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Studies on Egyptian Sesame Seeds (*Sesamum indicum* L.) and Its Products 1- Physicochemical Analysis and Phenolic Acids of Roasted Egyptian Sesame seeds (*Sesamum indicum* L.)

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Abstract: The effect of roasting on physical characteristics, chemical composition and phenolic acids of 2 sesame seeds varieties Giza 32 (G 32) and Shandawil 3 (Sh 3) were studied. The results showed that the roasted seeds contained 0.20-3.06% moisture, 18.92-23.18% crude protein, 3.01-4.38% ash, 6.75-7.34% crude fiber, 56.49-59.97% crude oil and 4.33-11.59% total carbohydrates. The oil from roasted sesame seeds was found to contain high levels of unsaturated fatty acids, especially oleic (up to 39%) and linoleic (up to 42%). *Sesamum indicum* L. oil can be classified in the oleic-linoleic acid group. The dominant saturated acids were palmitic (up to 7%) and stearic (up to 5%). Phenolic acids were identified by high performance liquid chromatography (HPLC). Ellagic acid was the most predominant amongst the sixteen phenolic acids identified in sesame seeds samples. Gallic acid, vanillic acid and benzoic acid increased with roasting. Our study has demonstrated that roasted sesame seeds gave the most desirable quality of raw sesame seeds with respect to phenolic content and fatty acid composition.

Key words: Fatty acids · Roasting · Microwaving · Phenolic acids · Sesame seeds samples

INTRODUCTION

Sesame (*Sesamum indicum*. L., synonymous with *Sesamum orientale* L.), also known as benniseed (Africa), benne (Southern United States), gingelly (India), gengelin (Brazil), sim-sim, semsem (Hebrew) and tila (Sanskrit), is the world's oldest oil crop. It belongs to the Tubiflorae order, Pedaliaceae family, which comprises of 16 genera and some 60 species. There are 37 species under the *Sesamum* genus. Among the 37 species, only *Sesamum indicum* is widely cultivated. As most of the wild species of sesame were found in Africa, it is generally believed that sesame originated in Africa. India may also be the origin of some species (*S. capense*, *S. prostratum* and *S. schenckii*) of sesame. The sesame species in the Middle East are similar to Africa; they are believed to be spread from Africa via Egypt [1, 2, 3]. The color varies from white, yellow, gray, red, brown, to black. The weight of 1000 seeds is around 2.5 to 3.5 g. The oil drops are located in the cotyledon. It is generally believed that the light-colored seeds with thin coats are higher in quality and oil content than the dark-colored seeds. Each year, the world consumes close to 120 million MT of edible fats and oils [4, 5].

Sesame oil, with an annual production of 760,000 MT in 2003, is the twelfth largest vegetable oil produced in the world, higher in quantity than olive oil and safflower oil [6]. Sesame seed contains high levels of fat and protein. The chemical composition of sesame seed varies with the variety, origin, color and size of the seed. The fat content of sesame seed is around 50% whereas the protein content is around 25%. Sesame seed contains about 5% of ash, whereas the fiber and carbohydrate contents show large variation [7]. The chemical composition of sesame shows that the seed is an important source of oil (44-58%), protein (18-25%), total carbohydrates (~13.5%) and ash (~5%) [8-15].

Sesame seed has about 17% seed weight as hull, which is high in oxalic acid (2~3%), calcium and crude fiber. Oxalic a cid could complex with calcium and reduces its bioavailability; indigestible fiber would reduce the digestibility of protein [7, 16]. Sesame seed is a rich source of edible oil. It contains more oil than the major oilseeds, such as soybean, rapeseed-canola, sunflower seed and cotton seed. Oil content of sesame seed varies with the variety of sesame; it may range from 28% to 59%. In general, the cultivated seed has around 50% oil, whereas the color of the seed coat exhibits slight

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influence on the oil content. Black seeds appear to contain slightly less oil than the white and brown seeds in the Japanese strains. Oil content was found to be influenced also by the growing condition, daily mean temperature and the cumulative degrees of daily temperatures during reproductive stage, which showed negative correlation with the oil content [8, 17]. Sesame oil belongs to the oleic-linoleic acid group. It has less than 20% saturated fatty acid, mainly palmitic (7.9-12%) and stearic (4.8-6.1%) acids. Oleic acid and linoleic acid constitute more than 80% of the total fatty acids in sesame oil. Unlike other vegetable oils in this group, the percentages of oleic acid (35.9-42.3%) and linoleic acid (41.5-47.9%) in the total fatty acids of sesame oil are close Besides the four major fatty acids, there are low percentages (less than 1%) of other fatty acids-myristic (ND-0.1), palmitoleic (0.1-0.2), heptadecanoic (ND-0.2), heptadecenoic (ND-0.2), linolenic (0.3-0.4), arachidic (0.3-0.6), eicosenoic (ND-0.3), behenic (ND-0.3) and lignoceric acid (ND-0.3). Fatty acid composition varies with the species of sesame seeds [11, 18].

Roasting is important for the development of desirable color and flavor for sesame oil and it will enhance the oxidative stability of sesame oil [19, 20]. The conditions of roasting may influence the sensory quality and composition of the roasted sesame oil.

Yoshida and Takagi [21] compared the quality of sesame oils prepared at roasting temperatures between 160°C and 250°C. They suggested that high-quality roasted sesame oil would be obtained by roasting for 25 min at 160°C and 180°C, 15 min at 200°C and 5 min at 220°C. Sesame seed has many culinary applications. It is used for many bakery products, for the production of oil (raw or roasted), as well as for the preparation of Tehina and Halva. Tehina is a paste, while halva is a cake-like product. The antioxidant activity of sesame seed and sesame seed oil and the various healthful properties are attributed to the presence of lignans such as sesamin, sesamolin, sesaminol, sesangolin, 2-episalatin and others [11, 18].

The purpose of the current study was to assess the effect of roasting treatments, on some physicochemical properties, chemical composition, fatty acid composition of sesame seeds and the phenolic acids fractions were investigated as well.

MATERIALS AND METHODS

Materials: Sesame seeds varieties Giza 32 (G 32) and Shandawil 3 (Sh 3) brought to from Oil Seeds Department, Field Crops Institute Research, Agricultural Research Center, Egypt during the Summer season 2012.

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 follow:

Raw Sesame Seeds (Control): Raw sesame seeds (Control) refers as such without roasting.

Soaked Roasted Sesame Seeds (SRSS): Soaked roasted sesame seeds (SRSS) refers to 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): Microwaved roasted sesame seeds (MRSS) refers to sesame seeds microwaved at 2450 MHz for 15 min using microwave oven.

The sesame seeds samples was crushed in a pestle and mortar before analysis.

Oil Extraction: Crushed sesame and sesame seeds samples (150 g) were placed in dark flasks (capacity = 1L) and homogenized with 750 ml hexane (1:5, g: v). The mixture was maintained under agitation for a period of one night. The extracts were undergone evaporation using a rotary evaporator at 40°C then the obtained oil was analyzed.

Methods of Analysis

Gross Chemical Composition: Moisture, crude protein, crude oil, crude fiber and ash were determined as described in the AOAC [22], while the carbohydrate content was calculated by difference according to Pellet and Sossy [23]. Triplicate determinations were carried out for each sample and the means were reported.

Refractive Index of Sesame Seeds Oil: The refractive index was determined using an Abbe refractometer (Bellin-ghan and Stanley Ltd, United Kingdom) at 20°C [24].

Fatty Acid Composition

Preparation of Fatty Acid Methyl Esters: The methyl esters of fatty acids were prepared from oil samples using 5ml 3% H_2So_4 in absolute methanol and 2ml benzene according to the method described by Rossel [25].

Identification of Fatty Acid Methyl Esters by Gas Liquid Chromatography: Analysis of methyl esters of fatty acids was carried out using Perkin-Elemar gas chromatograph (model F 22) with a flame ionizing detector (FID) in the presence of nitrogen as a carrier gas. The separation was carried out at 190-230°C (temperature rate 4°C/min) on a (3m x 3mm) glass column, packed with diethylene glycol succinate (DEGS) on chromosorb w, 80-100 mesh. The injector and detector temperatures were 220°C. The nitrogen, hydrogen and air flow rate were 30, 30 and 300 ml /min., respectively. The chart speed was 1cm/min. The peaks were identified by comparison with standard methyl esters by means of their relative retention times under identical conditions. The quantitative determination was performed by measuring the peak areas with an integrator.

Calculated Oxidizability Value (Cox): The oxidative stability of the extracted oils based on unsaturated fatty acids (USFAs) content was calculated according to Fatemi and Hammond [26] as follows:

Cox = [1(18:1%) + 10.3(18:2%) + 21.6(18:3%)]/100.

Determination of Phenolic Acids: The HPLC analysis of phenolic acids were carried out on a HPLC apparatus consisting of Merck-Hitachi L-7455 diode array detector (DAD) and pump L-7100 equipped with D-7000 HSM Multisolvent Delivery System. The separation was performed on a Li ChroCART® 125-3 Purospher® RP-18 (5 µm) Merck column. Column oven temperature was set to 30°C. 80% acetonitrile in 4.5% formic acid (reagent A) and 2.5% acetic acid (reagent B) were used as an eluent. The flow rate was 1 ml/min. The concentration of reagent A was stepwise increased to reach 15% after 7min, 20% after 15 min and 100% after 16 min. After 10 min of elution the concentration of reagent A was reduced to 0% to stabilize the column. During analysis the solvent were degassed in Merck degasser. Data logging were monitored at wavelength 280nm. Retention times and spectra were compared to those of pure standards [27].

Statistical Analysis: The data collected were analyzed with analysis of variance (ANOVA) Procedures using the MSTAT-C Statistical Software Package [28]. Differences between means were compared by LSD at 5% level of significant [29].

RESULTS AND DISCUSSION

Physical Characteristics of Sesame Seeds Cultivars and Sesame Seeds Oil: Table 1 shows the 1000 seeds weight, color and size of the sesame seed cultivars. The mean of white colored seeds were 3.61 and 3.75 grams per 1000 seeds for G 32 and Sh 3, respectively, which is in agreement with those reported by Al-Kahtani [30], as the seeds were medium. [31] reported that the weight of sesame seeds usually lie with in the range of 2 to 3.5 g/1000 seeds, however, the results may vary depending on variety and cultural conditions. The refractive index results recorded (1.4635 and 1.4640) were found to be within the given range by Seegeler [32] and Borchani *et al*. [33].

Effect of Roasting on the Gross Chemical Composition of Sesame Seeds Samples: The gross chemical composition of raw and roasted sesame seeds samples is presented in Table 2. Results indicated significant variation ($p<0.05$) in moisture contents of the samples and ranged between 0.20 and 3.06%. Results also indicated significant variation ($p<0.05$) in protein contents of the samples. It could be noticed that protein content was 23.18, 21.43% for control in both G 32 and Sh 3, while decreased in roasted samples. The data revealed that the oil contents of the samples ranged between 56.49% and 59.97%, with significant variation in content between individual treatments. The economic value of sesame seeds is dependent on its oil content rather than its protein content. The high percentage of oil makes this seed a distinct potential for the oil industry. According to Egbekun and Ehieze [34] variation in oil yield may be due to the differences in variety of plant, cultivation climate, ripening stage, the harvesting time of the seeds and the extraction method used. In general, the oil contents of the cultivars were found within the range reported for sesame seed cultivars grown in various parts of the world [35, 36]. As shown in Table 2 the G 32 MRSS, Sh 3 MRSS contained relatively considerable higher amounts of ash, total carbohydrates with values: 3.35, 4.38%, 8.23, 11.42, compared with 3.04, 4.04%, 4.33, 6.95%

Table 1: Physical characteristics of sesame seed cultivars

Sesame seed cultivars	1000 seeds weight (g)	Color	Size	Refractive index of oil
Giza 32	3.61	White	Medium	1.4635
Shandawil 3	3.75	White	Medium	1.4640

Table 2: Chemical composition of raw and roasted sesame seeds samples

Sample	Moisture	Ash	Crude protein	Crude oil	Crude fiber	Total carbohydrates
G 32 control	2.86^{A}	3.04^{G}	23.18^{A}	59.28^{D}	7.31^{B}	4.33^{H}
G 32 SRSS	0.96^{C}	3.01^{H}	21.25^{D}	59.89^{B}	7.27^{C}	7.62^{E}
G 32 RSS	0.20^{D}	3.15^{F}	22.00^{B}	59.97^{A}	7.34^{A}	7.34^{F}
G32 MRSS	1.04^{BC}	3.35^{E}	20.39^{E}	59.74^{C}	7.25^{D}	8.23^{D}
Sh 3 control	3.06^{A}	4.04^{C}	21.43^{C}	57.77^{E}	6.75^{H}	6.95^{G}
Sh 3 SRSS	1.18^{BC}	3.99^{D}	19.97^{F}	56.49^{H}	6.78^{G}	11.59^{A}
Sh 3 RSS	0.48^{D}	4.21^{B}	19.46^{G}	57.65^{F}	6.81^{F}	11.39^{C}
Sh 3 MRSS	1.33^{B}	4.38^{A}	18.92^{H}	57.12^{G}	6.83^{E}	11.42^{B}

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

Table 3: Fatty acid composition of sesame seeds oil samples (%).

Fatty acid (F.A)	Carbon: chain	G 32 control	G 32 SRSS	G 32 RSS	G 32 MRSS	Sh 3 control	Sh 3 SRSS	Sh 3 RSS	Sh 3 MRSS
Palmitic	16:0	8.47	8.24	8.76	8.04	7.81	8.02	8.58	7.75
Heptadecanoic	17:0	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Stearic	18:0	5.53	5.55	5.02	5.66	8.13	8.03	6.78	8.22
Arachidic	20:0	0.61	0.59	0.60	0.63	0.63	0.62	0.61	0.64
Behenic	22:0	0.11	0.10	0.11	0.12	0.12	0.11	0.12	0.13
Total saturated		14.76	14.52	15.53	14.50	16.74	16.83	16.15	16.80
Palmitoleic	16:1	0.12	0.18	0.16	0.17	0.11	0.16	0.14	0.15
Heptadecenoic	17:1	0.03	0.03	0.04	0.03	0.03	0.05	0.04	0.03
Oleic	18:1	41.63	41.01	41.20	41.39	39.79	39.22	39.46	39.38
Linoleic	18:2	42.77	43.01	42.82	43.21	42.66	42.98	42.62	43.02
Linolenic	18:3	0.42	0.34	0.38	0.39	0.38	0.32	0.31	0.33
Gadoleic	20:1	0.23	0.26	0.24	0.26	0.25	0.24	0.22	0.29
Total unsaturated		85.20	84.83	84.84	85.45	83.22	82.97	82.79	83.20
T. saturated /T. unsaturated		0.17	0.17	0.17	0.17	0.20	0.20	0.20	0.20

for the control in both G 32 and Sh 3 seeds samples and significant ($p<0.05$) differences were found among the treatments (Table 2).

Fatty Acid Composition and Calculated Oxidizability Value of Sesame Seeds Oil Samples: The fatty acid composition of seed oils varies widely among different plant species. Unsaturated fatty acids (USFAs) have favorable effect and positive health benefit than saturated fatty acid (SFAs) [37]. Fatty acids were identified in oils of raw and treated sesame seeds oil samples. These fatty acids vary in carbon chain length and in the number of unsaturated (double) bonds present. The composition of fatty acids of sesame seeds oil presented in Table 3. Palmitic (16:0), Heptadecanoic (17:0), Stearic (18:0), Arachidic (20:0), Behenic (22:0), Palmitoleic (16:1), Heptadecenoic (17:1), Oleic (18:1), Linoleic (18:2), Linolenic (18:3) and Gadoleic (20:1) fatty acids were observed in the oil samples. The total saturated and unsaturated fatty acid composition of raw sesame seeds oil, G 32 and Sh 3 are 14.76, 16.74% and 85.20, 83.22%, respectively and the most abundant fatty acid is Linoleic acid. The major saturated fatty acids in roasted sesame seeds oil samples were Palmitic (7.75- 8.76%), Stearic (5.02- 8.22%) acids with small Arachidic acid (0.59- 0.64%). The main unsaturated fatty acids are linoleic (42.66- 43.21%) and oleic (39.22- 41.63%) acids (Table 3). Sesame seeds oil can be classified in the oleic-linoleic acid group. The results obtained are in agreement with those reported by Teco Finance Export [38].

The USFAs contents in the studied cultivars were higher than SFAs. Oleic and linoleic acids were the two dominant fatty acids in the sesame seed oil according to 80 - 85% of the total amount, whereas palmitic and stearic acids were present at 13 to 16% (Table 3). In Li *et al*. [39] study the sesame fatty acid pattern is also the same. The determined fatty acids and the calculated ratios did not show any changes under roasting conditions and no difference was observed (Table 3). In addition, the profitable SFAs to USFAs ratio can be considered as

Table 4: Calculated oxidizability value (Cox) of raw and roasted sesame seeds samples

Sample	Cox
G 32 control	4.91
G 32 SRSS	4.91
G 32 RSS	4.90
G 32 MRSS	4.95
Sh 3 control	4.87
Sh 3 SRSS	4.89
Sh 3 RSS	4.85
Sh 3 MRSS	4.90

Table 5: Phenolic compounds of sesame seeds samples (µg/ 100gm dry weight)

Phenolic acid	G 32 control	G 32 SRSS	G 32 RSS	G 32 MRSS	Sh 3 control	Sh 3 SRSS	Sh 3 RSS	Sh 3 MRSS
Gallic	3.39	4.96	4.52	5.12	13.74	14.68	15.86	17.64
Pyrogallol	29.69	41.79	51.12	73.26	103.04	197.77	166.76	257.57
Protocatechuic	19.79	84.25	35.14	31.13	60.49	35.44	52.65	39.40
Catechol	14.76	87.20	40.63	37.44	100.51	49.82	67.03	81.62
Catechin	280.35	117.47	173.56	125.59	319.86	267.40	220.05	185.46
Chlorogenic	75.70	75.49	68.70	66.64	135.53	130.18	122.04	117.63
ρ-Coumaric	6.90	3.24	2.47	1.57	8.26	4.74	2.88	2.18
Caffeic	14.45	13.60	13.38	9.89	107.05	92.65	79.07	88.68
Vanillic	4.13	7.36	5.92	6.78	6.29	9.83	8.44	13.29
Caffeine	57.60	78.44	62.58	61.00	56.67	66.86	72.57	74.59
Ferulic	14.65	9.99	9.68	8.95	41.18	18.58	16.62	18.65
Ellagic	1076.40	729.11	772.27	1143.50	1786.30	1547.83	1484.21	1961.48
Cinnamic	6.09	5.86	5.78	4.01	7.83	6.47	4.29	4.32
Benzoic	23.40	62.37	86.50	100.16	43.41	76.68	102.28	400.66
Syringic	1.94	1.90	1.82	1.78	1.74	1.59	1.56	1.43
Chrysin	4.50	5.07	5.21	4.96	4.30	4.78	5.05	4.75

useful index to measure edible oils quality [40]. The ratio of SFAs to USFAs in analyzed oil samples was found between 0.17 to 0.20, which clearly indicated the high amount of USFAs and can be positively considered from the nutritional point of view.

The Cox value of unroasted and roasted samples was also determined. Table 4 shows that G MRSS and Sh RSS samples had the maximum (4.95) and minimum (4.85) Cox values, respectively. The Cox value index is calculated based on USFAs percentages, therefore more comprehensive experimental studies about tendency of sesame oil oxidation such as rancidity test or total polar material measurement (TPM) are recommended. Other supportive research showed roasted sesame oil was more stable to oxidation than unroasted sesame oil, the remarkable oxidative stability of sesame oil is relates to the presence of lignan compounds as well as tocopherols [41, 42, 43]. The Cox value results demonstrated that sesame oil is almost stable and it could be used for protection of vegetable oils against oxidative deterioration.

Phenolics Acid Fractionation of Sesame Seeds Samples: The composition of phenolic acids in sesame seeds samples is tabulated in Table 5. From these data it is clear that sesame seeds samples contained many phenolic acids in variable levels. Ellagic, chlorogenic, catechin, pyrogallol and benzoic acid were presented in reasonable amounts both in control and roasted samples. The results of HPLC had identified also, catechol, vanillic, caffeic, *p*-hydroxybenzoic acid and chrysin acids as phenolic constituents of sesame seeds samples. Caffeine and benzoic acids were also presented in sesame seeds samples. The content of caffeine and benzoic acids were increased in some samples, amounting to, 61.00, 74.59 and 100.16, 400.66, for G 32 MRSS and Sh 3 MRSS, respectively, as compared with 57.60, 56.67, 23.40, 43.41 µg acid / 100 gm dry weight for the control in both G 32 and Sh 3. In general, the content of polyphenolic acids presented in sesame seeds samples was influenced by thermal treatment and time. The Sh 3 MRSS sample contained a higher content of ellagic (1961.48), vanillic (13.29), gallic (17.64) and pyrogallol (257.57 µg acid / 100

gm dry weight) acids than the all samples under study. On the other hand, the contents of ferulic, caffeic, catechin, *p*-coumaric, cinnamic acids were decreased in G 32 SRSS, G 32 RSS, G 32 MRSS, Sh 3 SRSS, Sh 3 RSS and Sh 3 MRSS samples as compared with control seeds. The increase in phenolic acids in Sh 3 MRSS seeds was due to the release of phenolics from the sesame seeds during roasting. It is clear that the roasting by microwave might accelerate more phenolic compounds releasing from the breakdown of cellular constituents.

CONCLUSION

The data obtained in the present investigation pointed to that the changes in chemical composition, fatty acids and levels of all phenol classes might be due to the effect of roasting treatment on sesame seeds samples.

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