Egypt. J. Food. Sci. **Vol. 47,** No. 1, pp.11- 26 (2019)

Egyptian Journal of Food Science
http://ejfs.journals.ekb.eg/

Evaluation of Egyptian Chia (*Salvia hispanica* L.) Seeds, Oil and Mucilage as Novel Food Ingredients

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DUE to the great potential of chia (*Salvia hispanica* L.) seeds as a new promising food, this investigation was carried out to characterize the Egyptian chia seeds comparing with an imported one. Physical, chemical and technological properties of both seeds were determined. The results showed that the local chia seeds had slightly higher length, width, lightness (L*), redness (a*), yellowness (b*) , kernel percentage and relatively smaller seed index, thickness, bulk density and hull percentage than imported one. The content of lipids (~34%), proteins (~24%), crude fiber (~20%), mucilage (~7%) was relatively higher, ash (~4.5%) and nitrogen free extract (~9%) was slightly lower in imported than local chia seeds. Caloric value of both seeds was nearly similar, 522 kcal/100 g. Potassium, phosphorus and copper value was higher and sodium, zinc, manganese, magnesium and iron content was lower in imported than local chia seeds. The crude oil of both seeds had amber color, clear appearance, nearly the same constants and separated by TLC technique into identical seven classes and triglyceride groups. The major oil class was triglycerides and the main triglycerides were the nine double bonds group. Up to 80% of chia seed oil fatty acids was polyunsaturated mainly linolenic (~63%) and linoleic (~17 %) acids .Saturated to unsaturated and ω6 to ω3 fatty acids ratio's in chia seed oil were 1: 9.5 and 1: 3.5, respectively. Whole seeds and its flour, oil and mucilage were used in preparing cold and hot drinks, corn cake, biscuits, salad dressing, jam like product and jelly. The sensory characteristics of these products were well accepted by panelists.

Keywords: Chia seeds, Oil , Mucilage , Chia seed food products.

Inrtoduction

Nowadays lake of food security is one of the major world problems. Underutilized crops rich in essential nutrients may considered as an alternative to cover the shortage of staple ones and help in covering the food demand (Nandal and Bhardwaj, 2014 and Pearl & Burke, 2014). According to Dansi et al. (2012) chia seed is an underutilized and neglected crop. It is rich in nutrients with medicinal value, able to help in treating malnutrition and improve the health status of populations.

Chia plant (*Salvia hispanica* L.) belongs to Lamiaceae family, and Mexico and Guatemala as a native origin. It grows in light to medium clay and sandy soils and even in arid lands with good drainage. It is semi-tolerant to acid soils and drought. The leaves of the plant contain essential oils that act as insect repellents, thus chia can be grown without pesticides. The commercial yield per hectare is ranged from 500 to 600 kg of seeds with trading price varied from 800 to 1200 US $ per ton (Peperkamp, 2014 and Segura-Campos et al., 2014).

The seeds of this plant used for different purposes as a human food for about 5500 years with corn in Mexico and preparation of folk medicines in Southern California in USA

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Received:11/3/2019; accepted:23/6/2019
DOI: 10.21608/EJFS.2019.10416.1000

(Armstrong, 2004). It is now extensively used as a part of food in Mexico, Argentina, Chile, New Zealand, Japan, USA, Canada and Australia. It is considered as a safe food with no potentially harmful effects and widely utilized in baked goods, nutritional supplements, cereal bars, cookies, bread and snack products (Beltran-Orozco and Romero, 2003). According to European Food Safety Authority (EFSA) (2009) chia seeds do not cause any adverse allergenic, anti-nutritional or toxic effects. It is an oil seed (up to 32% oil content) rich in Omega-3 (ω3) fatty acids with good quality protein and high content of dietary fibers, vitamins, minerals and polyphenolic compounds (Bochicchio et al., 2015). European Economic Community released in 2013 usage of chia seeds as novel food ingredient for bakery products at addition level of 10% (Regulation 2013/50/EU).

Due to the great potential of chia seeds, this study was carried out to characterize the Egyptian chia seeds comparing with imported one to detect the influence of the location and environment conditions, evaluate its proximate composition, minerals content, mucilage, suitability as a primary oil crop and utilization in food purposes.

Materials and Methods

Materials

Chia seeds (Salvia hispanica L.*)*

Two types of black chia seeds were used in this study. The first was imported from USA, 2016 harvest. It was purchased from one commercial retail at Alexandria city, Egypt in November 2016. The second was locally produced in one private farm at El-Haddadeen city, El-Kalyobiya, Egypt, in November 2016. These seeds were locally produced by sowing the USA imported black chia, 2015 harvest, with 80% germination capacity at a seeding rate of 1.5 to 2 kg/acre. The seeds were grown in loamy soil in the period of November 2015 to April 2016. The seeds were not treated chemically prior to sowing and also with insecticides during growth. They were sown in drills with 5-10 cm deep in soil which has been leveled before cultivation. Before sowing, the soil was treated with super nitrate (100 kg/acre) fertilizer. At sowing, the seeds were planted in raws with 10 m long. The crop was irrigated 4 times at a rate of 15000 m^3/ acre. Rainfall was moderately occurred through end of December and first half of January and the mean of temperature was ranged from 18-24°C during growth of plant. All cultivation work was carried out manually. Seeds were manually harvested and their yield was 500 kg/acre. The harvested seeds were packed in polyethylene bags and stored under hygienic conditions.

Food ingredients

The following food ingredients were obtained from local market at Alexandria city, Egypt; 72% extraction wheat flour, corn flour, refined sunflower and corn oils, margarine, sugar, common salt, whole and skimmed dry milk powder, sugar can molasses (black strap), fenugreek grains, sesame, peanut, cinnamon park, lemon fruits, eggs, Dream jelly apple (Elborg for food industries, Co., Borg El-Arab city, Alexandria), dried lemon grass, vinegar (6%), an edible beef gelatin grade, processed cheese, baking powder and ammonium bicarbonate.

Chemicals

Most of the chemicals used in this investigation were purchased from El-Gomhouria Pharmaceutical Company and El-Nasr Pharmaceutical Chemical Company, Egypt.

Packing materials

Aluminum foil, trays, polyethylene bags, glass jars and bottles were purchased from local markets at Alexandria city, Egypt.

Methods

Physical and physicochemical methods

Triplicate random samples of 1000 chia seeds, cake and biscuit were weighed using Mettler Teledo AB 204 digital balance (±0.01 g sensitivity). The average of these triplicates was reported as the weight of 1000 seeds or seed index, cake and biscuit weight. Length, width and thickness and diameter of randomly taken 25 chia seeds and 10 biscuit pieces samples were measured using a digital micrometer with an 0.01 mm accuracy (Khattab, 2004). The hull and cotyledon were manually separated after soaking 100 g seeds in distilled water at a ratio of (1:20 w/v) at room temperature for 12 h, then dring at ambient conditions to a constant weight. Each fraction was weighed using Mettler Teledo AB 204 digital balance (±0.01 g) and percentage of each part was computed (William et al., 1988). The average weight of triplicate random samples of chia seeds required to fill 100 ml glass cylinder was determined and the bulk density as g/cm^3 was calculated (Ali, 1999). The color attributes (lightness L*, redness a* and yellowness b*) of chia seeds were evaluated by Hunter lab colorimeter ultra-scan VIS model (USA).The instrument was standardized during measuring with a black and a white tail (L*= 99.1, a*= -1.12 and b*= 1.26) (Santipanichwong and Suophanthanika, 2007). Total soluble solids (TSS) of chia seed drinks and jam like product was determined using the hand Atago refractometer at room temperature (23 ±2°C). pH values of the previous products were also estimated using a digital Toledo Mp 230 pH meter after dilution with distilled water (AOAC, 2003).The freeze–thaw stability of the isolated chia seed mucilage was tested following the methods employed by Tressler *et al*. (1968) and Baker and Rayas-Duarte (1998) using fifteen ml of 5% (w/w) solution of chia gel in water.

Chemical methods

The chia seeds were ground in a willy mill to pass through 60 mesh sieve (250 micron), filled in glass kilner jars and stored at 4°C until analysis. The chemical analysis of chia seeds was run in triplicate. Moisture content of chia seeds was determined by drying the samples at 130°C for 4 h. as described by Guiotto et al. (2013), while its crude oil content was determined using petroleum ether (40 - 60°C) in Soxhlet apparatus as stated by Amato et al. (2015). Total nitrogen was determined using the Kjeldahl method and crude protein content was calculated by multiplying the nitrogen content by factor of 6.25 (Nielson, 2010). Ash content was determined after pre-ashing in muffle furnace (Vulcan A-550) at 550ºC until getting light gray ash and a constant weight was resulted. The obtained ash was dissolved in 1:1 (v/v) hydrochloric acid: water ratio then filtered and adjusted to 100 ml in a volumetric flask. Sodium (Na) and potassium (K) were determined using flame photometer (Model PEP7, England), while iron (Fe), calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn) and zinc (Zn) were determined using Perkin Elmer Atomic Absorption Spectrophotometer (Model 2380) (Coorey et al*.,* 2014). Total phosphorus (P) was determined according to AOAC (2003). Crude fiber content was determined according to AOAC (2003) method via filter bags technology using Fiber analyzer (Ankom 200. Model No. A220, USA). Nitrogen free extract of chia seeds was calculated by difference. Caloric value was calculated from the Atwater coefficients, taking the caloric coefficients corresponding to proteins, carbohydrates and lipids, as shown in the below equation.

$$\text{Caloric value (kcal100/ g)} = (\text{g of protein} \times 4) + (\text{g of lipids} \times 9) + (\text{g of carbohydrates} \times 4)$$

Chia seeds oil were fractionated into different classes using 20 X 20 cm TLC plates coated with 0.25 mm thickness silica gel (Merk, G Type 60) and developing solvent system consisted of petroleum either (60-80°C): diethyl ether: glacial acetic acid (70:30:2 v/v). The oil classes were visualized by exposing to iodine vapor (Ali, 1999). Chromate-plates coated with a slurry of silica gel (Merk, G Type 60) in an aqueous silver nitrate, 20%, plates were dried and activated at 110°C for hour to use in fractionation of chia seed oil triglycerides using developing solvent consisted of toluene: diethyl ether (94: 6 v/v). The visualization of triglycerides was carried out by charring at 180°C for 10 min. (Ali, 1999). Aliquots of oil were saponified with methanolic KOH (0.5 M) for 5 min. at 100°C in tightly capped vial, then aqueous HCl/methanol (4:1 v/v) was added, heated for 15 min. at 100°C, cooled and extracted twice with petroleum ether. The organic phase was dried with anhydrous Na_2SO_4 and concentrated before determining fatty acid methyl esters by GLC analysis using a Toxichron GLC, model B-5 800-1 equipped with FID detector (PE Auto System XL) using 180 x 0.3 cm. column of DEGS on Chromosorb W and nitrogen gas at a flow rate of 40 ml/min. Analyses were conducted isothermally at 185°C (Taga et al., 1984). The relative density at 25°C, iodine value (IV), saponification value (SV) were determined as mentioned in AOAC (1990). The mucilage content of the chia seed was determined according to Woolfe et al. (1997) with some modifications. The chia seeds were submitted to mucilage extraction with water at a 1:20 ration (w/v) for 30 min. at 50°C. The obtained suspension was milled in a mixer and reheated at 50°C under continuous stirring for 15 min. then centrifuged at 4000 rpm. for 30 min. The supernatant containing gum layer was heated at 70°C for 5 min. to inactivate the enzymes and recentrifuged as mentioned before. The mucilage in the supernatant was precipitated with three volumes of ethanol 70%, washed with excess ethanol, dried at 40°C for 24 h., milled, weighed and the percentage of mucilage was calculated.

Technological methods

Cake making: The corn cake was prepared as described by Pizarro et al. (2013). The flours used for cake making was 100% corn flour and/or 95% corn flour with 5% whole chia seed flour. The basic formula of the cake was 100 g flour, 100 g sugar, 40 g whole fresh egg, 3.3 g baking powder, 70 g margarine, 11.2 g whole dry milk powder and 70 g water. The prepared dough was packed into aluminum pans and baked at 190°C for 40-45 min. in an electric oven (G.E.C. QA50QV I5A35OV). Cake was cooled and after 24 h. of baking, each of weight (g), volume (cm^3) and specific volume (cm^3/g) was determined.

Biscuits preparation: Both control and chia-enriched biscuits were prepared as mentioned by Mesías et al. (2016). The basic formula was formulated with wheat flour (130 g), sucrose (35 g), distilled water (30 g), sunflower oil (26g), sodium bicarbonate (0.8 g), ammonium bicarbonate (0.4 g) and salt (1 g). Two types of biscuits were prepared; control, free from chia seed flour and spraying with whole chia seeds at a ratio of 5% of wheat flour on the surface of biscuit dough. The dough was left for 60 min. before forming into bars and baking at 210°C for 8-10 min. After cooling biscuit was packed in polyethylene bags and after 24 h. of baking, biscuits weight, thickness, length and wide were measured as mentioned above.

Salad dressing: The following ingredients were used to prepare this product, 12.3% corn oil or mixture of 95% corn oil+ 5% chia seed oil, 15% vinegar (6%), 12% water, 8.9% egg yolk, 0.6% refined salt, 0.6% sugar, 2.2% Arabic gum, 32% processed chisster cheese, 0.4% white pepper and 16% skimmed milk powder. The method of Binsted *et al*. (1971) was utilized to prepare the gum base of chisster cheese dressing.

Drinks: The following drinks were prepared;

Chia seed lemon juice:- By soaking 6 g chia seeds in 100 ml water for one hour at room temperature (23± 2°C), before adding 2% sugar and 3 ml of the previous prepared filtered juice of washed, pressed fresh cut halves lemon fruits (Coorey et al*.,* 2014).

Chia seed cinnamon hot drink enveloped bag: Prepared by mixing the powder of both components at a ratio of 1:1 w/w in enveloped filter bags 2 g capacity. The drink was prepared by pouring 100 ml of fresh boiling water containing 2% sugar over one enveloped filter bag placed in a cup and allowed to infuse for 5 min. before drinking (Michele and Myriam, 2014).

Chia seed dried lemon grass and chia seed fenugreek hot drinks: Prepared as mentioned above using 1:1 w/w chia seed with each of whole dried lemon grass and/or fenugreek grains (Michele and Myriam, 2014).

Jam like products: It was prepared by adding (12.5%) wheat flour gradually into heated refined sunflower oil (6%) until wheat flour became red in color, then sugar cane molasses (black strap) (61.5% TSS) was added with continuous stirring for nearly 10 min. before adding fenugreek flour (12.5%) or mixture of chia seed and fenugreek flour at 1:1 w/w ratio with continuous stirring until get a thick consistency. Fried sesame (1.5%) and peanut (6%) were added to the hot cooked product with continuous stirring, cooled and filled in cleaned sterilized glass jars (Michele and Myriam 2014).

Jelly: Prepared by dissolving 70 g of Dream jelly apple in 250 ml boiled water with stirring then another 250 ml of cold water was added . The product was refrigerated for 4 h. at 4°C. This product was prepared before and after replacing gelatin with chia seed mucilage in apple jelly (Coorey et al*.,* 2014).

Sensory evaluation: The prepared chia seed products were subjected for sensory evaluation using ten panelists of the Food Science and Technology Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt. Each panelist was asked to evaluate the above properties according to the following methods; descriptive sheets to evaluate chia seed corn cake and chia seed biscuits according to Rendon-Villalobos et al. (2012) methods. Composite scoring test , in which the specific characteristics of product are rated separately according to their importance in quality attributes for chia seed products other than cake and biscuits. Within each product and according to the mean of the total score, the quality acceptance of each product was described excellent, very good , good and poor ,when total score was 90, 80, 70 and 60 , respectively (Ranganna, 1979).

Statistical analysis

Results of some analysis of local and imported chia seeds were analyzed for statistical significance at P≤ 0.05 by student's t-test using Statistical package for social sciences software (SPSS) version 22 (2018).

Results and Discussion

A. *Whole chia seeds*

1) *Physical properties and weight composition:* As shown in Fig. 1, both local and imported chia seeds were very small in size and had a dark color. The same observation was reported by Ixtaina et al. (2008). They stated that chia plant produces tiny seeds with dark and white color. Segura-Campos et al. (2014) mentioned that most of chia population that is commercially grown today contain a low percentage of white seeds. The shape of both local and imported chia seeds can be described oval or pear like (Fig. 1). But due to the flatness of the surface of local seed than imported one, the shape of first seed is appeared oblong or flattened obviate, (Fig. 1). Ixtaina et al. (2008) noticed that chia seed has three unequal semi-axes, therefore its shape may be described as being scalene ellipsoid.

Data in Table 1 reveal that the seed index (weight of 1000 seeds), length, width, thickness and bulk density varied from 1.1855 to 1.2043 g, 1.93 to 1.82 mm, 1.19 to 1.29 mm, 0.8 to 0.82 mm and 0.598 to 0.718 g/cm^3, respectively. The local chia seed had slightly higher length, width, relatively smaller seed index, thickness and bulk density than imported one. Such small variations may be attributed to the flatness of the surface of the local seeds. Generally, the determination of such seed biometry is an important for designing equipment for sowing, harvesting, storage and processing. It is also helping in estimating the storage capacity and transport system. Generally, the results of the dimensions of local and imported chia seeds agree with those found by Ixtaina et al. (2008), Hernandez (2012) and Pizarro et al. (2014). They stated that chia seeds are small in size with oval shape, 2-2.5 mm length, 1.2-1.5 mm width, 0.8-1 mm thickness, 1.11-1.227 g one thousand seed mass, 1.06-1.15 g/cm^3 true density and 0.7 to 0.72 g/cm^3 bulk density. Ixtaina et al. (2008) observed that the dimensions of chia seeds lie within the same range to those of quinoa and flaxseed.

The color attributes in Table 1 indicate that local chia seed had higher values of lightness (L*), redness (a*) and yellowness (b*) than imported one. Therefore, the color of local seeds can be described as a deep gray or beige with small dark spots. Meanwhile the imported seeds had a black or deep dark yellow color similar to that of dark coffee. Suleiman *et al.* (2015) showed that the lightness degree (L*), redness (a*) and yellowness (b*) of chia seed color differed from 41.3 to 42, 3.19 to 3.61 and 7.43 to 8.61, respectively. The levels of these color attributes increased with rise of seed moisture from 10 to 20%. Generally the color of chia seeds is a little bit black.

As seen from Table 1, the hull percentage represented up to 50% of the weight composition of chia seeds. It was higher in imported seeds than local ones. It is consisted of cuticle, exocarp, mesocarp, layers of scloroids and endocarp. According to Ixtaina et al. (2010) the thickness of chia hull was 13±0.41 µm. The hull's exocarp contains cells produce gum or mucilage when seeds get wet. Chia seed kernel ranged from 44.4 to 49%, Table (1). It was higher in local chia seed than imported one. It is composed of endosperm and ambryo forming from two cotyledons. It contains the major and minor store seed components, protein, oil, fibers, ash, carbohydrate, minerals, vitamins, enzymes, antioxidants…etc.

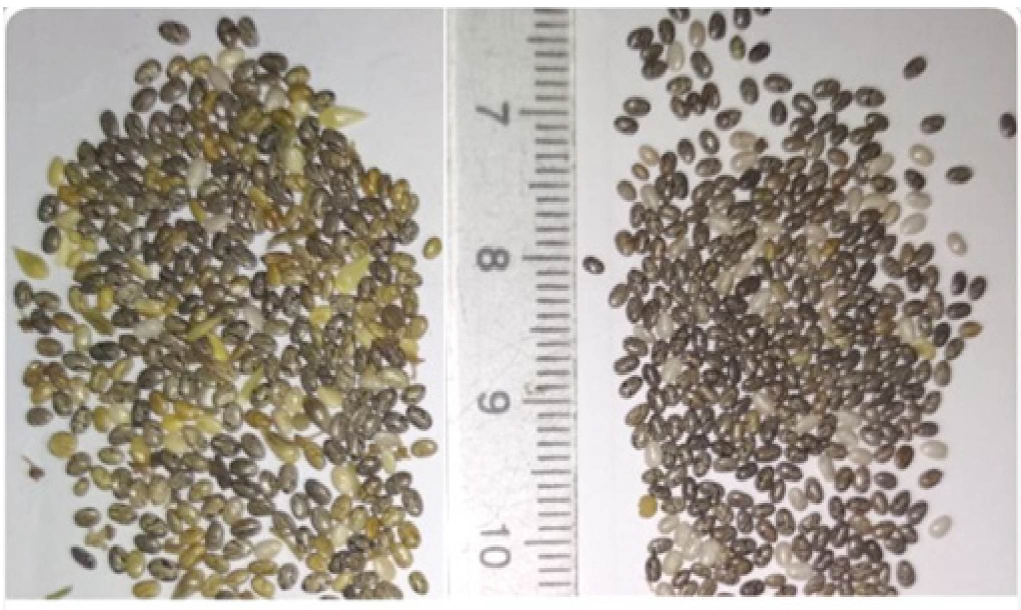

Fig. 1. Appearance of local and imported chia (*Salvia hispanica* L.) seeds.

TABLE 1. Physical properties and weight composition of chia (*Salvia hispanica* L.) seeds.

Property	Local chia	Imported chia
Seed index (g)	1.1855 ± 0.11	1.2043 ±0.06
Dimentions (mm)		
Length	1.93 ± 0.05	1.82 ± 0.02
Width	1.29 ± 0.00	1.19 ± 0.05
Thickness	0.80 ± 0.05	0.82 ± 0.04
Bulk density (g/cm³)	0.598^{b} ± 0.00	0.718^{a} ± 0.00
Color		
Lightness (L*)	50.92	48.53
Redness (a*)	2.47	1.99
Yellowness (b*)	8.09	5.10
Weight composition %		
Hull	50.6^{a}± 0.01	52.6^{b}± 0.01
Kernel	49.4^{a}± 0.01	47.4^{b}± 0.01

*Value with different superscripts within each row are significantly different at P≤0.05.

2) *Proximate composition and caloric value:* The data in Table 2 indicate that the moisture content of chia seeds was low (7.3 to 7.8%). This helps in keeping the quality of seeds during storage under proper condition. At this level of moisture, the micro-organisms growth and the biochemical reactions are usually inhibited. It is also increased from dry matter of chia seeds up to 90%. The lipid, protein, ash, crude fibers and nitrogen free extracts (other carbohydrate than fiber) ranged from 36.57 to 37.2, 26.1 to 27.89, 4.8 to 5.15, 22.22 to 24.31 and 5.8 to 9.96%, respectively in both local and imported chia seeds, (Table 2). The content of lipid, protein and crude fibers was relatively higher, ash and nitrogen free extracts was slightly lower in imported than local chia seeds. Lipid or fat represent the major compound of chia seeds followed by proteins then fibers, nitrogen free extracts and ash, respectively. Therefore, chia seed can be considered one of new oil seed sources. Generally, the results of proximate composition of either local or imported chia seeds were similar with those reported by other investigators such as Weber et al. (1991), Craig (2004), Ixtaina et al. (2008), Sandoval-Oliveros & Paredes- Lopez (2013), Goh et al. (2016) and Fernandes & Salas-Mellado (2017). They stated that chia seeds consisted of 30-33% oil, 15-25% protein, 26-41% carbohydrate high in dietary fibers (18-30%), 4-5% ash and 90-93% dry matter. According to European Food Safety Authority (EFSA) (2009) the dry matter, protein, fat, crude fiber, and ash of chia seeds ranged from 91 to 96, 12-21, 30-33, 19.4-30 and 4.6-5.2%, respectively according to environmental conditions, agricultural practice and locations than genetic type.

Both local and imported chia seed , had nearly similar caloric value (Table 2). This value varied from 562.25 to 566.8 kcal/100 g. It was higher than that reported by Michele and Myriam (2014), 519.9 kcal/100 g and agrees with that mentioned by Jin et al. (2012), 562 kcal/100 g. The high caloric value of chia seed is associated with its high level of lipids which are important source of fat soluble vitamins (A, D, E and K) and essential fatty acids.

3) *Mineral content:* As shown from Table 3 chia seed had high levels of phosphorus (769-814 mg/100 g), calcium (574-592 mg/100 g), potassium (323.79-535 mg/100 g), magnesium (287.4-296 mg/100 g) and low values of sodium (25.5 to 34.7 mg/100 g), iron (5.39 to 7.1 mg /100 g), zinc (3.76 to 5.19 mg/100 g), manganese (1.55-1.65 mg/100g) and copper (0.748 to 0.936 mg/100g). Among the macro elements, phosphorus was found in highest concentration followed by calcium and potassium. Within the micro elements, magnesium was only found in high level, while the other elements presented in trace amounts. Imported chia seed had higher values of potassium, phosphorus, copper, lower amount of sodium, calcium, zinc, manganese, magnesium and iron than local ones. These differences are mainly due to the production area, cultivation practices such as soil, fertilizers and irrigated water. The ratio between calcium to phosphorus was 0.75 in local and 0.70 in imported chia seeds. European Food Safety Authority (EFSA) (2009) reported the results of the analysis of the minerals as mg/100g of chia seed collected from Bolivia, Peru and Australia as following; 5-12.9 sodium, 660-809 potassium, 500-770 calcium, 6.3-9.9 iron, 325-396 magnesium, 600-780 phosphorus, 3.7-7.9 zinc, and 0.2-1.91 copper. Ullah et al. (2015) stated that chia seed contains 6, 11 and 4 times higher calcium, phosphorus and magnesium, respectively than 100 g milk. Calcium, phosphorus and potassium content of chia is many folds greater than wheat, rice and oat. Generally, the bioavailability of the seed minerals depends on the presence of some components which able to bind minerals such as phytate and the ratio between phytic acid and minerals particularly Ca and Zn.

4) *Mucilage:* Soaking chia seeds in water exudes a transparent mucilaginous gel. This gel remains strongly bonded to seed coat. This mucilage or gum is mainly composed of xylose, glucose and methyl glucuronic acid that form a branched polysaccharide of high molecular weight, ranged from 0.8 to 2×10^6 Dalton (Dick et al., 2015). Data in Table 3 refer that local and imported defatted chia seeds flour had 6.23 and 7.4% mucilage content, respectively. This lies in range reported by Michele and Myriam (2014), Goh et al. (2016) and Guiotto et al. (2016). Dick et al. (2015) reported that in 1996, chia mucilage was described by the Food and Agriculture Organization (FAO) as a potential source of polysaccharide gum due to its outstanding mucilaginous properties in water solution even at very low concentration. Therefore, chia mucilage can be employed in the food industry as a stabilizer, emulsifier, adhesive or binder due to its high water holding capacity and viscosity (Hernandez, 2012). Also, it can be used in the production of films, edible coating and capsules (Guiotto et al., 2016). Mucilage of chia seeds is easily fermented by colonic bacteria. It had high ability to retain water and to form gelatinous mass. This mass increases the viscosity of gastrointestinal contents and slows gastric emptying, providing great lubrication and volume of stool (Michele and Myriam, 2014).

TABLE 2. Proximate composition and total caloric value of chia (*Salvia hispanica* L.) seed.

Compound	Local chia		Imported chia	
	Wet basis	Dry basis	Wet basis	Dry basis
Moisture%	7.3	-	7.86	-
Lipid%	33.9 ± 0.17	36.57 ± 0.17	34.27 ± 0.02	37.2 ± 0.02
Protein%	24.2 ± 0.6	26.1 ± 0.6	25.7 ± 0.16	27.89 ± 0.16
Ash%	$4.77^a \pm 0.1$	$5.15^a \pm 0.1$	$4.45^b \pm 0.1$	$4.8^b \pm 0.1$
Crude fiber%	20.6	22.22	22.41	24.31
Nitrogen free extract%	9.23	9.96	5.31	5.8
Caloric value (kcal/100 g)	521	562.25	522	566.8

*Value with different superscripts within each row are significantly different at P≤0.05.

TABLE 3. Mineral and mucilage contents of chia (*Salvia hispanica* L.) seeds.

Mineral (mg/100g)	Local chia	Imported chia
Macro elements		
Potassium (K)	323.79	535
Sodium (Na)	34.7	25.5
Calcium (Ca)	592	574
Phosphorus (P)	796	814
Micro elements		
Copper (Cu)	0.748	0.936
Zinc (Zn)	5.19	3.76
Manganese (Mn)	1.65	1.55
Magnesium (Mg)	296	287.4
Iron (Fe)	7.1	5.39
Mucilage* (% on dry weight)	6.23	7.4

*Mucilage was determined in free oil chia seed flour.

B. *Chia seed oil*

Chia seeds contain more than 30% oil (Table 2). This amount of oil is more than that reported for some plant oil sources such as cotton seed (20-24% oil).

1) *Classes:* Figure 2 illustrates the TLC separation of crude chia seed oil classes. The oil of both local and imported chia seeds was fractionated into clear seven classes. These classes were, from origin to front, mono glycerides, 1,2 (or 2,3) diglycerides, free sterols, 1,3 diglycerides, free fatty acids, triglycerides and sterol esters and other hydrocarbons. According to the area and intensity of the seven separated classes, triglyceride represents the main components of both local and imported chia seed oils. The other classes appear faint and with small areas or concentrations. Results of Amato et al. (2015) indicated that the extracted oil content and its composition from Italian chia seeds did not quantitively significant different than imported one due to planting location.

2) *Triglycerides:* Figure 3 shows the TLC separation of triglycerides of the crude oils of both local and imported chia seed. This separation was carried out according the unsaturation degree or unsaturation bonds of triglycerides. Triglycerides of local and imported chia seed oil were fractionated into identical seven groups. The intensity of the separated groups was differed. It was highest in the separated group one followed by group 2 , 3 , 4 , 5 , 6 , and 7 , respectively, (Fig. 3). Ixtaina et al. (2010) found that Argentinian chia seed oil consisted of the following triglycerides; 33.8% Ln Ln Ln, 20.3% Ln Ln L, 13.8% Ln L L, 7.7% Ln Ln P, 1.1% L L S, 2.1% Ln O S and 1% Ln S P. The main triglycerides in this oil were Ln Ln Ln, Ln Ln L, and Ln L L. Timilsena et al. (2017) showed that the trilinolenin (Ln Ln Ln) was the most abundant triglycerides in chia seed oil. It was comprised 33.2% of the total triglycerides of chia seed oil. This means that chia seed oil is high in polyunsaturated fatty acids and sequentially has low oxidation stability. The important protection of chia oil is a critical factor to keep its quality (Guiotto et al., 2016).

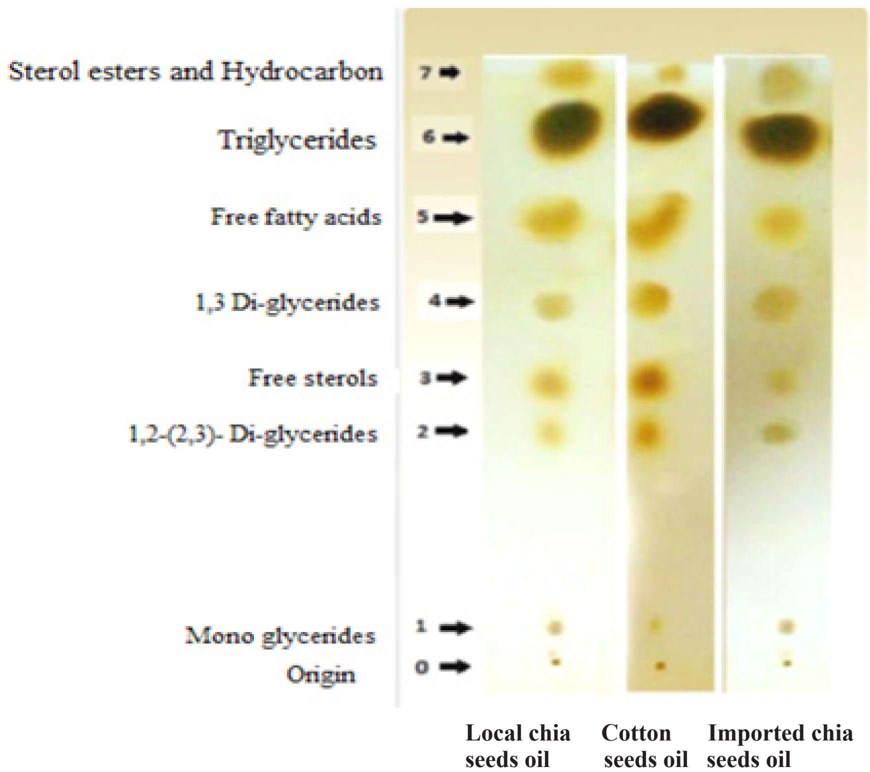

Fig. 2.TLC separation of chia (*Salvia hispanica* L.) seed and cotton seed oils classes.

Coating material: Silica Gel G Merck type 60.
Developing solvent: Petroleum ether: Diethyl ether: Glacial acetic acid (70:30:2 v/v)
Visualization: Iodine vapor

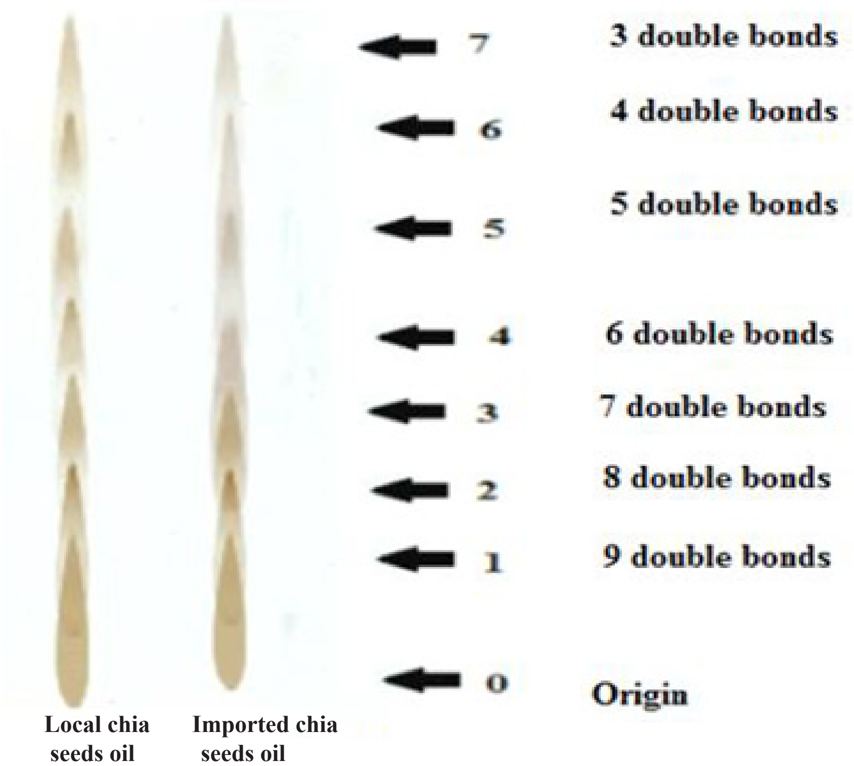

Fig. 3. $AgNO_3$ TLC of the triglycerides of chia (*Salvia hispanica* L.) seed oil.

Coating material: Silica gel- G 60- ($AgNo_3$)
Solving System: Toluene: Diethyl ether (94: 6 v/v).
Visualization: Charring

3) *Fatty acid composition:* Results in Table 4 reveal that up to 80% of fatty acid composition of chia seed oil was polyunsaturated fatty acids. Both ω3 linolenic acid (62.93-64.56%) and ω6 linoleic acid (16.77-20.67%) were the major components of chia seed oil. This oil contained oleic acid (6.03-6.35%), palmitic acid (6.3-7.15%), stearic acid (1.31-1.78%) and traces of other saturated fatty acids. Slight differences were noticed in fatty acid composition between both local and imported chia seed oil. The mean of ratio between saturated to unsaturated fatty acids and ω6 fatty acid to ω3 one was 1: 9.6 and 1: 3.5 in oil of both local and imported seeds, respectively. Timilsena et al. (2017) found that the ω3 to ω6 fatty acid ratio of Australian chia seed oil was 3:1. It is comparable to flaxseed oil and higher than fish oil. According to Ayerza (1995), Vázquez-Ovando *et al*. (2013) and Timilsena et al. (2017) among all natural oil sources, chia seed oil has the highest percentage of linolenic acid. Ayerza (2010) observed no significant variations in oil content and its fatty acid composition and ω6: ω3 fatty acid ratio between white and black spotted chia seeds. The same observation was mentioned by Amato et al. (2015) in oil extracted from Italian and Argentinian chia seeds. Ixtaina et al. (2011) reported that the high level of α-linolenic acid in chia seed oil is very appreciated for incorporation in preparing functional food. Presence of α-linolenic acid in high proportion in chia seed oil is important in cardiac and hepatic protection (Bochicchio et al., 2015).

4) *Identity characteristics:* The oil extracted from both local and imported chia seeds had a light amber color and clear appearance. Segura-Campos et al. (2014) showed that the color of chia seed had more yellow (70) than red (9.1) units. Results in Table 4 indicated that the relative density, iodine value and saponification index ranged from 0.9239 to 0.9241 at 20°C, 194.7 to 198.4 g I_2/100 g oil and 189.1 to 191.3 mg KOH/g oil in chia oil of both local and imported seeds. These values lie in the ranges reported by Segura-Campos et al. (2014) and Timilsena et al. (2017). Because chia seed oil contains high amount of unsaturated fatty acids its relative density was high. Generally, the relative density of chia seed was similar with that of sunflower (0.91), safflower (0.92) and soy (0.919) oils at 20°C (Segura-Campos et al., 2014).

The saponification index or value of chia seed oil was also similar with that of sunflower (188-194 mg KOH/g oil), soybean oil (189-195 mg KOH/g oil). It means also that chia seed oil contains lower proportion of short chain fatty acids like such oils. It is also expected the rise of iodine value of chia seed oil due to its content of unsaturated fatty acids particularly linolenic one, up to 60%. Therefore, this type of oil has higher iodine value than linseed or flaxseed oil (189), sunflower oil (141) (Timilsena et al., 2017). Ixtaina et al. (2012) and Ullah et al. (2015) found that crude chia seed oil has light amber color, 0.9358 relative density at 25°C, 193-174.8 mg KOH/g oil saponification value and 190-207 g I_2/100 g oil iodine value.

C. *Utilization in food purposes*

Whole seeds, oil and mucilage of local chia plant were used in preparing several types of functional or bioactive food products.

1) *Drinks:* Fresh lemon juice in 6% whole chia seeds infusion, hot drinks from a mixture of 1:1 w/w ratio of whole chia seeds flour with each of dried lemon grass, cinnamon and fenugreek grains in an enveloped filter bags were prepared. Lemon fruits, lemon grass, cinnamon and fenugreek grain were selected due to their health benefits and to their popularity in Egypt. Table 5 tabulated the TSS, pH and the averages score of the sensory characteristics of theses drinks as assessed by panelists. The results indicate that; TSS and pH values were differed among drinks according to water soluble matters of the raw material used in their preparation and the interaction with those in chia seeds. The panelists accepted all fresh and hot drinks containing chia seeds. Chia seeds addition affected the color and flavor (odor and taste) scores of such drinks. Such effects were less in hot drinks than fresh one. In the other hand the slight improves in consistency of the drinks due to use chia seed may contribute to the excretion of chia seed mucilage during preparing such drinks. According to Coorey et al. (2014) chia seed used in preparing drink known as an agua de chia or chia fresca in Mexico.

TABLE 4. Fatty acid composition and some identity characteristics of chia (*Salvia hispanica* L.) seed oil.

Constituent	Local chia	Imported chia
1-Fatty acid (%)		
Caprlyic acid C8:**0**	0.00	0.37
Lauric acid C12:0	0.24	0.24
Myristic acid C14:0	0.03	0.63
Palmitic acid C16:0	7.15	6.3
Stearic acid C18:0	1.78	1.31
Arachidic acid C20:0	0.00	0.62
Total saturated fatty acids	**9.20**	**9.47**
Tetradecanoic acid (phytoseric) C14:1 n5	0.6	0
Oliec acid C18:1n9	6.35	6.03
Total mono unsaturated fatty acids	**6.95**	**6.03**
Linoleic acid C18:2n6	16.77	20.67
Linolenic acid C18:3n3	64.56	62.93
Polyunsaturated fatty acids	**81.33**	**83.60**
Saturated to unsaturated FA ratio	1: 9.6	1: 9.5
ω6:ω3 FA ratio	1: 3.9	1: 3
2-Some identity characteristics		
Relative density at 20°C	$0.9239^{b} \pm 0.00$	$0.9241^{a} \pm 0.00$
Iodin value (g I_2/100 g oil)	$194.7^{b} \pm 0.01$	$198.4^{a} \pm 0.01$
Saponification value (mg KOH/g oil)	$189.1^{b} \pm 0.01$	$191.3^{a} \pm 0.01$

*Value with different superscripts within each row are significantly different at $P \leq 0.05$

TABLE 5. Total soluble solids TSS (%), pH and score average of sensory characteristics of each of lemon, lemon grass, cinnamon and fenugreek drinks free and containing whole chia (*Salvia hispanica* L.) seeds.

Drink	TSS	pH	Score average of sensory characteristics					Quality acceptance
			Appearance (20)	Consistency (20)	Flavor (40)	Defects (20)	Total score (100)	
Fresh lemon juice	11.3	2.13	18	17	36	19	90	Excellent
Fresh chia seed lemon juice	11.3	2.11	16	18	31	19	84	Very good
Hot lemon dried grass	3	7.46	18	17	37	19	91	Excellent
Hot chia seed lemon dried grass	3	7.47	15	18	33	19	84	Very good
Hot cinnamon	2.6	7.53	19	18	38	19	94	Excellent
Hot chia seed cinnamon	2.6	7.55	16	18	34	19	87	Very good
Hot fenugreek	2.6	8.21	17	17	37	19	90	Excellent
Hot chia seed fenugreek	2.6	8.23	18	18	37	19	92	Excellent

2) *Baked products*

a) *Corn cake :* Table 6 shows the physical and organoleptic characteristics of cake. The evaluation of the physical properties of cake showed that the 100% corn cake, length, width and weight, were slightly less than those of that containing 5% chia seed flour. Mucilage in chia seed may be behind such small difference. It helps in keeping the located air bubbles inside the cake which increases cake weight, volume and dimensions. According to Guiotto et al. (2016) chia seed mucilage has a gum characteristic at very low concentration (0.75%). It can be used as stabilizer or thickener agent in food industry. Panelists did not observe any differences in general appearance and leavening of two types of cake. Both cakes had an excellent appearance and spongy leavening. Meanwhile crust color, porous distribution, porous structure, crumb color, crumb texture, chewiness and taste of corn containing 5% whole chia seed flour were described by panelists as strong, parallel uniform, moderate, dark brown, soft moist, excellent and excellent, respectively comparing with 100% corn flour cake. The latter had normal crust color, uniform porous structure, fine porous distribution, yellow crumb color, slightly soft or dry crumb texture, good chewiness and good taste. These variations are mainly due to the addition of chia seed flour and its content of oil, protein, sugar, fibers, minerals, enzymes (mainly amylases) and mucilage. Such components increased from browning, water holding, both structure and distribution of porous in cake. According to results of Pizarro et al. (2013) replacing 15% of wheat flour with whole chia seed flour in pound cake caused significant increase in ω3 level, lower acceptance of color and taste than control. In contrast, Rendon-Villalobos et al. (2012) found that replacing 15% of corn flour with whole chia seeds powder did not affect the sensory properties of tortillas and increased its nutritional value.

b) *Biscuits:* Data in Table 7 show the physical properties and sensory characteristics of these products. The dimension of biscuits, length, width and thickness, was equal in 100% wheat flour (A) and 100% wheat flour spray with whole chia seeds (B). The panelists accepted the two types of biscuit. They observed that the two products had the same general appearance, surface characteristics and leavening. Breakness, texture, chewiness and taste were slightly tender, fine, excellent and excellent, respectively in 100% wheat flour biscuit, control. Using chia seed at 5% level caused changes in breakness from slightly tender to crispy, texture from fine to moderate, chewiness from excellent to good and taste from excellent to good. According to Mesías et al. (2016) adding chia seed flour in wheat based biscuit formulation enhanced the nutritional quality of this product, increasing protein, dietary fiber, antioxidants and polyunsaturated fatty acids.

TABLE 6. Physical and sensory characteristics of corn cake free and containing 5% whole chia (*Salvia hispanica* L.) seeds flour.

Cake type	Physical properties						Cake characteristics								
	Length (cm)	Width (cm)	Hight (cm)	Weight (g)	Volume (cm^3)	Specific volume (g/ cm^3)	General appearance	Crust color (browning)	Leavening	Porous distribution	Porous structure	Crumb color	Crumb texture	Chewiness	Taste
100% corn flour	13	7	4	130	364	2.8	Excellent	Normal	Spongy	Uniform	Fine	yellow	Slightly soft/dry	Good	Good
95% corn flour + 5% whole chia seed flour	14	8	4	135	448	3.3	Excellent	Strong	Spongy	Parallel uniform	Moderate	Dark brown	Soft/ moist	Excellent	Excellent

TABLE 7. Physical and sensory characteristics of biscuits free and containing 5% of each of whole, chia (*Salvia hispanica* L.) seeds flour.

Biscuit type	Physical properties				Sensory characteristics						
	Length (cm)	Width (cm)	Thickness (cm)	Weight of 10 pieces (g)	General appearance	Surface and bottom characteristics	Leavening	Breakness	Texture	Chewiness	Taste
100% wheat flour	10	3	0.5	220	Excellent	Slightly bubbled	Very leavening	Slightly tender	Fine	Excellent	Excellent
100% wheat flour spray with whole chia seeds.	10	3	0.5	221	Excellent	Slightly bubbled	Very leavening	Crispy	Moderate	Good	Good

3) *Jam like product:* Results in Table 8 indicate that the two products, fenugreek jam and chia seed fenugreek jam, had the same pH (5.41) and total soluble solids (69%). The panelists showed the two products had nearly the same score of the sensory properties. Both products had brown color, solid texture, sweet oily taste and roasted flavor resulting from using fried sesame and peanut. The quality acceptance of both products was excellent.

4) *Salad dressing:* Data in Table 8 indicate that both types of salad dressing, 100% corn oil and corn oil + chia seed oil cheese dressing had nearly the same pH value and sensory properties score. The quality acceptance of both products was excellent. Crude chia oil caused slight changes in appearance, odor and taste of this product. Generally, both products had a bland flavor, semisolid texture and light creamy color.

5) *Jelly :* Chia seed mucilage is a hydrocolloids or gum. It can be used as a new food stabilizer. Therefore, the freeze-thaw stability of the isolated chia seed mucilage was examined to measure its ability to prevent the water separation (syneresis) after freezing and thawing. The analysis was performed in two freezing-thaw cycles as mentioned in materials and methods section using gelatin as reference. The results of freeze–thaw stability of chia (*Salvia hispanica*) seeds mucilage and gelatin showed that both chia seed mucilage and gelatin were very stable and had no water separation of the first and second cycle. This can be attributed to their high water holding capacity which reduces the amount of the available water that able create ice crystals causing water separation after thawing (Pongsawatmanit and Srijunthongsiri, 2008).

Due to the excellent freeze-thaw stability of chia seed mucilage it was used in this study to replace gelatin in preparing apple jelly. The results of evaluating the sensory properties of this jelly (Table 8) were nearly identical with those of the same product containing gelatin as mentioned by panelists. Both products had the same appearance and color (light green), texture (gel texture), acceptable odor and taste, as well as no syneresis. Flavor of this product was slightly reduced as a result of chia mucilage addition. Coorey et al. (2014) reported that chia seed gum has a good freeze-thaw ability stability due to high WHC. It can be used as a food stabilizer in frozen food.

TABLE 8. TSS (%), pH value and sensory characteristics score average of jam like products, chisster cheese dressing and apple jelly free and containing chia (*Salvia hispanica* L.) seeds and its oil.

Product	TSS	pH	Score average of sensory characteristics					Quality acceptance
			Appearance (20)	Consistency (20)	Flavor (40)	Defects (20)	Total score (100)	
Fenugreek jam	69.3	5.41	19	18	38	19	94	Excellent
Chia seed fenugreek jam	69.3	5.41	19	18	37	19	93	Excellent
100% Corn oil chisster cheese dressing	N.D	4.31	19	19	38	19	95	Excellent
95% Corn oil+ 5% chia seed oil chisster cheese dressing	N.D	4.33	18	18	37	19	92	Excellent
Apple jelly with gelatin	N.D	N.D	19	19	38	18	94	Excellent
Apple jelly with chia seed mucilage	N.D	N.D	19	19	36	18	92	Excellent

Conclusion

The above results showed that chia seed (*Salvia hispanica* L.) and its fractions can be used as novel ingredients in preparing functional food.

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تقييم بذور الشيا المصرية (*Salvia hispanica* L.) والزيت والموسيلاج كمكونات غذائية جديدة

أسامة بكير ربيع محمد، أمل محمد عبد الرازق، منى حسن حسين بخيت و يحيى جمال الدين محرم
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نظرًا للفوائد الكثيرة لبذور الشيا (*Salvia hispanica* L.) كغذاء واعد جديد ، تم إجراء هذا البحث لتقدير كل من الخواص الفيزيائية والكيميائية والتكنولوجية لبذور الشيا المصرية مقارنة مع مثيلاتها الأمريكية المستوردة. وأوضحت النتائج زيادة طول وعرض وارتفاع قيم الأضاءة (L*) ودرجة الاحمرار (a*) والأصفرار (b*) للون والنسبة المئوية للأنوية وانخفاض سمك والكثافة الظاهرية والنسبة المئوية للقشور لبذور الشيا المحلية عن المستورة. بينما كانت نسب كل من الدهون (حوالي ٣٤ ٪) ، والبروتينات (حوالي ٢٤ ٪) ، والألياف الخام (حوالى ٢٠ ٪) ، والموسيلاج (حوالى ٧ ٪) والبوتاسيوم والفوسفور والنحاس أعلى والرماد (حوالى ٤,٥ ٪) والمستخلص الخالى من النيتروجين (حوالى ٩ ٪) والصوديوم والزنك والمنجنيز والماغنسيوم والحديد أقل في البذور المستوردة عن المحلية. وتقاربت القيمة السعرية لكلا البذور (٥٢٢ كيلو كالوري / ١٠٠ جم) وتميز الزيت الخام المستخلص من بذور الشيا المحلية و المستوردة باللون العنبرى والمظهر الرائق ، ونفس الثوابت تقريبًا ومحتواه من الأقسام والجليسريدات الثلاثية المختلفة حيث كانت الجليسريدات الثلاثية المحتوية على ٩ روابط غير مشبعة هى الأعلى تركيزا.ومثلت الأحماض الدهنية الغير مشبعة أكثر من ٨٠ ٪ (أساساً حامض اللينولينيك "~ ٦٣٪" وحامض اللينوليك "~ ١٧٪") من الأحماض الدهنية المكونة للزيت. وكانت نسبة الأحماض الدهنية المشبعة الى غير المشبعة ١: ٩,٥ ونسبة الاوميجا ٦ إلى الاوميجا ٣ ١: ٣,٥. وقد استخدمت كل من البذور الكاملة ودقيقها والزيت والموسيلاج المستخلص منها في اعداد مشروبات باردة وساخنة وكيك مع دقيق الذرة وبسكويت مع دقيق القمح وتتبيلة السلطة ومنتج شبيه بالمربى ولهم خواص حسية جيدة وفقا لتقييم المحكمين.