ranged from 10.77 to 14.43 mg/100g as catechol equivalent while, Santa Mora had the highest level (14.43 mg/100g), followed by NA 112 (14.00 mg/100g), Giza 716 (13.47 mg/100g), and Sakha 4 (13.12 mg/100g). The lowest content was observed in Sakha 1 (10.77 mg/100g). All varieties showed a considerable decrease in the content of L-DOPA with regard to different processing methods (soaking, germination, and cooking processes). The highest loss percentage occurred in the cooking treatment (38.44-51.64%), and NA112 showed the highest loss. Cardador-Martínez *et al.* (2012) and Jakubczyk *et al.* (2019) found that the amount of total vicine and L-DOPA in faba beans varies depending on the variety and is affected by the thermal processing method. Boiling and cooking treatments had a significant reduction in the total vicine of faba bean varieties, and the decrease in L-DOPA by boiling was 16%.

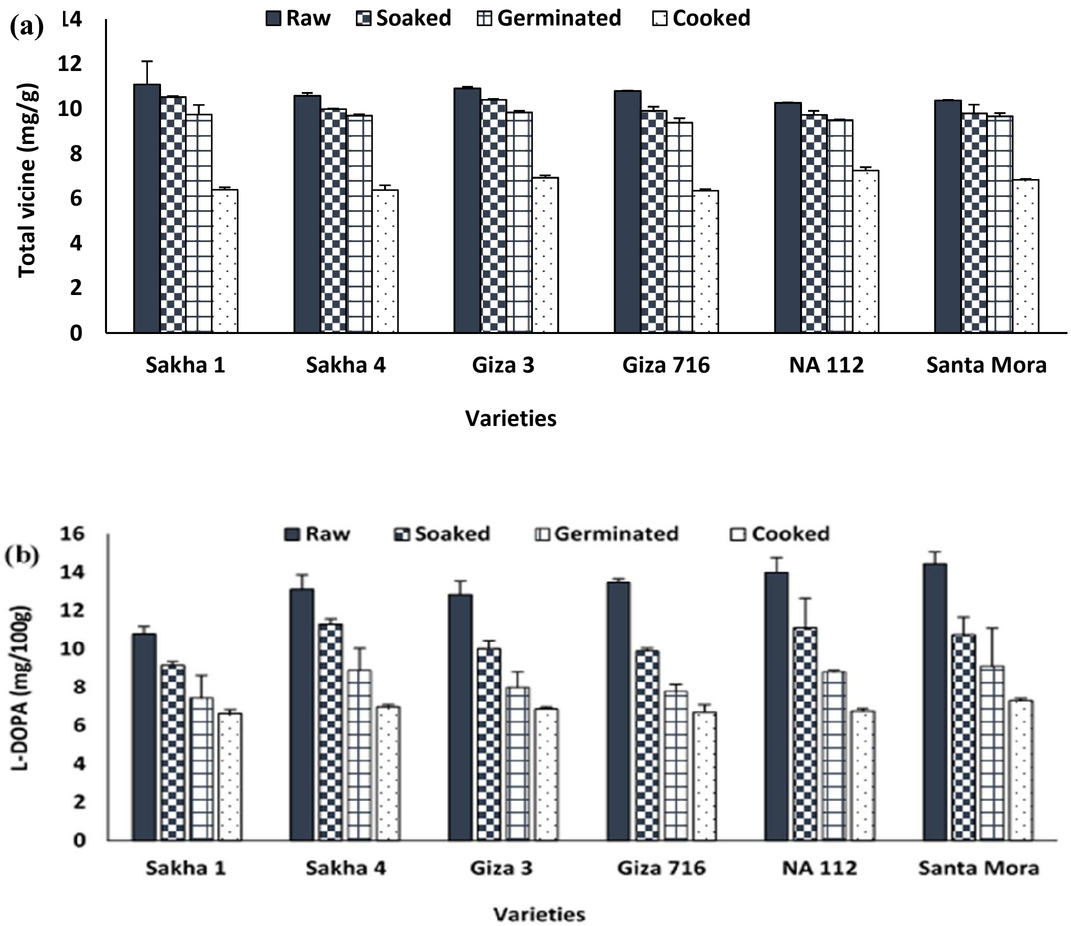


Fig. 3: Total vicine (a) and L-DOPA (b) of faba bean varieties before and after treatments (on dry weight basis). L-DOPA= L-3,4-Dihydroxy phenyl alanine. Data are presented as means (n=3)± SD.

3.6. Technological characteristics

3.6.1. Imbibed water, hydration coefficient and seed parts after soaking

Table 4 shows the water absorption (imbibed water), hydration coefficient, and seed parts of faba beans after soaking for 12 hours. Data revealed that the variety affected the water absorption and hydration coefficient. The water absorption percentages of different varieties were significantly different. It ranged from 82.74 to 97.57%, and the NA 112 variety had the highest value, followed by Santa Mora (97.57% and 96.19%, respectively), while Sakha 4 and Giza 3 had the lowest value. In terms of the hydration coefficient, it varied between 182.61 and 197.57%, and the NA 112 variety had the highest value, followed by Santa Mora (197.57% and 196.19%, respectively). Abdel-Aleem *et al.* (2019) observed that the water absorption percentages of faba beans ranged from 76.96 to 88.17% after 12 hours of soaking.

Data in the same Table indicated that there were differences among varieties in cotyledons, seed coat percentages, and cotyledon/seed coat ratio (C/H). The Santa Mora variety was the highest cotyledon percentage (86.97%) and C/H ratio (6.68), while Sakha 4 was the highest seed coat percentage (13.76%). Mahgoup *et al.* (2019) reported that faba beans had a 83.30% cotyledon percentage, 11.45% seed coat percentage, and a 7.28 C/H ratio.

Table 4: Water absorption, hydration coefficient and seed parts after soaking.

Varieties	Water absorption (%)	Hydration coefficient (%)	Cotyledons (%)	Seed coat (%)	Cotyledons/seeds coat ratio
Sakha 1	$92.69^{b}\pm4.07$	$192.67^{bc}\pm4.04$	$86.61^{ab}\pm0.06$	$13.39^{ab}\pm0.05$	$6.47^{ab}\pm0.03$
Sakha 4	$84.23^{c}\pm2.77$	$184.02^{d}\pm2.71$	$86.24^{b}\pm0.54$	$13.76^{a}\pm0.55$	$6.27^{b}\pm0.28$
Giza 3	$82.74^{c}\pm0.26$	$182.61^{d}\pm0.54$	$86.71^{ab}\pm0.53$	$13.29^{ab}\pm0.54$	$6.53^{ab}\pm0.30$
Giza 716	$92.79^{b}\pm1.51$	$191.28^{c}\pm0.15$	$86.55^{ab}\pm0.50$	$13.45^{ab}\pm0.51$	$6.44^{ab}\pm0.28$
NA 112	$97.57^{a}\pm1.06$	$197.57^{a}\pm1.06$	$86.77^{ab}\pm0.10$	$13.23^{ab}\pm0.10$	$6.56^{ab}\pm0.06$
Santa Mora	$96.19^{ab}\pm0.04$	$196.19^{ab}\pm0.22$	$86.97^{a}\pm0.17$	$13.03^{b}\pm0.17$	$6.68^{a}\pm0.10$

Data are presented as means (n=3)± SD, and different letters in the same column are significantly different at $p\leq 0.05$.

3.6.2. Cooking quality

The cooking quality of the whole faba bean seeds, is usually evaluated by consumers according to their suitability for the final used product. Table 5 shows the cooking quality of the faba bean varieties. Giza 716 had the highest value in imbibed water (185.37%), followed by Sakha 4 (184.76%), and Giza 3 had the lowest value (176.29%). The stewing percentages varied from 80.00 to 95.00%. Sakha 4 and Giza 716 had the highest stewing values, while Giza 3 and NA 112 had the lowest. Concerning the total soluble solids (%), results cleared, also, that total soluble solids ranged from 7.37 to 8.37%, and were non significantly difference ($p>0.05$) among varieties except for the NA 112 variety. The imbibed water (water absorption) percentage of cooked faba bean seeds ranged between 125.20 and 157.10% (Abdel-Aleem *et al.*, 2019). According to Nzewi and Egbuonu (2011), boiling process affects the faba bean stewing by improving the tenderization of the cotyledon.

Table 5: Cooking quality of faba bean varieties.

Varieties	Imbibed water (%)	Stewing (%)	Total soluble solids (%)
Sakha 1	$177.00^{b}\pm2.95$	$85.00^{b}\pm5.00$	$8.12^{a}\pm0.82$
Sakha 4	$184.76^{a}\pm4.96$	$95.00^{a}\pm5.00$	$8.37^{a}\pm0.33$
Giza 3	$176.29^{b}\pm1.92$	$80.00^{b}\pm0.00$	$8.16^{a}\pm0.02$
Giza 716	$185.37^{a}\pm4.16$	$95.00^{a}\pm5.00$	$8.31^{a}\pm0.28$
NA 112	$181.60^{ab}\pm1.22$	$83.33^{b}\pm2.89$	$7.37^{b}\pm0.23$
Santa Mora	$184.04^{a}\pm2.94$	$93.33^{b}\pm5.77$	$7.66^{ab}\pm0.36$

Data are presented as means (n=3)± SD, and different letters in the same column are significantly different at $p\leq 0.05$.

3.7. Sensory evaluation of cooked faba beans

The sensory quality of the cooked faba bean seeds (*i.e.,* color, texture, taste, odor, and overall acceptability) was evaluated to define consumer acceptability (Table 6). The data revealed that there were significant differences in all sensory parameters among varieties except for odor values, which were non-significantly different among all varieties. Sakha 1, Sakha 4, and Giza 716 recorded the highest sensory acceptability with regard to color, texture, taste, odor, and overall acceptability. The results revealed that the values of color, taste, and overall acceptability in the NA 112 and Santa Mora varieties were lower compared with other varieties. The lower acceptability of NA 112 and Santa Mora may be due to their darker color. The results are in line with those of Abdel-Aleem *et al.* (2019), who evaluated the sensory quality of faba bean seeds. Karatas *et al.* (2017) mentioned that the consumption of the faba bean with its seed coat is advisable, because the seed coat is a good source of phenols, dietary fibers, and minerals. The thermal processes of pulses, like boiling, could enhance tenderization of the cotyledons by increasing palatability and nutritional value (Nzewi and Egbuonu, 2011). Liu *et al.* (2017) observed that cooking, and extrusion, have been enhanced the use of faba beans by minimizing their beany taste.

Table 6. Sensory evaluation of faba beans varieties.

Varieties	Color	Texture	Taste	Odor	Over all acceptability
Sakha 1	$8.35^{a}\pm0.41$	$8.00^{a}\pm0.88$	$8.20^{a}\pm0.89$	$8.30^{a}\pm0.79$	$8.35^{a}\pm0.62$
Sakha 4	$8.15^{a}\pm0.67$	$8.20^{a}\pm0.71$	$8.40^{a}\pm0.81$	$8.55^{a}\pm0.47$	$8.45^{a}\pm0.37$
Giza 3	$8.10^{ab}\pm0.46$	$7.30^{b}\pm0.41$	$7.70^{ab}\pm0.79$	$8.35^{a}\pm0.78$	$7.70^{b}\pm0.42$
Giza 716	$8.30^{a}\pm0.35$	$8.00^{a}\pm0.58$	$8.25^{a}\pm0.49$	$8.75^{a}\pm0.35$	$8.30^{a}\pm0.59$
NA 112	$7.50^{c}\pm0.82$	$7.15^{b}\pm0.47$	$7.25^{b}\pm0.59$	$8.30^{a}\pm0.48$	$7.40^{b}\pm0.94$
Santa Mora	$7.65^{bc}\pm0.24$	$8.00^{a}\pm0.74$	$7.35^{b}\pm1.03$	$8.35^{a}\pm0.44$	$7.55^{b}\pm0.60$

Data are presented as means (n=10)± SD, and different letters in the same column are significantly different at $p\leq 0.05$.

4. Conclusions

In conclusion, the varied phytochemical compounds, quality attributes, and protein content of faba bean varieties may affect faba bean consumption and cultivation chances. The contents of L-DOPA in faba bean seeds across various raw and processed seed varieties may help Parkinson's disease patients find natural and affordable sources of L-DOPA in their daily meals. The most acceptable variety with higher-quality features was the Giza 716, followed by the Sakha 4. In terms of colored varieties, Santa Mora, followed by NA 112 varieties, showed the highest phytochemical content and antioxidant activity. Evaluating the quality of the seeds is critical to reduce seed importation. Generally, collaboration with faba bean breeders will help in variety selection that is vicine-free or has higher L-DOPA content.

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