

Studies on Egyptian Sesame Seeds (*Sesamum indicum* L.) and its products.
3.Effect of Roasting Process on Gross Chemical Composition,
Functional Properties, Antioxidative Components and
Some Minerals of Defatted Sesame Seeds Meal (*Sesamum indicum* L.)

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Abstract: Sesame seed (*Sesamum indicum* L.) is one of the world's most important and oldest oilseed crops with a high level content of nutrients and antioxidants known to human health. Sesame seeds are usually roasted prior to expelling oil. The changes of chemical composition, functional properties and antioxidant activity of defatted sesame seeds meal (DSSM) before and after roasting were investigated. The DSSM samples contained 1.72-2.76% moisture, 2.20-3.58% crude oil, 45.05-55.20% crude proteins, 9.60-20.51% carbohydrate (by difference), 22.49-24.48% crude fiber and 5.11-6.94% ash. A significant reduction was observed in the mineral composition with roasting treatment when compared with the raw sample. Functional properties (WAC and OAC) of DSSM were also determined. The antioxidant factors responsible for the stability of DSSM are highly affected by the roasting process. The total phenolics content in the methanolic extract from DSSM and the antioxidant activity of DSSM also increased with roasting.

Key words: Antioxidant activity • Chemical composition • Crude oil and protein • Functional properties
• Roasting • Sesame seeds

INTRODUCTION

Sesame seed (*Sesamum indicum* L.) is an important oil seed crop. Sesame is grown in tropical zones as well as in temperate zones between latitudes 40°N and 40°S. It has been cultivated for centuries, especially in Asia and Africa. In 2009, the world production of sesame seed was 3,976,968 tons and the major production areas were Asia (2,489,518 tons) and Africa (1,316,690 tons), constituting about 62.6 and 33.1% of the total world production [1]. A part from being an important source of edible oil, sesame seeds and kernels are used for the preparation of sweets, confectionary and bakery products [2]. Since millennia, sesame (*Sesamum indicum* L.) had has a highly important place in human food. This product has been used as an essential constituent in different recipes [3]. Archeological records indicate that it has been known and used in India for more than 5,000 years and is recorded as a crop in Babylon and Assyria some 4,000 years ago. Sesame powder had also been used throughout East Africa where it is mainly grown for grain and oil [4].

So, many countries produce and export this product, mainly China, Japan, India, Cameroon, Egypt, Senegal, Brasilia and Iran [5, 6]. The seeds are typically crushed intact for the oil. This, however, yields a meal that is bitter and somewhat indigestible due to the presence of the fibrous husk. As such the meal is only useful as cattle feed. The quality of the meal can be improved by removing the seed coat, dehulling, before crushing [7]. Sesame meal has a composition of 7.92% moisture, 27.83% fat, 30.56% protein, 6.22% fiber, 5.27% ash and 28.14% carbohydrate. Extraction of oil has led to increased protein content of defatted sesame meal (41.15-49.58%). This meal can be used as a protein source ingredient in the food industry [8]. The residue sesame oil cake contains on an average 32% crude protein, 8-10% oil, total oil and albuminoids of 40-42% and rich in essential amino acids namely methionine and cystine. Since these amino acids are missing from a number of other sources of vegetable protein, such as soy, sesame meal or flour has been used as an excellent protein supplement for dairy cattle and can be added to recipes to give a better nutritional balance to

health food products [9, 10]. The meal remaining after oil extraction has unique nutritional properties. Sesame protein complements very well most oil seeds and vegetable proteins. The seed cake is also an excellent protein supplement in the animal feed industry [11].

Sesame seed (*Sesamum indicum* L.) is an important crop widely cultivated all over the world. Seeds of sesame are used to garnish bread loafs, in preparation of sweets and desserts and after extraction of oil is used as a cattle feed. Since antiquity sesame meal has been used for human and animal nutrition. It was also reported that sesame seed meal can be incorporated at a higher level in the diet of fish fingerlings after suitable processing. Oil free sesame contains 40-50% protein. It is necessary to modify the meal so that it could be used for human consumption [12, 13]. Defatted sesame seeds meal (DSSM) obtained from oil extraction are mainly used as a feed ingredient for domestic animals or are composted. It has been reported that sesame oil extracted from seeds with hulls is more stable than that extracted from dehulled seeds [14], indicating that antioxidant components may exist in sesame hull. Chang *et al.* [5] reported that sesame coat has a significant antioxidant activity in various in vitro systems. Antioxidant activities of defatted sesame meal extract increased as the roasting temperature of sesame seed increased, but the maximum antioxidant activity was achieved when the seeds were roasted at 200°C for 60 min. Roasting sesame seeds at 200°C for 60 min. significantly increased the total phenolic content, radical scavenging activity, reducing powers and antioxidant activity of sesame meal extract and several low-molecular weight phenolic compounds such as 2-methoxyphenol, 4-methoxy-3-methylthio-phenol, 5-amino-3-oxo-4-hexenoic acid 3,4-methylenedioxyphenol (sesamol), 3-hydroxy benzoic acid, 4-hydroxy benzoic acid, vanillic acid, filicinic acid and 3,4-dimethoxy phenol were newly formed in the sesame meal after roasting sesame seeds at 200°C for 60 min. These results indicate that antioxidant activity of defatted sesame meal extracts was significantly affected by roasting temperature and time [15]. Shyu *et al.* [16] investigated the antioxidative activity of methanolic extract from defatted black sesame meal roasted at three different temperatures (180, 200, 220°C) for different durations (5-30 min).

The effects of roasting condition on the browning index of sesame meal and the total phenolic content of the methanolic extract were also investigated. Results showed that the total phenolic content in the methanolic extract from defatted sesame meal and the browning level of sesame meal were increased with roasting temperature and

time. Lignans and lignan glycosides present in sesame appear to be the important functional components. Lignans are found in sesame oil, while lignan glycosides exist mainly in the defatted sesame meal. There have been reports on the antioxidative activities and composition of lignans and lignan glycosides in sesame seed. Although sesame seeds are often roasted to enhance the aroma and oxidative stability of sesame oil in addition to facilitate the pressing of the oil, little information is available on how roasting condition affecting the antioxidative activity of sesame meal. Thus, many authors investigate the effect of roasting condition on the antioxidative activity of sesame meal. The results provide information on how to improve the processing condition in order to increase the antioxidant activity of sesame meal, which, in turns, would enhance the utilization of sesame meal [17, 18]. Sesame seeds contained significant amount of important minerals with the Potassium concentration being the highest, followed by Phosphorus, Magnesium, Calcium and Sodium [19]. For White sesame seed (*S. indicum* L.) from Sudan, oil was 52.24%, protein 25.97%, fibre 19.33% and ash 4.68% [20]. The predominant mineral composition was calcium followed by potassium, magnesium and phosphorus. All other elements were present in comparatively low concentrations [21, 22]. The nutritional value of the meal makes it a potential source of livestock feed; this is because it is a relatively good source of crude protein. Studies carried out on incorporation of sesame oil cake in rations had positive effects on calves' performance. Thus the use of sesame cake in areas where sesame is produced will be beneficial to farmers [23].

The objective of this study was to investigate the chemical composition, functional properties, polyphenolic compounds, the antioxidative activity and some minerals of roasted defatted sesame seeds meal.

MATERIALS AND METHODS

Materials: Sesame seeds varieties (Giza 32 and Shandawil 3) obtained from Oil Seeds Department, Field Crops Institute Research, Agricultural Center Research, Giza, Egypt.

Sample Preparation: Sesame seeds were cleaned manually by removing all the foreign matter such as stones, dirt and broken seeds. They were washed in abundant water before being drained on a sieve and then treated as follows:

Raw Sesame Seeds (Control)

Soaked Roasted Sesame Seeds (SRSS): Sesame seeds soaked in water for about an hour then roasted at 200°C for 15 min. Using an electrical drying oven. (Model D-63450, Hanau, Germany).

Roasted Sesame Seeds (RSS): Roasted sesame seeds (RSS) refers to sesame seeds roasted at 200°C for 15 min. using an electrical drying oven. (Model D-63450, Hanau, Germany).

Microwaved Roasted Sesame Seeds (MRSS): Sesame seeds microwaved at 2450 MHz for 15 min. using microwave oven.

The sesame seeds samples storage at room temperature and crushed in a pestle and mortar before analysis.

Defatted Sesame Seeds Meal (DSSM): The sesame seeds samples were crushed in a pestle and mortar before defatting. Cold extraction method with n-hexane for 72 hours was used to extract the oil from the sesame samples. The ratio of sample to solvent was 1g: 5 ml. The extracts were undergone evaporation using a rotary evaporator at 40°C to obtain the oil and the residue [defatted sesame seeds meal samples (DSSM)] was collected and dried at room temperature then stored in a freezer (-20°C) until time for analysis.

Methods of Analysis: Gross Chemical Composition: Moisture, crude protein, crude oil, crude fiber and ash were determined as described in the AOAC [24], while the carbohydrate content was calculated by difference according to Pellet and Sossy [25]. Triplicate determinations were carried out for each sample and the means were reported.

Functional Properties: Water and Oil Absorption Capacity: One gram of sample was mixed with 10ml refined corn oil or distilled water in a weighed 20 ml centrifuge tube. The slurry was agitated on a Vortex mixer for 2 minutes, allowed to stand at 28°C for 30 minutes and then centrifuged at 500×g for 30 minutes. The clear supernatant was decanted and discarded. The adhering drops of oil or water were removed and the tube was weighed. The weight of oil or water absorbed by 1g of flour of protein was calculated and expressed as oil or water absorption capacity [26, 27].

Total Phenolics Compounds: Total phenolics in the studied samples were determined spectrophotometrically using Folin-Denis reagent [28]. To each test tube add 30mg of dry finely ground sesame seeds. Add 10ml of 50% aqueous methanol (50% methanol: 50% distilled water) and extract for two hours shaking every 15 minutes. After samples have cooled and settled, pipette off 5ml and save for analysis. The methanolic extracts (0.1 ml) of samples were diluted with distilled water (75 ml) in a volumetric flask. Folin-Denis reagent (5 ml) was added and the contents of the flask were mixed thoroughly. After 3 min, 10 ml of Na₂CO₃ solution (10 g/100 ml) was added and finally quantified to 100 ml with distilled water. The mixture was allowed to stand for 30 min with intermittent shaking. The blue color was measured by spectrophotometer at 750nm. The concentration of total phenolic compounds in samples was determined comparing with the absorbance of standard tannic acid at different concentrations.

Total Flavonoids: The aluminium chloride colorimetric assay was used for total flavonoids determination, as described by Marinova [29]. Extraction of flavonoids in the samples (n=3) was achieved by homogenizing 2 g of the sample in 50 ml distilled water in pestle and mortar. The mixture was transferred into a shaker for 12 h. to ensure full extraction. Thereafter, the mixture was filtered and the filtrate (extract) made up to 50 ml. Precisely, 1 ml of extracts or standard solution of catechin (20, 40, 60, 80 and 100 mg/l) was added to test tubes containing 4 ml of redistilled water. To this mixture 0.3 ml of 5% NaNO₂ was added. After 5 min, 0.3 ml 10% AlCl₃ was added. Immediately, 2 ml 1M NaOH was added and the total volume was made up to 10 ml with redistilled water. The solution was mixed thoroughly and the absorbance of both the samples, blank and standard, were read at 510 nm using UV-Visible spectrophotometer Model UV 1601 version 2.40 (Shimadzu). Total flavonoids content was expressed as mg catechin equivalents.

Antioxidant Activities Assays:

Total Reduction Activity by Fe³⁺- Fe²⁺ Transformation: The reducing activity of samples was determined by the method of Oyaizu [30]. The capacity of samples to reduce the ferric-ferricyanide complex to the ferrous-ferricyanide complex of Prussian blue was determined by recording the absorbance at 700 nm after incubation. Increased absorbance of the reaction mixture indicates greater reduction capability.

Hydrogen Peroxide Scavenging Activity: The hydrogen peroxide scavenging ability of samples was determined according to the method of Ruch *et al.* [31]. A solution of H_2O_2 (40 mM) was prepared in phosphate buffer (pH 7.4). Sample extract, at the 30 μ g/ml concentration in 3.4 ml of phosphate buffer, was added to an H_2O_2 solution (0.6 ml, 40 mM). The absorbance value of the reaction mixture was recorded at 230 nm against blank solution containing the phosphate buffer without H_2O_2 .

Determination of Minerals: Minerals (Ca and Mg) were analyzed by GBC Atomic Absorption 906 A.A. Na, K were determined by a flame photometer corning 400 and P was determined by spectrophotometer [32] after wet ashing by method described in AOAC [33].

Statistical Analysis: The data collected were analyzed with analysis of variance (ANOVA) Procedures using the MSTAT-C Statistical Software Package [34]. Differences between means were compared by LSD at 5% level of significant [35].

RESULTS AND DISCUSSION

Chemical Composition and Functional Properties of Defatted Sesame Seeds Meal (DSSM): The chemical composition of DSSM from both the varieties before and after roasting were analyzed and presented in Table 1. Results obtained showed that the DSSM contained 1.72- 2.76 moisture, 2.20-3.58 crude oil, 9.60-20.51 carbohydrate (by difference), 22.49-24.48 crude fiber and 5.11-6.94% ash (Table 1). Except moisture content there was significant difference ($P < 0.05$) in the crude protein, crude lipid, crude fiber and ash contents of the samples under study. The data indicate that the meals contain about 45-55% protein which may be used for the fortification enrichment of the baked products. This result of proximate composition of DSSM was closely comparable with that of Jimoh *et al.* [36] who noticed that defatting the sesame seeds increased the crude protein value significantly.

The functional properties have been defined as the physicochemical properties which affect the processing and behavior of flour in food systems as judged by the quality attributes of the final product. Water and oil absorption capacities are from studied samples are shown in Fig. 1. Giza 32 (MRSS); Shandawil 3 (MRSS) showed a higher water absorption capacity, 388.39 and 377.70 g water/ 100 g dry weight, respectively, than the other

observed samples. Oil absorption of the DSSM samples ranged between 323.74 and 393.30 (Fig. 1). It was found that OAC of Shandawil 3 (control) was 323.74 whereas it increased in the other Shandawil 3 variety samples. From these results it was observed that oil absorption capacity OAC of Giza 32 (control) was 389.73 g oil /100g dry weight while Giza 32 (RSS) and Giza 32 (MRSS) showed a lower OAC as compared with control as shown in the Fig. 1. Interactions between water and oil with protein are important in food systems because of their effects on the flavor and texture of food. Intrinsic factors affecting water binding of food protein include amino acid composition, protein conformation and surface polarity/hydrophobicity [37].

Effects of Seed Roasting Conditions on the Polyphenolic and Antioxidant Activity Contents of Defatted Sesame Seeds Meal: Phenolic compounds are known to act as antioxidants not only because of their ability to donate hydrogen or electrons but also because they are stable radical intermediates, which prevent various food ingredients from oxidation [38].

The methanolic extracts of samples showed obviously different amount of total phenolics, with a range from 73.74 to 128.80. Giza 32 (MRSS) showed the highest content of phenolics, with 128.80, followed by Shandawil 3 (MRSS), with 103.89. The lowest phenolic content was obtained from Shandawil 3 (control) with 73.74 mg tannic acid/100g dry weight (Fig. 2). The amount of flavonoids varied in sesame meal samples from 13.75 to 17.70 in Shandawil 3 (SRSS) and Giza 32 (MRSS), respectively; also the amount of total flavonoids in the extract of sesame meal increased from 16.09, 14.51 in Giza 32 (control), Shandawil 3 (control) to 17.70, 16.54 mg catechin equivalents /100g dry weight in G (MRSS) and Shandawil 3 (MRSS). The Total flavonoids of DSSM increased as a result of roasting by microwave oven (Fig. 2). The antioxidant activities of DSSM extracts have been evaluated using total reduction activity and H_2O_2 scavenging activity methods. Total reduction activity of DSSM extract increased with roasting process from 25.31 to 27.21 with Giza 32 (control), Giza 32 (SRSS) treatment and from 26.73 to 27.25 reducing ferric ions /100 g dry weight with Shandawil 3 (control), Shandawil 3 (RSS) treatment (Fig. 2). With Shandawil 3 (SRSS) or Shandawil 3 (MRSS) treatment, the total reduction activity of DSSM extract was not increased. The H_2O_2 scavenging activity in methanolic extract of 8 samples of DSSM was determined before and after roasting process.

Table 1: Chemical composition of defatted sesame seeds meal

Sample	Moisture %	Ash %	Protein %	Oil %	Crude fiber %	Total carbohydrates %
Giza 32 (control)	2.55 ^{N.S}	5.11 ^H	55.20 ^A	3.16 ^C	24.38 ^B	9.60 ^H
Giza 32 (SRSS)	2.02 ^{N.S}	5.40 ^G	50.59 ^D	2.49 ^E	24.25 ^C	15.25 ^E
Giza 32 (RSS)	1.72 ^{N.S}	5.81 ^E	52.38 ^B	3.31 ^B	24.48 ^A	12.30 ^G
Giza 32 (MRSS)	1.92 ^{N.S}	6.19 ^C	48.54 ^E	2.20 ^G	24.17 ^D	16.98 ^D
Shandawil-3 (control)	2.76 ^{N.S}	6.17 ^D	51.96 ^C	3.15 ^C	22.49 ^H	13.47 ^F
Shandawil-3 (SRSS)	2.09 ^{N.S}	5.71 ^F	47.55 ^F	3.58 ^A	22.51 ^G	18.56 ^C
Shandawil-3 (RSS)	1.72 ^{N.S}	6.55 ^B	46.33 ^G	2.95 ^D	22.69 ^F	19.76 ^B
Shandawil-3 (MRSS)	2.31 ^{N.S}	6.94 ^A	45.05 ^H	2.42 ^F	22.77 ^E	20.51 ^A

*Means having different superscripts within the column are significantly different at $p < 0.05$

N.S non significant at $p < 0.05$

Table 2: Minerals composition of defatted sesame seeds meal samples (g/ 100g dry weight)

Sample	P	K	Na	Mg	Ca
Giza 32 (control)	0.15 ^D	0.51 ^H	0.29 ^E	3.36 ^A	2.00 ^A
Giza 32 (SRSS)	0.12 ^F	0.62 ^F	0.34 ^C	1.00 ^G	1.00 ^D
Giza 32 (RSS)	0.15 ^D	0.52 ^G	0.34 ^C	1.44 ^E	1.20 ^C
Giza 32 (MRSS)	0.14 ^E	0.70 ^D	0.35 ^B	1.56 ^D	0.60 ^F
Shandawil-3 (control)	0.16 ^C	0.77 ^B	0.35 ^B	1.56 ^D	1.40 ^B
Shandawil-3 (SRSS)	0.62 ^A	0.66 ^E	0.31 ^D	1.60 ^C	0.80 ^E
Shandawil-3 (RSS)	0.17 ^B	0.75 ^C	0.31 ^D	2.04 ^B	0.60 ^F
Shandawil-3 (MRSS)	0.15 ^D	1.00 ^A	0.39 ^A	1.20 ^F	0.40 ^G

*Means having different superscripts within the column are significantly different at $p < 0.05$

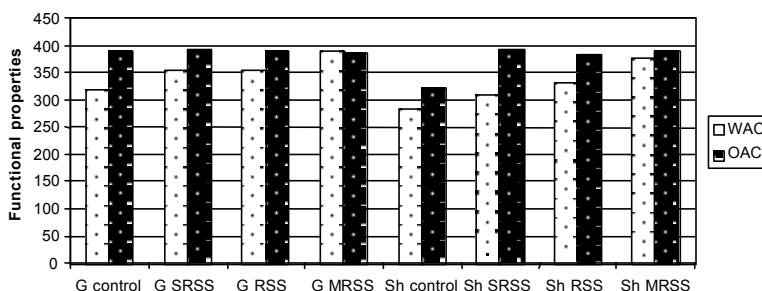


Fig. 1: Functional properties content of defatted sesame seeds meal*

G= Giza 32 Sh = Shandawil 3

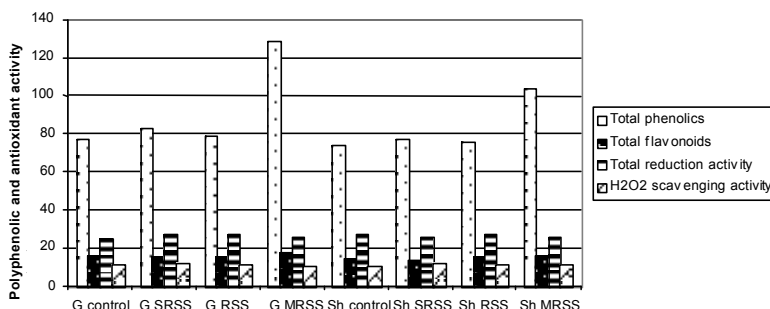


Fig. 2: Polyphenolic and antioxidant activity contents of defatted sesame seeds meal

G= Giza 32 Sh = Shandawil 3

The range of H_2O_2 scavenging activity values was between 10.53, 12.20 in Giza 32 (MRSS) and Shandawil 3 (SRSS) samples, respectively. The H_2O_2 scavenging activity value increased from 10.76 in unroasted Shandawil 3 as a control to 11.54 H_2O_2 molecules /100g

dry weight after roasting by microwave in Shandawil 3 (MRSS). Our results are in agreement with those obtained by Jeong *et al.* [15] who showed that antioxidant activity of defatted sesame meal extracts was affected by roasting conditions.

Mineral Composition of DSSM: The mineral composition of raw and roasted defatted sesame seeds meal are shown in Table 2. There were significant differences ($P < 0.05$) in the mineral composition between the raw and the roasted. Magnesium and Calcium were the most abundant minerals in defatted sesame seeds meal. The defatted sesame seeds meal contained significant amounts of important minerals (Table 2). The Magnesium concentration (3.36, 1.56) was the highest, followed in descending order by Calcium (2.00, 1.40), Potassium (0.51, 0.77), Sodium (0.29, 0.35), Phosphorus (0.15, 0.16 g/100g dry weight) for the Giza 32 (control) and Shandawil 3 (control) samples, respectively. Magnesium is essential mineral for enzyme activity, like Calcium and Chloride; Magnesium also plays a role in regulating the acid-alkaline balance in the body. Calcium and Magnesium plays a significant role in photosynthesis, carbohydrate metabolism, nucleic acids and binding agents of cell walls. Calcium assists in teeth development. Potassium is an essential nutrient and has an important role is the synthesis of amino acids and proteins. Phosphorus is needed for bone growth, kidney function and cell growth. It also plays a role in maintaining the body's acid-alkaline balance [39].

CONCLUSION

Defatted roasted sesame seeds meals were found to be a good source of protein, crude fiber and carbohydrates. Functional properties were increased in most samples as a result of roasting. Giza 32 (MRSS) and Giza 32 (SRSS) had the higher water and oil absorption properties than the other studied samples. Functional properties of the DSSM allow its use in food ingredients and in food formulation systems such as meat and sauce products. The study of the antioxidant properties shows that the defatted roasted samples, compared to the raw sesame seeds, present a considerably higher content in polyphenolic compounds and antioxidant activity. In conclusion, the results indicate that all parameters under study of sesame seeds were affected by roasting temperature and time. DSSM can attract consumers and processors for value-based food products.

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