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EFFECT OF PROCESSING AND STORAGE AT DIFFERENT TEMPERATURES ON THE PHYSICOCHEMICAL AND MINERALS CONTENT OF SESAME SEEDS AND TEHINA

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Abstract

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The effect of tehina processing and storage during six months at 25 and 35°C on the physicochemical and minerals of sesame seeds and tehina was evaluated. Chemical composition results showed that tehina samples had higher contents of dry matter, fat and protein than that in raw, dehulled unroasted and roasted sesame seeds. Tehina storage period and temperature did not significantly ($P \leq 0.05$) influence the chemical composition. ΔE and chroma were the highest in roasted sesame seeds. Tehina storage period and temperature were increased ΔE and chroma significantly. The acidity results of tehina increased significantly during six months at 25°C and 35°C. Raw sesame seeds had the lowest peroxide values (0.48 meq O_2/Kg oil). Also, storage of tehina or six months at 25°C and 35°C increased peroxide values. Water activity was lowest in tehina followed by raw and roasted sesame seeds. Tehina storage period and temperature did not change the water activity of any of the samples. Phosphorus was the highest value within mineral contents (Na, Ca, K, and P) of sesame seeds and tehina. Ca was low in all samples, while Na, K and P were found in high amounts.

Key words: tehina; sesame seeds; physicochemical properties

Introduction

Sesame (*Sesamum indicum L.*) plays an important role in human nutrition., It's seeds are used essentially for the production of oil, but also in the production of the paste called tehina and in food formulations such as halaweh (sweetened tehina), java beans and salads (Abou-Gharbia et al., 2000; Abu-Jdayil et al., 2002). The chemical composition of sesame shows that the seed is an important source of oil (44–58%), protein (18–25%), carbohydrate (13.5%) and ash (5%) (Elleuch et al., 2007). The oil fraction is remarkably stable to oxidation (Abou-Gharbia et al., 2000). Oxidative stability of sesame oil is superior to that of other vegetable oils although it contains nearly 85% unsaturated fatty acids (Sonntag, 1981). This could be attributed to endogenous antioxidants (lignans) together with tocopherols (Yoshida et al., 1995).

Roasting of sesame seeds is the most significant step in tehina processing that causes important physical, chemical, structural and sensorial changes (Yoshida and Kajimoto, 1994). Sesame roasting is carried out to enhance flavor, desired color and texture changes that ultimately increase the overall palatability (Shahidi et al., 1997). Color is one of the most important appearance attributes of food materials, since it influences consumer acceptability (Maskan, 2001). It is used for process control during roasting, because the brown

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pigments increase as the browning and caramelization reactions progress (Moss and Otten, 1989). In Jordan about 30 commercial plants, some of which are equipped with a modern production lines and are automated, produce tehina. Major concerns facing the tehina industries are the production of a product with proper consistency, emulsion stability, color and textural properties (Abu-Jdayil et al., 2002). Therefore, this work is important in terms of the estimation of physicochemical properties of sesame seeds and tehina. In this investigation, the effect of storage time for six months and temperatures (25°C and 35°C) on some physiochemical properties of sesame seeds (raw, dehulled unroasted and roasted) and tehina samples including chemical analysis, minerals content, acidity and peroxide value, water activity, and color were studied.

Materials and Methods

Sample collection

Sesame seeds (row seeds, dehulled unroasted seeds, roasted seeds) and tehina samples were obtained from the Balsam Manufacturing Company, Amman-Jordan.

Sample preparation

Tehina produced by Balsam Manufacturing Company by cleaning and sieving row sesame seeds then they soaked in water for two hours (at room temperature) in preparation for dehulling by electronic peeler. Dehulled sesame seeds and coats were separated by soaking in a saturated sodium chloride solution. Dehulled seeds were then washed with potable water to remove salt residues. Seeds were roasted in a steam double jacketed tunnel (130°C) with mixer. Finally, roasted sesame seeds milled to a viscous paste using stone mills. After milling, tahini was filled into 250 g plastic containers. Tehina samples were stored at two different temperatures (25°C and 35°C) during six months until the time of analysis.

Physiochemical and chemical analysis

Dry matter, ash, protein, fat and crude fiber were determined for sesame seeds (raw, dehulled unroasted and roasted) and tehina samples stored during six months at different temperatures (25°C and 35°C) and calculated on dry weight basis according to the standard approved in AOAC (1984). Three replicates were used to calculate the mean value. Carbohydrate content of sesame samples were calculated by difference according AOAC (1984).

Color measurement

Color of sesame seeds (raw, dehulled unroasted and roasted) and tehina were determined by a colorimeter (12MM Aperture U 59730 Inc., Pittsford, New York, USA). Color was determined by reflection mode and expressed as L* (luminosity), a*(greenness and redness) and b*(blue and yellow) parameters. The colorimeter was calibrated using a standard white ceramic reference tile (Commission International-ale de I`Eclairage L* = 97.91, a* = – 0.68, and b* = +2.45. Three replicates were used to calculate the mean value. The net difference of color (ΔE) and chroma were calculated using the following equations:

$$\Delta E = [(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2]^{1/2},\ \text{chroma} = [(a)^2 + (b)^2]^{1/2}.$$

Acidity

The acidity (expressed as percent of oleic acid) was determined by titration of oil dissolved in methanol/diethyl ether (1:1, v/v) with 0.1 M sodium hydroxide solution with 1 % phenol naphthalene indicator. Three replicates were used to calculate the mean value (AOAC 1984).

Peroxide value

Peroxide value (expressed as milliequivalents of active oxygen per kilogram of oil ($meqO_2/Kg$)) was determined as follows: a mixture of oil and chloroform/acetic acid 3:2 (v/v) was allowed to react in the dark (at room temp) with saturated potassium iodine solution. The free iodine was then titrated with 0.01 M sodium thiosulfate solution in the presence of starch indicator. Three replicates were used to calculate the mean value (AOAC 1984).

Water activity determination

Water activity (a_w) was determined using (Aqua Lab 3, USA). Sample bowl was filled stirred and mixed sesame seeds or tehina and placed in the measuring chamber. Three replicates were used to calculate the mean value.

Mineral determination

The sesame seeds and tehina samples were ashed at 550°C. Ash was dissolved in hydrochloric acid, and the volume was made up to 50 ml using a volumetric flask. A flame photometer (model, BWB XP, UK) was used to determine calcium, sodium and potassium in sesame seeds (raw, dehulled unroasted and roasted) and tehina samples. Phosphorous was determined according to the procedures reported by Fiske and Subbarow (1925). Three replicates were used to calculate the mean value.

Statistical analysis

Data were analyzed using the general linear model (GLM) procedure with JMP statistical package (JMP Institute Inc., Cary, NC). Means were separated by LSD analysis at a least significant difference of 0.05 P-value.

Results and Discussion

Chemical composition

Data on chemical composition of sesame seeds and tehina product stored for six months at two temperatures (25 and 35°C) are shown in Table 1. Dry matter content varied significantly**;** The tehina product had the highest values dry matter however there was no significant variation in due to storage temperature (25 and 35°C). Dry matter levels ranged from 67.4% (unroasted dehulled sesame seeds) to 98.8% (tehina stored for two months at 35°C). Elleuch et al. (2007) found slightly lower values of dry matter (95.3%) in row sesame seeds. Dry matter content of unroasted dehulled sesame seeds was the lowest among all other samples, this could be due to seeds soaking in water during processing, this led to water entrance through membranes inside seeds.

Coats of dehulled sesame seeds humidified with water as a result of water injection used to facilitate dehulling process (Elleuch et al., 2007). Roasted sesame seeds have higher dry matter value; this could be due to that roasting process using high temperature which decreases moisture content within seeds. Increased values of dry matter content of tehina were noted in the investigated samples. No significant difference was found in dry matter content of tehina samples stored during six months at two different temperatures (25 and 35°C).

Ash content of sesame seeds and tehina product stored for six months at two temperatures (25 and 35°C) varied significantly. The tehina product had the highest ash content and there was no significant variation in levels of ash content of due to storage temperature (25 and 35°C). The highest ash content was found in raw sesame seeds (5.2%) while the lowest was found in roasted seeds (3.5%) as shown in Table 1.

Elleuch et al. (2007) reported that ash content of raw seeds was the highest due to high ash content of coats. Our value for raw seeds was comparable to that of Borchani et al. (2010) value (5.4%) and higher than the values reported by Nzikou et al. (2009) and Abou-Gharbia et al. (1996). The differences in ash content in tehina samples were not significant due to storage temperatures. Higher values of ash content were reported by Sawaya et al. (1985).

Generally fat content was high in sesame seeds (raw, dehulled unroasted and roasted) and tehina, ranging from 50.9% (raw seeds) to 56.8% (tehina stored for four months at 35°C). Fat content in raw sesame seeds found to be lower than that reported by Borchani and et al. (2010) (52.67%) and higher than that found in local and introduced Sudanese sesame seeds (El Khier et al., 2008). Roasted sesame seeds have higher content of fat compared to raw and dehulled unroasted sesame seeds but the fat is lower than in tehina. Tehina stored for six months at two different temperatures did not vary significantly. A comparable fat content was found

Table 1

Dry matter and chemical composition (%) of sesame seeds and tehina stored during six months at different temperatures[#]

Treatments	Storage time (month)	Storage temp. (°C)	Dry Matter (%)	Ash (%)	Fat (%)	Protein (%)	Crude Fiber (%)	Carbohydrates (%)
Raw Sesame Seeds	0	25	*96.6 ± 0.17 c	5.2 ± 0.04 a	51.0 ± 0.38 c	24.6 ± 0.84 b	3.8 ± 0.14 a	15.5 ± 0.82 b
Unroasted Dehulled Sesame Seeds	0	25	67.4 ± 0.40 d	4.4 ± 0.13 b	33.3 ± 0.23 d	27.1 ± 0.92 a	3.5 ± 0.06 b	31.6 ± 1.05 a
Roasted Sesame Seeds	0	25	98.2 ± 0.20 b	3.5 ± 0.03 d	55.2 ± 0.32 b	26.3 ± 0.19 a	3.1 ± 0.10 c	11.9 ± 0.55 c
Tahineh	0	25	98.7 ± 0.11 a	3.6 ± 0.01 c	56.5 ± 0.22 a	26.5 ± 0.71 a	2.2 ± 0.02 d	11.2 ± 0.89 c
	2	25	98.7 ± 0.09 a	3.6 ± 0.01 c	56.6 ± 0.15 a	26.2 ± 0.42 a	2.3 ± 0.13 d	11.4 ± 0.21 c
	2	35	98.8 ± 0.09 a	3.6 ± 0.00 c	56.7 ± 0.11 a	26.4 ± 0.34 a	2.2 ± 0.15 d	11.1 ± 0.33 c
	4	25	98.7 ± 0.11 a	3.6 ± 0.03 c	56.7 ± 0.25 a	26.3 ± 0.39 a	2.1 ± 0.07 d	11.3 ± 0.23 c
	4	35	98.6 ± 0.12 a	3.6 ± 0.04 c	56.8 ± 0.38 a	26.1 ± 0.41 a	2.2 ± 0.08 d	11.3 ± 0.40 c
	6	25	98.7 ± 0.09 a	3.6 ± 0.02 c	56.7 ± 0.42 a	26.2 ± 1.09 a	2.2 ± 0.03 d	11.3 ± 0.73 c
	6	35	98.7 ± 0.05 a	3.6 ± 0.02 c	56.6 ± 0.17 a	26.5 ± 0.69 a	2.2 ± 0.08 d	11.2 ± 0.65 c

[#]All values are means of three replicates and calculated on dry matter basis

*Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

Temp = temperatures

by Akbulut and Coklar (2007) in tehina (56.42%).

Tehina chemical composition reported by Sawaya et al. (1985) who found that fat content was higher than that in the current investigation (58.9%). Data on protein content are shown in Table 1. Values ranged from 24.6% (raw seeds) to 27.0% (dehulled unroasted seeds). Elleuch et al. (2007) found higher protein content (25.8%) in raw sesame seeds than found in the present investigation. Raw sesame seeds contain less protein than dehulled unroasted seeds, which could be due to a low protein in seed coat (Elleuch et al., 2007). On the other hand no significant difference was found among dehulled unroasted seeds, roasted seeds and tehina samples. Protein content in the investigated tehina was higher than the value reported by Akbulut and Çoklar (2007) and by Sawaya et al. (1985).

Fiber content of sesame samples were also determined and found to vary significantly ranging from 2.1% (tehina stored for four months at 25°C) to 3.8% (raw sesame seeds). Comparable values were reported by Egbekun and Ehieze (1997) and Nzikou et al. (2009) in raw sesame seeds. Lower fiber content in dehulled seeds and tehina samples could be because raw sesame seed coats are high fiber in content (Elleuch et al., 2007). No significant differences occurred in crude fiber content in tehina samples stored during six months at two different temperatures. Tehina fiber content found to be in agreement with value reported (2.3%) by Sawaya et al. (1985).

Carbohydrate content ranged from 11.0% (dehulled unroasted seeds) to 15.5% (raw seeds). Carbohydrate content of raw seeds was higher than in tehina samples and roasted seeds. This could be a temperature effect during the roasting process. The reduction caused by roasting was investigated by Elleuch et al. (2007) in sesame coats. Unroasted dehulled seeds exhibited the highest value of carbohydrate content of all samples. Our data on carbohydrates content in tehina was lower than that reported by Borchani et al. (2010) (13.5%).

Color

Table 2 shows the color attributes in sesame seeds and tehina stored for six months at 25°C and 35°C. Color system consists of a luminance or lightness component (l*) and two chromatic components: a* component for green (−a) to red (+a), b* component from blue (−b) to yellow (+b) colors, ΔE (L*, a* and b*) and chroma (a* and b*) values. All color parameters varied significantly during processing and storage. L* values varied significantly and ranged from 19.7 (tehina at zero time) to 30.2 (roasted seeds). Raw sesame seeds had low L* values (darker) than dehulled unroasted seeds; this could be due to lower L* values in raw seeds coats. As this was explained by Elleuch et al. (2007) who found that

Table 2

Color parameters: L*, a*, b*, ΔE and chroma of sesame seeds and tehina stored during six months at different temperatures[#]

Treatments	Storage time (month)	Storage temp. (°C)	L*	a*	b*	ΔE	Chroma
Raw Sesame Seeds	0	25	*21.5 ± 1.07 cd	3.1- ± 0.24 a	14.9 ± 1.25 c	26.4 ± 1.05 d	15.2 ± 1.28 c
Unroasted Dehulled Sesame Seeds	0	25	25.7 ± 2.36 b	4.9- ± 0.50 c	13.5 ± 0.23 d	29.4 ± 2.22 c	14.4 ± 0.37 c
Roasted Sesame Seeds	0	25	30.2 ± 2.51 a	5.3- ± 0.10 c	20.8 ± 0.95 a	37.1 ± 2.39 a	21.4 ± 0.94 a
Tahineh	0	25	19.7 ± 0.17 d	3.8- ± 0.23 b	12.2 ± 0.36 e	23.5 ± 0.36 e	12.8 ± 0.41 d
	2	25	22.0 ± 0.90 c	5.0- ± 0.05 c	13.3 ± 0.52 de	26.3 ± 0.52 d	14.2 ± 0.50 c
	2	35	22.8 ± 0.19 c	5.2- ± 0.37 c	13.5 ± 0.62 d	27.1 ± 0.54 d	14.5 ± 0.72 c
	4	25	25.4 ± 0.59 b	6.2- ± 0.31 d	15.9 ± 0.56 cb	30.6 ± 0.72 bc	17.1 ± 0.63 b
	4	35	25.5 ± 0.61 b	6.2- ± 0.15 d	15.8 ± 0.59 cb	30.6 ± 0.84 bc	16.9 ± 0.59 b
	6	25	26.0 ± 0.22 b	6.5- ± 0.36 de	16.8 ± 0.77 b	31.6 ± 0.29 b	18.1 ± 0.78 b
	6	35	26.1 ± 0.18 b	6.7- ± 0.24 e	16.4 ± 0.55 b	31.6 ± 0.48 b	17.8 ± 0.58 b

[#]All values are means of three replicates

*Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

Temp = temperature

L* values was lower in sesame coats than in whole sesame seeds; they also found that the roasting process increases L* value so this may explain why roasted seeds had higher L* values unroasted dehulled seeds.

The high L* values in roasted sesame seeds could be related to scattering light from oil droplets embedded in protein matrix (Kahyaoglu and Kaya, 2006). L* value decreased after milling of roasted seeds.

Shahnawaz and Sheikh, (2008) found that lighter color indicates loss of redness since anthocyanins and lutein pigments are sensitive to heat during processing and lost their original color during storage at room temperature. On the other hand redness (a*value) reduction can lead to increase in whiteness (Kahyaoglu and Kaya, 2006). The a*values were found to vary significantly and ranged from -6.7 (tehina stored for six months at 35 °C) to -3.1 (raw sesame seeds). Negativity indicates greenness of sesame samples. Low a* value of raw seeds is may be related to the higher a* value in coats than whole seeds (Elleuch et al., 2007). Significant reduction in a*value (greenness increased) resulted from dehulling and roasting which caused an increase in green pigment and particularly in chlorophyll content (Elleuch et al., 2007).

a* value of tehina samples decreased considerably through the storage period. Ciftci et al. (2008) reported that the color of tehina is influenced by composition and by the presence of colorants, like carotene, green pigments, chlorophyll. Oomah et al. (2002) showed that microwave treatment of hempseed produced an increase in the oil chlorophyll pigment and a lower a*value related to greenness increment.

Yellowness (+ b*value) in sesame samples ranged from 12.2 (tehina at zero time) to 20.8 (roasted seeds). This yellow color, which includes carotenoids, is beneficial, since it stimulates the appearance without the use of primary colorants, such as carotenes and annattos, commonly used in the oil and fat industry (Oomah et al., 2000). Raw sesame seeds had higher b* values than in unroasted dehulled seeds. Decreasing in b-value may be related to dehulling process. Elleuch et al. (2007) found lower b* values of whole sesame seeds than that of seeds coats. The b* values significantly increased after roasting process**.** Our data agree with Elleuch et al. (2007) who investigated roasting effect on color of sesame coats. Kahyaoglu and Kaya (2006) found that the b*values increased with increasing roasting time and temperature.

Tehina samples b* values increased significantly during the storage period. Kongkiattikajorn (2008) reported that the storage of rice cause increasing in b* value that came from brown pigments increased during storage. Total color difference (ΔE) values were observed to vary significantly and ranged from 23.5 (tehina at zero time) to 37.1 (roasted sesame seeds). Variation in (ΔE) related to changes in the L*, a* and b* values. Increasing color parameters after roasting lead to highest ΔE in roasted seeds. Tehina samples ΔE found to be increased significantly during storage period and not affected by different temperatures used. Chroma values varied and ranged from 12.8 (tehina at zero time) to 21.8 (roasted sesame seeds) and related to a* and b* values. No significant difference was found in chroma values between raw sesame seeds and unroasted dehulled seeds. The roasting process increased chroma in roasted seeds. Storage of tehina samples lead to gradual increase of chroma values.

Acidity and peroxide value

Acidity of sesame oil extracted from sesame seeds and tehina are shown in Table 3. There were significant differ-

Table 3

Peroxide value (meq/kg oil) and acidity (mg NaOH/kg oil) of sesame seeds and tehina stored during six months at different temperatures[#]

Treatments	Storage time (month)	Storage temp. (°C)	Peroxide value meq/kg oil				Acidity mg NaOH/kg oil			
Raw Sesame Seeds	0	25	*0.48	±	0.01	g	0.65	±	0.05	a
Unroasted Dehulled Sesame Seeds	0	25	0.93	±	0.01	f	0.35	±	0.02	e
Roasted Sesame Seeds	0	25	1.35	±	0.04	c	0.39	±	0.04	de
Tahineh	0	25	0.92	±	0.01	f	0.37	±	0.01	de
	2	25	1.18	±	0.02	e	0.41	±	0.01	cd
	2	35	1.21	±	0.01	e	0.43	±	0.02	bc
	4	25	1.28	±	0.02	d	0.43	±	0.01	bc
	4	35	1.33	±	0.03	c	0.45	±	0.01	b
	6	25	1.40	±	0.04	b	0.44	±	0.02	bc
	6	35	1.47	±	0.01	a	0.46	±	0.01	b

[#]All values are means of three replicates

*Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

Temp = temperatures

ences among sesame samples and values ranged from 0.35 mg NaOH/g (unroasted dehulled seeds) to 0.65 mg NaOH/g oil (raw seeds). Acidity of raw seed oil was the highest, which could be due to acidity of seeds coat, so acidity decreased significantly after dehulling, reducing acidity in raw seeds (Mohammed and Hamza, 2008; 0.5 mg kOH/g oil). Zanardi et al. (2008) found slightly higher values than that found in our result.

Unroasted dehulled seeds oil had lower acidity levels roasted seeds oil**.** This value agreed with that of Yoshida (1994), who found an appreciable increase in free fatty acids after roasting. Also, Fukuda (1990) reported that roasted sesame oils contain more free fatty acids and fat-soluble substances. Acidity in tehina samples varied significantly through storage time and temperature. Acidity of raw seeds oil was higher than in tehina. Borchani et al. (2010) found that acidity of raw seed oil was higher than in tehina oil acidity.

The value shows significant increased in acidity of tehina samples from 0.37 mg KOH/g oil to 0.46 mg KOH/g oil during the six months storage period**.** This increase of acidity could be explained by hydrolysis of triglycerides to free fatty acids (Gutiearrez and Fernaandez, 2002; Pristouri et al., 2009; Ciafardini and Zullo, 2002). Temperature effect on aciditys at 25°C and 35°C were not significant with some mathematical increase. A significant but slight increases in aciditys of tehina were observed during the storage period. The peroxide value of sesame seeds (raw, dehulled unroasted and roasted) and tehina oil are shown in Table 3**.** Values ranged from 0.48 meq O_2/kg oil (raw sesame seeds) to 1.47 meq O_2/kg oil (tehina stored for six months at 35°C). Oil extract from raw seeds had the lowest peroxide value which could be due to higher phenolics and antioxidant compounds found in this investigation. Abou-Gharbia et al. (2000) reported comparable peroxide values in raw sesame seeds oil (0.46 meq O_2/kg oil) to our value**.** Antioxidant compounds in sesame hulls transfer to the oil during extraction enhancing its oxidative stability (Abou-Gharbia et al., 1997). Also, Ullah et al. (2003) reported that natural and synthetic antioxidants can decrease peroxide value of oil in sunflower and soybean.

Dehulled seed oil peroxide value increased significantly in raw seeds oil but was lower than that of roasted seeds oil. Yoshida, (1994) reported that fresh oil from roasted sesame seeds had much higher PV (5 meq/kg oil) than that found in the present study (1.35 meq/kg oil), and a lower value than that of roasted seeds oil (0.88 meq/kg oil) reported by Abou-Gharbia et al. (2000). Yoshida and Takagi (1997) reported that roasted sesame seeds oil peroxide value increased with increasing roasting temperature and time. Decreasing in peroxide value was observed in tehina at zero time when compared in roasted seeds oil. Furthermore, we noticed that tehina samples peroxide values varied significantly. Generally, peroxide values were affected by storage time and temperature**.** Peroxide value of tehina were investigated by Abou-Gharbia et al. (1996) and found to be comparable (0.9 meq/kg oil) to our values**.** They also found that peroxide values of stored tehina increased with increasing time and temperature. Abou-Gharbia et al. (1996) reported that sesame oils prepared under different processing conditions, exhibited an increase in their PV with storage time. Peroxide values of raw sesame seed, tehina and olive oils were studied by Borchani et al. (2010). Lower values were found in raw sesame seeds and tehina than that in olive oil.

Water activity

Water activity (aw) of sesame seeds and tehina are presented in Figure 1. Values varied significantly and ranged from 0.21 (tehina stored during 0, 2, 4 and 6 months) to 0.96 (unroasted dehulled seeds). Values of sesame samples (except in unroasted dehulled seeds) showed a scant availability of water which excludes any possibility of microbial development. Raw seeds also had low water activity. Water activity of raw seeds was investigated by Borchani et al. (2010), who found higher value (0.51) than in the present study. Water activity was significantly increased in dehulled unroasted seeds which could be due to high water content during processing. Lower water activity was found in roasted seeds than in raw and dehulled unroasted seeds. Tehina samples had lower water activity content than sesame samples without significant difference through storage during six months at different temperatures. Water activity contents of tehina samples were analyzed from manufacturing plants in Jordan and ranged from 0.12 to 0.18 (Yamani and Isa, 2006). This agrees with Akbulut and Çoklar, (2007) who found comparable water activity values in tehina (0.193).

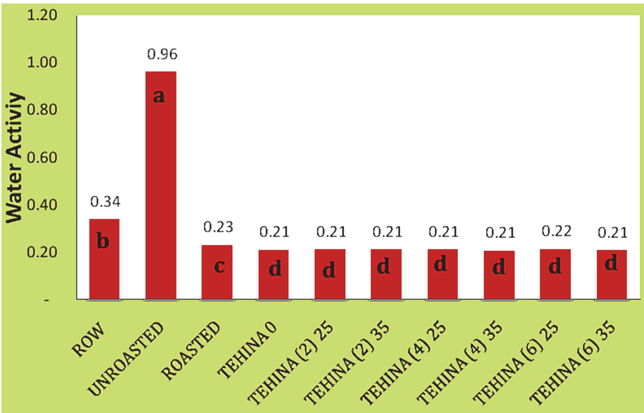

Fig. 1. Water activity contents of sesame seeds and tehina stored during six months at different temperature

Minerals analysis

Mineral contents (Na, Ca, K and P) were determined as shown in Table 4. Sodium content of sesame seeds and tehina is present in Table 4. Values varied significantly and ranged from 518.9 mg/100g (raw sesame seeds) to 287.8 mg/100g (tehina stored for four months at 25 °C).

Raw sesame seeds contained the highest amount of sodium among all investigated samples; this could be related to the high amount of sodium in the seed coat. Elleuch et al. (2007) investigated the raw sesame seed coat and found high content of sodium. Sodium value in raw sesame seeds was higher than that found by Nzikou et al. (2009) and was lower than sodium values determined in raw groundnut (710 mg/100 g) (Ayoola and Adeyeye, 2010). Unroasted dehulled seeds have lower sodium content than raw sesame seeds and higher than roasted and tehina. Samples exhibited a significant reduction after roasting process. Sodium content was higher in tehina samples than that reported by Sawaya et al. (1985) and El-Adawy and Mansour (2000). No significant differences between roasted seeds and tehina samples stored during six months at different temperatures.

Also calcium content was determined and found to vary significantly. Raw seeds contained the highest calcium content (72.2 mg/100 g) and tehina stored for four months had the lowest value (19.2 mg/100 g). A significant decrease was noticed during sesame seed processing. The variation in values of raw and dehulled unroasted seeds is possibly due to processing**.** Roasting could be responsible for lower values in roasted seeds and tehina samples. Where higher amount of calcium found in sesame coats than that in raw seeds, significant reduction happened in coat content of calcium after roasting (Elleuch et al., 2007). Raw sesame seeds value were found to be lower than that determined by Nzikou et al. (2009) and Borchani et al. (2010). Tehina samples have lower calcium content than value obtained by Sawaya et al. (1985) and El-Adawy and Mansour (2000). No significant differences were noticed between roasted seed and tehina samples.

Table 4 presents data for sesame seeds (raw, dehulled unroasted and roasted) and tehina content of potassium. The values differed significantly and ranged from 270.2 mg/100 g (tehina stored during four months at 35°C) to 407.3 mg/100 g (raw sesame seeds). Unroasted dehulled seeds contained less potassium than raw seeds. The roasting effect could result in lower content of potassium than in roasted seeds and tehina samples; this in agreement with Okorie (2010) in other types of seeds (*Artocarpus communis)***.** Potassium content was reduced after roasting.

Phosphorus exhibited the greatest variation among all other investigated minerals in sesame samples. Values

Table 4

Mineral composition (mg/100g) of sesame seeds and tehina stored during six months at different temperatures[#]

Treatments	Storage time (month)	Storage temp. (°C)	Sodium	Calcium	Potassium	Phosphorus
Raw Sesame Seeds	0	25	518.9 ± 46.58 a	72.2 ± 2.17 a	407.3 ± 7.97 a	504.7 ± 3.53 c
Unroasted Dehulled Sesame Seeds	0	25	361.0 ± 3.96 b	36.8 ± 1.61 b	349.1 ± 13.86 b	713.8 ± 7.44 a
Roasted Sesame Seeds	0	25	289.3 ± 15.18 c	20.6 ± 0.92 c	274.3 ± 18.94 c	572.6 ± 5.90 b
Tahineh	0	25	288.6 ± 10.63 c	20.4 ± 1.74 c	276.5 ± 2.20 c	570.8 ± 4.42 b
	2	25	293.7 ± 8.06 c	19.9 ± 0.46 c	276.4 ± 1.62 c	574.8 ± 2.86 b
	2	35	294.0 ± 9.16 c	19.9 ± 1.98 c	272.9 ± 8.85 c	571.9 ± 3.69 b
	4	25	287.8 ± 10.06 c	19.2 ± 0.47 c	271.3 ± 1.41 c	573.7 ± 5.58 b
	4	35	292.0 ± 12.11 c	19.2 ± 0.62 c	270.2 ± 9.29 c	574.4 ± 4.75 b
	6	25	290.7 ± 10.74 c	19.3 ± 0.82 c	275.9 ± 1.24 c	572.9 ± 5.48 b
	6	35	292.6 ± 5.88 c	19.3 ± 0.70 c	272.7 ± 2.19 c	573.1 ± 4.50 b

[#]All values are means of three replicates calculated on dry matter basis

*Means in the same column with the same letter are not significantly different ($P \leq 0.05$)

Temp = temperatures

ranged from 504.7 mg/100 g (raw sesame seeds) to 713.8 mg/100 g (dehulled unroasted seeds). Phosphorus concentration was lowest in raw seeds. Dehulling increased the potassium concentration significantly. The explanation of this difference could be due to low phosphorus concentration in seeds coats as found by (Elleuch et al., 2007). Raw seeds phosphorus concentration was found to be higher than determined by Nzikou et al. (2009) and Egbekun and Ehieze (1997). In tehina phosphorus content was lower than that found by Sawaya et al. (1985). In roasted seeds and tehina phosphorus amount decreased significantly compared with dehulled unroasted seeds.

Values were found to be in agreement with results of Okorie (2010) for phosphorus in *Artocarpus communis.* No significant difference occurred found among tehina samples stored during six months at different temperatures.

Conclusions

Chemical composition of the investigated samples varied significantly during tehina processing, on the other hand, storage period and temperatures had no significant effect on chemical composition. Color parameters (L*, a*, b*, ΔE and chroma) increased significantly during the roasting process. Storage period increased these parameters significantly, while a* value decreased. Storage period and temperatures decreased the quality of extracted sesame oil by increasing of acidity and peroxide value. Low water activity content of tehina was found. Phosphorus, potassium and sodium were found in high concentrations, while calcium was found in low concentration in the investigated sesame samples. Storage period and temperatures had no effect on minerals contents but roasting process decreased minerals contents significantly.

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