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IMPACT OF ROASTING PROCESS ON THE QUALITY OF FLAXSEEDS

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ABSTRACT

The present work was carried out to study the effect of roasting on some physico-chemical characteristics of flaxseeds. Fatty acids & sterols compositions and physico-chemical characteristics of extracted oil from unroasted and roasted flaxseeds were analyzed. Roasting of flaxseeds was carried out at temperatures of 160, 180 °C for 5, 10 and15 min. Results revealed that moisture content was decreased and oil content was increased after the roasting of flaxseeds. Also, the results showed that roasting process was occurred little effect on the fatty acids profile. The total sterols in the roasted flaxseeds recorded higher content than in the unroasted seeds. Further, the results revealed that minerals composition of flaxseeds showed that magnesium, phosphorous and calcium contents were 3875.89 mg/kg, 3125.26 mg/kg and 998.69 mg/kg, respectively in unroasted flaxseeds. Moreover, sodium and potassium contents recorded increment by the roasting process. No significant difference was observed between sesame candy bars (control) and flaxseed 25% candy bars.

Key Words: Roasting; Flaxseed, Sakha 5; Flaxseed candy bars.

INTRODUCTION

Flaxseed (*Linum usitatissimum*) is one of the oldest crops, cultivated for oil and fiber. It was used for medical purposes in ancient Egypt and Greece, and as an energy source. Flaxseed has nutritional and functional properties because it provides us with oil rich in omega-3, soluble dietary fibers, lignans, vitamin E, proteins and carbohydrates to satisfy basic needs of human diet and health maintenance **(Elsorady, 2020).** Flaxseed has high content of α-linolenic acid, an essential fatty acid, usually greater than 50% of the fatty acid composition. However, α-linolenic acid is sensitive to oxidation and therefore, flaxseed oil is usually cold-pressed from the seeds **(Choo *et al.*, 2007).** Also, flaxseeds have lignans, phenols and flavonoids **(Bernacchia *et al.*, 2014; Ganorkar and Jain, 2013).**

Roasting is an important treatment in various oil seeds intended for consumption as snacks or previously to extract the oil from the seeds. This treatment can cause desirable or undesirable changes in the physical, chemical and nutritional properties of the seeds and the extracted oil **(Veldsink *et al.*, 1999).** Roasting process facilitates antioxidants extraction by modifying the cellular structure. It has been previously reported that roasted seeds yielded oil with higher content of polyphenols (**Wijesundera *et al.*, 2008)** and tocopherols (**Kim *et al*., 2002).**

Use of whole raw flaxseeds in human nutrition could be limited by factors such as an unpleasant flavour and palatability characteristics that make them rather difficult to crack and chew, decreasing nutrient digestibility, and bioavailability. These limitations can be overcome by thermal pre-treatment. Roasting can improve both the flavour profile (adding a nutty flavour) and the capacity of flaxseeds to be broken up by chewing or grinding/milling **(Werner, 2008).** Moreover, roasting can also help to reduce contamination of the flaxseed surface with pathogenic fungi and bacteria as well as to decrease antinutrition content (i.e. cyanogenic glucosides) in the seeds **(Werner, 2008 and Tuncel *et al*., 2017).**

Roasting is an important step of food processing such as coffee, peanuts, and beans, resulting in important physical, chemical, structural, and organoleptic changes **(Ozdemir and Devres, (2000) ; Pittia *et al.*, 2001; Anjum *et al.*, (2006) ; Cammerer and Kroh, (2009).**

Therefore, the objective of this study was to compare the chemical composition, physicochemical parameters, fatty acid and sterols profiles between oils from unroasted and roasted flaxseeds at different temperatures (160 and 180°C) for different heating times (5, 10 and 15 min).

MATERIALS AND METHODS

Materials

Flaxseeds (*Linum usitatissimum*) (Sakha 5, CV) were obtained from Fiber Crop Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. The seeds were cleaned and roasted in convection oven at 160 and 180°C for 5, 10 and 15 min. After roasting, the seeds were allowed to cool at room temperature. After cooling (30 min), roasted samples were immediately ground. The raw and roasted samples were grinded using laboratory grinder.

Proximate composition

Moisture content, ash, fat, fiber, and protein were determined using the method of **AOAC (2012)** and total carbohydrate was determined by difference.

Minerals profile of flaxseed

Minerals including, calcium, magnesium, zinc, manganese, sodium and potassium were determined using an Atomic Absorption Spectrometry (GBC Avanta E, Victoria, Australia) according to **AOAC (2012).**

Extraction of flaxseed oil

Flaxseed oil was extracted by solvent extraction technique as described in **AOCS (2020).**Hexane used as solvent, was recovered by Rotary Evaporator Apparatus. The extracted oil was stored in dark brown glasses at (-20 °C) until used.

Physicochemical parameters

Refractive index (RI) (20ºC), free fatty acid (FFA) (as oleic acid, %), peroxide value (meq. O_2 / Kg oil), conjugated dienes, conjugated trienes, saponification values and unsaponifiable matter of extracted oil from raw and roasted flaxseeds were carried out according to **AOCS, (2020).** TBA number was determined according to **Allen and Hamilton (1989).** The TBA number calculated as mg malonaldehyde / kg oil.

Determination of fatty acids composition

Gas chromatography (Agilent 6890) was used for determination fatty acids of flaxseed oils. All GC measurements for each oil sample were made in triplicate and the average values were reported according to the methods of **Cossignani *et al*., (2005).**

Determination of sterols composition

A five g oil sample was dissolved in 3 ml of hexane, and then 0.5 m1 of 5∝-cholestane (0.4 mg ml $^{-1}$), internal standard was added. The mixture was saponified with sodium hydroxide solution in methanol (2N) at water bath for 1-2 h. Then, unsaponifaible matters were extracted. Then 1 µ1 of the sample extracted by unsaponifiable matter was injected into a Agilent 6890 series GC apparatus (setup:DB-5 capillary column, A N_2 carrier gas at 0.9 ml min^{-1} constant flow rate, split/splitless injector at 230°C in the splitless mode. Oven temperature: 50°C hold for 2 min, ramped to 230°C at 15°C min^{-1}, ramped to 310°C at 3°C min^{-1}, hold for 10 min. The internal standard method (5∝- cholestane) was used for quantification **(Szterk *et al*., 2010).**

Flaxseed candy bars preparation

Roasted flaxseed & sesame seed and combination between them were performed with fixed amount to ingredients (glucose syrup and vanilla) as mentioned in Table 1 for processing candy bars. The sesame and flaxseed were used in various combinations for better taste and texture and compare them with sesame candy bars as control sample.

Table 1. Treatment combinations of flaxseed candy bars

Treatment	Flaxseed	Sesame seed
Control	0	100
Flaxseed 25%	25	75
Flaxseed 50%	50	50
Flaxseed 75%	75	25
Flaxseed 100%	100	0

Sensory evaluation

Sensory evaluation was carried out to know the level of acceptance by consumers using score from 1 to 5, where 1 score for low acceptance and 5 score for high acceptance. It is used to analyze and interpret the responses to product that are perceived by sense of smell, colour, texture, flavour and overall acceptability.

Statistical analysis

Statistical analyses were conducted using SPSS program version 16.0. Treatment means were compared with Duncan's Multiple Range Test at probability P - of 5% level as indicated by **Duncan (1955).**

RESULTS AND DISCUSSION

Results of chemical composition of unroasted (control sample) and roasted flaxseeds at different temperatures for different times are shown in Table 2. A significant decrease in moisture content and increase in oil content was observed when compared with the unroasted seeds. The lowest moisture content was found in samples roasted at the highest temperature and the longest time (180 °C, 15 min). The changes observed in the chemical composition of roasted flaxseeds compared to unroasted flaxseeds were probably due to water elimination during roasting process. These results agree with **Liaotrakoon *et al.* (2016); Chauhan *et al.* (2018) and Waszkowiak *et al.* (2020). Mohamed and Awatif, (1998).**They reported that high amounts of oil were extracted from roasted sesame seeds. There were no significant differences in ash content among unroasted and roasted flaxseeds.

Table 2: Effect of roasting conditions on chemical composition of flaxseeds.

Characteristics	Roasting conditions						
	Unroasted	160 ° C			180 ° C		
		5 min	10 min	15 min	5 min	10 min	15 min
Moisture	$6.24±0.20^{f}$	$1.90±0.05^{e}$	$1.68±0.03^{cd}$	$1.59±0.03^{bc}$	$1.78±0.04^{de}$	$1.52±0.04^{b}$	$1.10±0.05^{a}$
Oil	$36.52±0.22^{a}$	$37.10±0.10^{b}$	$38.32±0.12^{d}$	$38.55±0.10^{e}$	$37.99±0.11^{c}$	$38.78±0.10^{f}$	$39.68±0.08^{g}$
Proteins	$14.85±0.30^{a}$	$15.12±0.25^{a}$	$15.55±0.20^{b}$	$15.86±0.22^{bc}$	$15.20±0.10^{a}$	$16.10±0.05^{cd}$	$16.42±0.07^{d}$
Fibers	$11.05±.04^{a}$	$11.07±0.02^{a}$	$11.25±0.05^{b}$	$11.32±0.02^{c}$	$11.20±0.04^{b}$	$11.40±0.05^{d}$	$11.54±0.03^{d}$
Ash	$3.08±0.03^{a}$	$3.08±0.03^{a}$	$3.12±0.02^{a}$	$3.07±0.05^{a}$	$3.12±0.01^{a}$	$3.11±0.02^{a}$	$3.09±0.02^{a}$
Carbohydrates	$28.25±0.79^{a}$	$31.73±0.44^{e}$	$30.08±0.42^{cd}$	$29.62±0.40^{bc}$	$30.70±0.30^{d}$	$29.09±0.22^{b}$	$28.15±0.21^{a}$

***different superscripts indicate significant differences ($p < 0.05$)**

The mineral contents in unroasted and roasted flaxseed are presented in Table 3. Magnesium (Mg, 3875.89 mg/kg) was the primary mineral in unroasted flaxseeds, followed by phosphorous (P, 3125.26 mg/kg) and Calcium (Ca, 998.69 mg/kg). These results agree with **Hady and Elsorady, (2020). Morris (2007)**.It was reported that flaxseed is a good source of minerals especially, phosphorous, magnesium and calcium. It contains high amount of potassium among various foods and high potassium intake is inversely associated with to platelet aggregation, free radicals in blood and incidence of stroke (**Carter 1993).**

Roasting treatment showed variable effects on mineral profile in flaxseeds, it enhanced the amounts of P, Na, and K in flaxseeds. However, it reduced the levels of Mg, Ca, Fe, and Zn (Table 3). The increase in P, K, and Na contents in roasted flaxseed may be related to the thermal degradation of anti-nutritional factors and formed complexes with minerals, thereby leading to liberation of these minerals **(Makinde and Akinoso, 2013). Shinde *et al.* (2019)** reported that roasting treatment enhanced Phosphorus and Iron and reduced Calcium.

Table 3: Effect of roasting conditions on mineral profile of flaxseeds.

Mineral	Roasting conditions						
	Unroasted	160 ° C			180 ° C		
		5 min	10 min	15 min	5 min	10 min	15 min
Phosphorus (P)	3125.26	3165.30	3192.12	3235.14	3178.58	3210.87	3257.69
Sodium (Na)	730.25	738.54	745.69	750.24	742.57	751.47	765.28
Calcium (Ca)	998.69	975.23	963.47	950.74	962.14	952.41	841.65
Magnesium (Mg)	3875.89	3754.21	3645.58	3564.21	3710.24	3568.32	3487.25
Potassium (K)	701.58	736.10	756.24	775.65	742.31	775.68	789.35
Iron (Fe)	100.58	87.42	84.87	81.56	85.67	82.54	78.21
Zinc (Zn)	45.36	43.21	41.02	39.54	42.51	40.24	38.31

The effects of roasting temperature and time on physicochemical properties of extracted oil from flaxseed are presented in Table 4. Data showed that the initial refractive index (RI) value of flaxseed oil was 1.4746 and it was increased with the increasing roasting temperature and time. The refractive indexes in all samples were agreed with **Codex standards (1999).** The FFA and Peroxide Value (PV) in unroasted flaxseed oil used in this study were 0.32% and 1.25 meqO_2/kg oil, respectively. FFA and PV were expected to rise as roasting time increased at the same temperature, with more obvious increases at higher temperatures. This might be the result of thermal oxidation of unsaturated fatty acids in flaxseed oil. The PV was lower (15 meqO_2/kg,) which is recommended in cold pressed oils **(Codex, 1999**). These results agree with **Hady and Elsorady, (2020).**

TBA is a common method for determining the oxidative changes in food products. It is more reliable than PV in determining oil deterioration as it measures the secondary stages of oxidation or accumulation of secondary products **(Che Man and Tan, 1999)**. Results in Table (4) show that TBA value increased from 0.32 for oil extracted from unroasted flaxseed to 0.46 (mg malonaldehyde/kg oil) for those roasted at 180°C for 15 min. As the TBA value is a measure of oxidation, these results are expected. Also, Saponification values were expected to rise as roasting time increased at the same temperature, with more obvious increases at higher temperatures. **Codex standard (1999)** reported that saponification value of flaxseed oil is 185-197 (mg KOH/g oil). Results of roasting at 160 °C for 5, 10 min and roasting at 180 °C for 5, 10 min were within the limits fixed by **Codex. Chauhan *et al.* (2018**) reported that saponification value of linseed oil increased after roasting. The results indicated that roasting increased the oxidative process of the oils from flaxseeds causing meaningful changes in their physico-chemical properties (Table 4), as the increase of free fatty acids, peroxide index and saponification value, and also the reduction of the refractive index.

Table 4: Effect of roasting conditions on some physicochemical properties of oil extracted from flaxseeds.

Characteristics	Roasting conditions						
	Unroasted	160 ° C			180 ° C		
		5 min	10 min	15 min	5 min	10 min	15 min
RI (at 20° C)	1.4746± 0.0001[d]	1.4746± 0.0001[d]	1.4744± 0.0002[cd]	1.4741± 0.0001[ab]	1.4746± 0.0001[d]	1.4743± 0.0002[bc]	1.4740± 0.0001[a]
FFA % (as oleic acid)	0.32± 0.02[a]	0.39± 0.03[b]	0.46± 0.03[c]	0.55± 0.04[d]	0.40± 0.03[b]	0.48± 0.02[c]	0.59± 0.03[d]
PV (meqO_2/kg oil)	1.25± 0.04 [a]	1.36± 0.03 [b]	1.49± 0.02 [c]	1.62± 0.02[d]	1.37± 0.01 [b]	1.52± 0.02 [c]	1.65± 0.04 [d]
TBA (mg malonaldehyde/ kg oil)	0.32± 0.01 [a]	0.33± 0.01 [ab]	0.36± 0.02 [bc]	0.43± 0.03[d]	0.33± 0.01 [ab]	0.38± 0.02[c]	0.46± 0.03 [d]
Saponification value (mg KOH/g)	182.32± 1.03 [a]	190.44± 0.78 [b]	194.05± 1.13 [c]	201.35± 1.05 [e]	192.15± 0.92 [bc]	196.35± 0.95 [d]	203.21± 1.56 [e]

***different superscripts indicate significant differences (p < 0.05)**

The fatty acid composition of oil is significantly related to its stability, thermal properties, and nutritional value. Fatty acid profiles of the oils extracted from unroasted and roasted flaxseed are described in Table 5. Flaxseed is mainly consists of polyunsaturated fatty acids (more than 75% of total fatty acids), followed by monounsaturated fatty acids fatty acids (15.83%) and saturated fatty acids (7.74%). **Morris (2007)** found higher amounts of saturated fatty acids (9.0%) and lower amounts of unsaturated ones (91.0%) than current study. The predominant polyunsaturated fatty acid present in both unroasted and roasted flaxseed oils was linolenic acid ($C_{18:3}$), which present 55.89–57.21% and with a lesser amount of linoleic acid ($C_{18:2}$, 19.22-19.44%).

Results showed that fatty acid composition of flaxseed had minor changes during the roasting process at 160 and 180°C (Table 5). The level of α-linolenic acid in flaxseed significantly (P<0.05) decreased from 57.21 to 55.89% during the roasting process at 180°C for 15 min. **Manthey *et al.* (2009**) and **Schorno *et al.* (2010)** reported that α-linolenic acid is mostly affected by oxidation because autoxidation reaction rate increases with the number of double bonds present in a fatty acid. However, **Epaminondas *et al.* (2011**) reported that the level of α-linolenic acid in whole flaxseed did not vary with toasting process at 160°C for 15 min. On the other hand, the percentage of oleic acid in flaxseed slightly significant (P<0.05) increased from 15.43 to 15.94% during the roasting process at 180°C for 15 min. Fatty acid composition of oils extracted from unroasted and roasted flaxseeds at different temperatures for different times were within **Codex standard (1999)**. The fatty acid ratio remained slightly change between unroasted and roasted flaxseed oils, suggesting that roasting had little effect on the fatty acid profile of flaxseed oils. The reduction of $C_{18:3}$ occurs because of a series of oxidative reactions during the grain roasting process: one or more of the double bonds in unsaturated fatty acids are broken, which increases the concentration of $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ **(Morello *et al.,* 2004)**. The results are in good agreement with **Moknatjou *et al.* (2015); Kanmaz**, (**2017); Waszkowiak et al. (2018); Hady and Elsorady, (2020).**

Table 5: Effect of roasting conditions on fatty acids composition of oils extracted from flaxseeds.

Fatty acid	Roasting conditions						
	Unroasted	160 ° C			180 ° C		
		5 min	10 min	15 min	5 min	10 min	15 min
$C_{16:0}$	5.40 ± 0.07^{ab}	5.56 ± 0.08^{cd}	5.53 ± 0.11^{bc}	5.29 ± 0.01^{a}	5.68 ± 0.03^{de}	5.70 ± 0.04^{de}	5.72 ± 0.11^{e}
$C_{16:1}$	0.26 ± 0.01^{c}	0.25 ± 0.00^{abc}	0.24 ± 0.01^{ab}	0.25 ± 0.01^{bc}	0.23 ± 0.01^{a}	0.23 ± 0.00^{ab}	0.25 ± 0.00^{abc}
$C_{18:0}$	2.24 ± 0.05^{a}	2.41 ± 0.03^{b}	2.44 ± 0.03^{bc}	2.54 ± 0.04^{de}	2.41 ± 0.05^{b}	2.50 ± 0.04^{cde}	2.59 ± 0.03^{e}
$C_{18:1}$	15.43 ± 0.04^{a}	15.61 ± 0.10^{b}	15.72 ± 0.10^{bc}	15.85 ± 0.07^{cd}	$15.75\pm.07^{bc}$	15.86 ± 0.06^{cd}	15.94 ± 0.10^{d}
$C_{18:2}$	19.22 ± 0.12^{a}	19.33 ± 0.08^{abc}	19.36 ± 0.04^{bc}	19.42 ± 0.03^{bc}	19.30 ± 0.08^{ab}	19.40 ± 0.05^{bc}	19.44 ± 0.05^{c}
$C_{18:3}$	57.21 ± 0.23^{d}	56.63 ± 0.19^{c}	56.50 ± 0.28^{c}	56.46 ± 0.14^{bc}	56.43 ± 0.19^{bc}	56.11 ± 0.21^{ab}	55.89 ± 0.04^{a}
$C_{20:0}$	0.10 ± 0.00^{ab}	0.11 ± 0.00^{ab}	0.11 ± 0.00^{ab}	0.10 ± 0.00^{a}	0.10 ± 0.00^{ab}	0.11 ± 0.00^{b}	0.10 ± 0.00^{ab}
$C_{20:1}$	0.13 ± 0.01^{e}	0.11 ± 0.01^{d}	0.10 ± 0.01^{cd}	0.09 ± 0.01^{bc}	0.09 ± 0.01^{bc}	0.07 ± 0.00^{ab}	0.07 ± 0.01^{a}
Σ SFA*	7.74 ± 0.08^{a}	8.08 ± 0.11^{bc}	8.08 ± 0.14^{bc}	7.93 ± 0.05^{b}	8.20 ± 0.07^{cd}	8.31 ± 0.09^{de}	8.41 ± 0.12^{e}
Σ USFA**	92.26 ± 0.08^{e}	91.92 ± 0.11^{cd}	91.92 ± 0.14^{cd}	92.07 ± 0.05^{d}	91.80 ± 0.07^{bc}	91.69 ± 0.09^{ab}	91.59 ± 0.12^{a}
MUSFA***	15.83 ± 0.05^{a}	15.97 ± 0.10^{ab}	16.07 ± 0.10^{bc}	16.19 ± 0.06^{cd}	16.07 ± 0.05^{bc}	16.17 ± 0.07^{cd}	16.26 ± 0.11^{d}
PUSFA****	76.43 ± 0.11^{d}	75.96 ± 0.21^{c}	75.86 ± 0.23^{c}	75.88 ± 0.11^{c}	75.73 ± 0.11^{bc}	75.52 ± 0.16^{ab}	75.33 ± 0.02^{a}
$C_{18:1}/C_{18:2}$	0.80 ± 0.00^{a}	0.81 ± 0.00^{b}	0.81 ± 0.00^{bc}	0.82 ± 0.00^{cd}	0.82 ± 0.00^{cd}	0.82 ± 0.00^{d}	0.82 ± 0.00^{d}
$C_{18:3}/C_{18:2}$	2.97 ± 0.03^{d}	2.93 ± 0.02^{c}	2.92 ± 0.02^{bc}	2.91 ± 0.01^{bc}	2.92 ± 0.02^{bc}	2.89 ± 0.02^{ab}	2.87 ± 0.01^{a}
USFA / SFA	11.91 ± 0.13^{e}	11.38 ± 0.17^{cd}	11.38 ± 0.22^{cd}	11.61 ± 0.07^{d}	11.20 ± 0.10^{bc}	11.03 ± 0.13^{ab}	10.88 ± 0.17^{a}

-different superscripts indicate significant differences ($p < 0.05$)

***SFA: saturated fatty acids. **USFA: unsaturated fatty acids. *** MUSFA: monounsaturated fatty acids. ****PUSFA: polyunsaturated fatty acids.**

Table 6 shows sterol profiles of oils extracted from unroasted and roasted flaxseed. Sitosterol and campesterol were the predominant sterols in the profiles. They were followed by stigmasterol, Δ5-avenasterol and Δ7-avenasterol. The sterols compositions of flaxseed oils agree with **Ciftci *et al.* (2012).** Results revealed that roasting influenced the amount of sterols in the flaxseed oils (Table 6). The total sterols content in oils extracted from roasted seed were higher than in those extracted from unroasted flaxseeds. The highest content were 3892.73 (mg/kg) in roasted flaxseeds at 160 °C for 10 min followed by 3771.33 mg/kg for roasted flaxseeds at 180 °C for 10 min. These results agree with **Waszkowiak *et al.* (2020)** for flaxseed and also agree with **Gao *et al.* (2019)** for walnut. The highest sterols content in the roasted seed oils may be caused by cell structure damage, which increased sterols extractability**. Wroniak *et al.* (2016**) observed structural changes in protein bodies and damage of lipoprotein membranes surrounding lipid bodies in microwave-treated rapeseeds as a result of thermally induced denaturation. In the current study, roasting probably caused similar changes in the structure of flaxseed. Also, data indicated that roasting caused an increased in the percentage of unsaponifiable matter from 1.25 to 1.39 %.

The aim of using flaxseeds in the manufacture of candy bars was to increase the nutritional value of sweets made from sesame and fortified with flaxseeds, as flaxseed contains omega-3 and high protein content, in addition to dietary fiber and natural antioxidants that are important for health.

Table 6: Effect of roasting conditions on sterols profile of oils extracted from flaxseeds.

Sterols profile	Roasting conditions						
	Unroasted	160 ° C			180 ° C		
		5 min	10 min	15 min	5 min	10 min	15 min
Campesterol	910.58±3.52^{a}	886.03±3.15^{e}	990.61±5.22^{g}	934.95±4.98^{f}	892.55±6.91^{b}	991.19±8.69^{d}	984.95±10.52^{c}
Stigmasterol	235.94±5.56^{b}	290.32±4.47^{a}	314.92±3.43^{d}	260.97±5.05^{c}	284.58±4.05^{a}	298.34±6.51^{d}	258.81±5.55^{d}
Sitosterol	1610.13±8.02^{a}	1793.83±5.09^{cd}	1852.03±9.08^{e}	1829.23±9.59^{b}	1675.63±6.56^{c}	1715.43±6.98^{d}	1697.13±2.79^{b}
Δ5-Avenasterol	220.53±4.87^{a}	274.87±3.60^{c}	289.91±3.67^{d}	249.50±5.63^{b}	272.02±5.93^{c}	280.67±7.00^{c}	248.08±2.83^{b}
Δ7-Avenasterol	180.13±5.51^{a}	194.96±3.44^{b}	199.06±4.42^{b}	201.62±3.52^{b}	202.34±3.09^{b}	219.29±3.74^{c}	215.58±3.87^{c}
Total sterols (mg/kg)	3353.83±5.21^{a}	3658.33±7.32^{d}	3892.73±9.14^{g}	3730.23±8.35^{e}	3561.23±7.81^{b}	3771.33±8.60^{f}	3637.83±11.73^{c}
Campesterol / Stigmasterol	3.85±0.07^{e}	3.05±0.04^{a}	3.14±0.01^{b}	3.58±0.05^{d}	3.14±0.02^{b}	3.32±0.04^{c}	3.80±0.04^{e}
Unsaponifiable matter (%)	1.25±0.04^{a}	1.32±0.03^{ab}	1.35±0.04^{b}	1.34±0.03^{b}	1.34±0.03^{b}	1.39±0.05^{b}	1.36±0.03^{b}

***different superscripts indicate significant differences ($p < 0.05$)**

The tabulated data in Table (7) show that the sensory evaluation of flaxseed candy bars. Results revealed that control sample has the best scores for all sensory attributes followed by flaxseed 25%, flaxseed 50%, flaxseed 75% and flaxseed 100%, respectively. No significant difference observed between control candy bars and flaxseed 25% bar. The difference in the sensory evaluation scores of different candy bars samples may be attributed to the occurrence of reactions as a result of roasting sesame components as well as flaxseeds such as carbohydrates, proteins and fats in addition to the aroma compounds in the seeds to give new compounds that improve the colour, taste and smell of the final product.

Table 7.Sensory evaluation of flaxseed candy bars

Sensory attribute	Sesame 100% (control)	Flaxseed 25%	Flaxseed 50%	Flaxseed 75%	Flaxseed 100%
Smell	5.00±0.00^{d}	5.00±0.00^{d}	4.50±0.00^{c}	4.17±0.29^{b}	3.83±0.29^{a}
Colour	5.00±0.00^{c}	5.00±0.00^{c}	4.33±0.29^{b}	4.17±0.29^{b}	3.67±0.29^{a}
Flavour	5.00±0.00^{c}	4.67±0.29^{c}	4.17±0.29^{b}	3.83±0.29^{ab}	3.67±0.29^{a}
Texture	5.00±0.00^{c}	4.67±0.29^{c}	4.00±0.00^{b}	3.67±0.29^{ab}	3.33±0.29^{a}
Overall acceptability	5.00±0.00^{c}	4.67±0.29^{bc}	4.33±0.29^{b}	3.67±0.29^{a}	3.67±0.29^{a}

CONCLUSIONS

The present study showed that the chemical composition; minerals; fatty acids; and sterols profile of flaxseed were significantly influenced by the roasting process. A significantly decrease in moisture content and significantly increase in oil content after roasting. Moreover, the minerals contents, i.e. P, Na and K were increased by the roasting process. Therefore, roasting can improve the nutritional value and reducing anti-nutritional factor. The oxidative processes, total sterol content and unsaponifiable matter in the roasted flaxseed were higher than in the unroasted flaxseeds. Therefore, it can be concluded that the roasting process may be used to improve the quality of flaxseed oil. No significant difference was observed between control candy bars and flaxseed 25% candy bars.

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تأثير عملية التحميص على جودة بذور الكتان

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تم دراسة تأثير عملية التحميص على بعض الخصائص الفيزيائية والكيميائية لبذور الكتان. تم تحليل الأحماض الدهنيه والاستيرولات والخصائص الفيزيائية والكيميائية للزيوت المستخرجة من بذور الكتان غير المحمصة والمحمصة. حيث تم إجراء عملية التحميص لبذور الكتان عند درجات حرارة 160 و180 درجة مئوية لمدة 5 و 10 و 15 دقيقة. أظهرت النتائج انخفاض محتوى الرطوبة وزيادة محتوى الزيت بعد تحميص بذور الكتان. و أيضًا ، كان لعملية التحميص تأثير بسيط على تركيب الأحماض الدهنية. سجلت الستيرولات الكلية في بذور الكتان المحمصة محتوى أعلى من البذور غير المحمصة. كما أوضحت النتائج أن تركيب العناصر المعدنية لبذور الكتان أن محتويات المغنيسيوم والفوسفور والكالسيوم كانت 3875.89 مجم / كجم و 3125.26 مجم / كجم و 998.69 مجم / كجم في بذور الكتان غير المحمصة على التوالي. علاوة على ذلك ، سجلت محتويات الصوديوم والبوتاسيوم زيادة نتيجة عملية التحميص . لم يلاحظ فروق معنوية بين بار الحلوى لعينة السمسم المقارنه وبار الحلوى المحتوى على 25% بذور الكتان.