Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

Physicochemical Properties of Sesame *(Sesamum indicum L.)* Seed Oil Extracted by Traditional and Mechanical Pressing Methods

Mozdlefa Ahmed Mohammed Ahmed, Mahdi Abbas Saad Shakak,[1] Maha Fadul Mohammed [2]

1 - Department of Food Science and Technology, College of Agricultural Studies, SUST.
2- Department of Food Science and Technology, College of Agricultural Studies, SUST.

Abstract: Objective of this study was to compare the properties and the quality of two types of sesame oils extracted by camel (traditional) and one type by mechanical press. Seven Samples of oil and cakes were obtained from both types of presses in the Khartoum State. Physicochemical analysis, sensory evaluation, and oil contents of cakes were determined. Sesame seeds from the three locations (Khartoum-North, Khartoum, and Omdurman) presses had insignificant differences in moisture, ash and fiber content. Sesame seed from Khartoum locations registered the highest oil content (53.88 %) and the lowest carbohydrates content (13.64 %), while sesame seed from Khartoum North registered the highest protein content (25.05 %). The physical analysis revealed that there were no significant differences between different samples. While the chemical analysis showed that there were insignificant differences between the different extraction methods. Taste, aroma, colour and general acceptability showed no significant difference between normal and walad oil type obtained from the different locations in Khartoum State and the commercial one. This study showed that there is no significant difference between samples of Walad and normal types of sesame oil which are traditionally pressed. Also it was found that the commercial sample met the Sudanese Standard Meteorological Organization measurements for sesame oil.

Keywords: - sesame oil, camel press, screw press, expellers, traditional method, seed cakes**.**

Introduction

Sesame is probably the most ancient oilseed known and used by mankind dating back to as early as 1600 B.C, Sesame seeds are the oldest condiment known to man. It is also known as benniseed, gingelly, simsim and til (Saydut *et al.*, 2008).

By weight, the bulk (45 – 60%) of sesame seed is oil. Depending on sesame species, oleic and linoleic acids constitute the majority (75 – 85%) of the fatty acids of this oil (Chung *et al.*, 1995). The oil composition varies and depends on climatic conditions, soil type, plant maturity, variety and method of processing.

Sesame seed is traditionally used for direct consumption and a source of oil of excellent quality due to the presence of natural antioxidants such as sesamin and sesamol (Brar and Ahuja, 1979).

The total production of sesame seeds in Sudan was approximately 5,000,000 tons during the last ten years according to a report published in 2018 by the Department for Planning and Agricultural Economics, Ministry of Agriculture and Irrigation. The production of sesame rose from 525 thousand metric tons in season 2016/2017 to 782 thousand metric tons in season

2017/2018 by the rate of 49.6% because of the expansion in the cultivated area and productivity by 16.3% and 17.5% respectively.(CBOS,2018).

Most of Sudanese people believe and prefer to use the Walad sesame oil because they claim that it has better quality, although it is more expensive (almost double the price) when compared with normal sesame oil (traditional) and the oil produced by mechanical extraction. Walad type of sesame oil is collected after several days from the wood or steel vessel which holds the oil residues in the camel press and according to the interest of the press owner to maximum of seven days, this is to verily the claim of the majority of Sudanese people that the walad sesame oil is far better in quality than the other types.

The objectives of this study were:-

- To determine the physical and chemical characteristics and quality of sesame oil extracted by camel press and mechanical expression methods.
- To determine oil content in cakes obtained from both types of mills.

Materials and Methods

Samples of sesame seed and sesame oils (3Normal and 3Walad) from three traditional press (camel press) were collected from Khartoum North, Khartoum and Umdourman towns and one commercial sample of sesame oil which was bought from local market. Also four samples of sesame cake were collected from both types of presses. Approximate analysis of sesame seeds which included moisture content, total ash, crude fiber, oil content, crude protein and total carbohydrates were carried out according to AOAC (2008) method .Physicochemical characteristics such as refractive index, specific gravity, peroxide value, free fatty acid, saponification value and iodine value were determined according to the method described by AOAC, (2008). Colour intensity of oils was determined using a Lovibond Tintometer as unit of red, yellow and blue in the manner described by AOAC, (2008). Fatty acid composition of sesame oil was determined by gas chromatography apparatus (PYE-UNICAM model GCD). (ACMLT 1990).Sensory evaluation test of sesame oil samples was carried out according to Yalegama *et al.* (2007).

Statistical Analysis

The data obtained in this study were subjected to statistical analysis by Tukey's multiple range test ($P \leq 0.05$) (Steel et al., 1997). Mean values were obtained by the Analysis of Variation (ANOVA). And a least significant difference (LSD) test with a confidence interval of 95% was used to compare the means.

Results and Discussion

Moisture content of sesame seeds (Table 1) collected from Khartoum North, Khartoum and Umdourman, were 5.80%, 5.58% and 5.86% respectively. These readings were found to be lower than those obtained by Nzikou *et al.*, (2009); Hirata *et al*., (1996) and Mohammed *et al.*, (2011) from (5 to 6%). Also ash content (Table 1) of sesame seeds collected from Khartoum North , Khartoum and Umdourman, were 3.50% , 3.39 % and 3,40% respectively, these values agreed with the ones of Nzikou *et al.,(*2009); Hirata *et al*., (1996) and Mohammed *et al.*, (2011). Khartoum North, Khartoum and Umdourman, sesame seed samples had similer ($p>0.05$) crude

fiber (Table 1). These readings of crude fiber of sesame seed samples were similar to those obtained by Nzikou *et al.,* (2009); Hirata *et al*., (1996) and Mohammed *et al.,* (2011). The fat content (Table 1) of sesame seed from Khartoum North was lower than those obtained from Umdourman and Khartoum (45.57, 51.72 and 53.88%) respectively. Such fat content values were similar to those reported by Mariod *et al*.; (2014); Nzikou et al., (2009); Hirata *et al*.,(1996) and Mohammed *et al*.,(2011).

Table (1) Proximate composition (%) of sesame seeds collected from three locations in Khartoum State

Location	Moisture	Ash	Crude fiber	Fat	Crude protein	Carbohydrates
Khartoum North	5.80^{a} ±0.07	3.50^{a} ±0.07	3.20^{a} ±0.02	45.57^{c} ±0.58	25.05^{a} ±0.50	17.42^{a} ±0.16
13.64^{b} ±0.50	5.58^{a} ±0.25	3.39^{a} ±0.12	3.18^{a} ±0.04	53.88^{a} ±0.11	20.32^{b} ±0.27	
Umdourman	5.86^{a} ±0.05	3.40^{a} ±0.02	3.21^{a} ±0.02	51.72^{b} ±0.80	21.12^{b} ±0.62	17.06^{a} ±0.27

Mean(s) bearing different superscript letter(s) in a column are significantly different (P≤0.05). reported that the protein content was 20.0%, but they were lower than that found b

The crude protein (table 1) of sesame seed samples collected from Khartoum North, Umdourman and Khartoum (25.05%, 21.12 %and 20.32%) respectively. These readings were found to be higher than those obtained by Nzikou *et al., (*2009) who y Hirata *et al*., (1996) and Mohammed *et al.,* (2011) who reported value that ranged between 15 and 20%. Carbohydrates from Khartoum North and Umdourman sesame seed had similar (p>0.05) carbohydrate content (17.42% and 17.06%) which were higher (p<0.05) than that from Khartoum (13.64%). These readings were higher than those found by Nzikou *et al., (*2009), who recorded (13.4%), Hirata *et al*., (1996) and Mohammed *et al.,* (2011) who mentioned that the carbohydrates ranged between 10 to 15%. These differences in sesame seed chemical composition such as oil and protein contents might be attributed to different conditions of agricultural practices, climate, soil types, plant varieties etc.

Physical Properties of Sesame Oil

Table (2) shows the physical properties of sesame oils extracted by traditional and mechanical pressing. The Refractive index of sesame oil samples ranged between 1.4700 and 1.4780, there was a significant difference between the three different locations (P≤0.05). The obtained results

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

were similar to those reported by Mariod *et al*., (2014); Gebrail, (2010) and Nweket *et al*. (2011). But higher than those of the Codex standards (1999).

There was no significant difference of specific gravity between all samples of sesame seeds oil collected from three different locations in Khartoum North, Khartoum and Umdourman for both types of oils (normal and walad) which were (0.9170, 0.9180), (0.9130, 0.9140), (0.9210, 0.9180) respectively, There was no significant difference in the specific gravity readings between both types of oils produced by traditional pressing method and the commercial sample which was extracted through screw press (0.9180). Sesame oil standards according to the Codex (1999) and SSMO (2002) readings were ranged (0.9150-0.9240); Mariod *et al*.,(2014) suggested that the specific gravity of normal oil was ranged between 0.9176 and 0.9533,while the specific gravity of walad oil was ranged between 0.9172 and 0.9535. Gebrail, (2010) reported that the specific gravity of sesame oil was 0.9190, but Yagoub *et al*.,(2008) showed lower value than this study 0.8920. Nweket *et al*., (2011) also pointed 0.88336.

Table (3) shows colour values of normal and walad sesame oils obtained from three different locations in Khartoum State and commercial oil samples which were bought from local markets in Khartoum. The yellow colour of normal and walad oils from Umdourman were found to be of high values (20.8, 21.0) when compared to samples collected from Khartoum and Khartoum North (11.7, 10.8), (7.40, 8.70) respectively. The commercial sample showed the highest value of yellow colour when compared with all other samples of oil of both types (21.7). No significant difference was noticed in red colour values of normal and walad oil of all samples (0.90), but they were significantly different when they were compared with the red colour of commercial sesame oil, which was (0.7). The variation in yellow and red colour unit values were due to differences in period of sesame seeds storage and sources and the amounts of natural pigments and dyes such as chlorophyll.

Table (2) refractive index and specific gravity of sesame oils extracted by two extraction methods

Parameter	Camel Extraction						Mechanical extraction	$Lsd_{0.05}$	SE
	Khartoum North		Khartoum		Umdourman				
	Normal	Walad	Normal	Walad	Normal	Walad			
Refractive Index	1.4760^{b} ±0.05	1.4740^{dce} ±0.03	1.4730^{e} ±0.02	1.4750^{cb} ±0.04	1.4780^{a} ±0.06	1.4700^{f} ±0.01	1.4740^{dce} ±0.03	0.0018	0.0005
Specific gravity	0.91767^{a}	0.91833^{a}	0.91367^{a}	0.91433^{a}	0.9210^{a}	0.91867^{a}	0.9180^{a}	0.0925	0.0001

Values are mean ±SD

Mean(s) bearing different superscript letter(s) in a row are significantly different (P≤0.0).

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

Table (3) Colour intensity of sesame oils extracted by camel and mechanical press.

Colour	Camel Extraction						Mechanical extraction	$Lsd_{0.05}$	SE
	Khartoum North		Khartoum		Umdourman				
	Normal	Walad	Normal	Walad	Normal	Walad			
Blue	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	-	
Yellow	7.40^{g} ±0.00	8.70^{f} ±0.00	11.70^{d} ±0.00	10.80^{e} ±0.00	20.80^{c} ±0.00	21.00^{b} ±0.00	21.70^{a} ±0.00	0.5419**	0.0368
Red	0.90^{a} ±0.00	0.90^{a} ±0.00	0.90^{a} ±0.00	0.90^{a} ±0.00	0.90^{a} ±0.00	0.90^{a} ±0.00	0.70^{b} ±0.00	0.1827*	0.0154

Values are mean±SD

Mean(s) bearing different superscript letter(s) in a row are significantly different (P≤0.0). and carotene which were usually found to be higher in crude oil than completely refined oils.

Chemical properties of sesame oil

Table (4) shows the chemical composition of three samples of sesame oils (normal and walad) collected from different locations and commercial samples of sesame oils.

There was significant difference in peroxide value of oil (normal and walad) samples extracted by traditional methods, which were collected from Khartoum North and Khartoum (2.50, 2.90) and (2.20, 1.50meqO_2/kg oil) respectively. While there was no significant difference noticed in peroxide value between (normal and walad) oil obtained from Umdourman city (3.10, 3.10) respectively. But all samples of oils extracted by the traditional method from the three locations showed significant difference in peroxide value when they were compared to oil brought from the market which was extracted by the expellers (5.10 meqO_2/kg oil), the local market sample was found to be similar of those which were reported by Mariod *et al*., (2014) (5.104 meqO_2/kg oil), but they were agreed with the peroxide value of sesame oil produced by traditional sesame seed press mentioned by Yagoub *et al*., (2008) which was 2.2 meqO_2/kg oil. Peroxide values of these samples which were obtained from different places in Khartoum State were lower than those which were indicated by Nweket *et al*., (2011) and Gebrail, (2010) they were (21.33 and 19.70 meqO_2/kg oil) respectively. Variations in peroxide value might be due to the difference in

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

locations of sesame seeds origins and other conditions such as storage period of both sesame seed and oil. It was noticed that there was high fluctuation in peroxide value for the same type of oil from different places and less fluctuation for two types (normal and walad) from the same place. But all oil samples collected from different places in Khartoum State including the commercial one were in the same standard of peroxide value stated by both Codex (1999) and SSMO (2002) which should be less than 10 meqO_2 per kg of sesame oil.

Free fatty acid value of normal and walad sesame oil collected from three locations Khartoum North, Khartoum and Umdourman (0.773, 0.70, 0.577, 1.31 and 0.85, 0.477%) showed significant difference with each other and with the commercial oil sample which was collected from the market (0.45%), All the above free fatty acid value were lower than those reported by Gebrail, (2010) and Yagoub *et al.*, (2008), Who were recorded (3.4 and 2.5%) respectively.

Saponification value of both normal and walad types of sesame oil collected from Khartoum North, Khartoum and Umdourman where found to be significantly differed with each other (192.90, 195.3, 191.26, 195.7 and 196.52, 193.9) and also with the commercial oil sample which was brought from the market. It was also noticed that there were no significant difference in saponification value of walad oil brought from Khartoum North when was compared with saponification value of walad oil type both from Khartoum area sample, saponification value of commercial sample was found to be (192.65) the result was recorded in Table (4), the saponification value was similar to Mariod *et al*., (2014) who was reported 192.0, also Codex (1999) was ranged between 187.0 and 195.0, also the same was pointed out by Nzikou *et al.,(*2009)and Yagoub *et al*., (2008) which were (192.0 and 191.68) but they were lower than those found by Gebrail, (2010) and Nweket *et al*., (2011) (182.79 and 186.0) respectively. Iodine value of both normal and walad types of sesame oil collected from different three locations Khartoum North (112.97,115.18), Khartoum (113.82,116.9) and Umdourman (114.88,117.0) where found to be significantly different with each other and also with the commercial oil sample which was brought from the market. The iodine value of samples was of the similar value which was recorded by Nzikou *et al.*, (2009) (112.4) and Mariod *et al*., (2014) who reported 113.9. The variation of these results, in chemical properties was due to the difference in seasons of sesame oil and the place of origin of the sesame seeds and which may also refer to their storage periods.

Table (4) Chemical properties of sesame oils extracted by two extraction methods

Parameter	Khartoum North		Khartoum		Umdourman		Mechanical extraction	$Lsd_{0.05}$	SE
	Camel Extraction								
	Normal	Walad	Normal	Walad	Normal	Walad			
Peroxide value (m.Eq/kg)	2.50^{d} ±0.01	2.90^{bc} ±0.01	2.20^{e} ±0.02	1.50^{f} ±0.01	3.10^{b} ±0.01	3.10^{b} ±0.01	5.10^{a} ±0.01	0.2817*	0.052
Free fatty acids	0.773^{bc}	0.70^{c}	0.577^{d}	1.31^{a}	0.85^{b}	0.477^{e}	0.45^{ef}	0.075*	0.006

ISSN (Print): 1605 427x e-ISSN (Online): 1858-6716

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

(%)	±0.03	±0.05	±0.03	±0.00	±0.03	±0.03	±0.00		
Saponification	192.90^{e} ±0.586	195.31^{b} ±0.99	191.26^{f} ±0.37	195.71^{b} ±0.07	196.52^{a} ±1.13	193.98^{d} ±0.50	192.65^{e} ±0.77	0.812*	0.074
Iodine value	112.97^{f} ±0.66	115.18^{c} ±0.54	113.82^{e} ±1.46	116.98^{b} ±0.66	114.88^{d} ±0.60	117.05^{a} ±0.18	112.60^{f} ±0.20	0.069*	0.005

Values are mean±SD
Mean(s) bearing different superscript letter(s) in a row are significantly different (P≤0.05).

Table (5) Fatty acids composition of sesame oils extracted by two extraction methods

Types of sesame oils	**Unsaturated**				**Saturated**			
	Linoleic	**Oleic**	**Linolenic**	**Palmitoleic**	**Palmitic**	**Stearic**	**Elcosenoic**	**Others**
	%							
Normal/Khartoum-North	34.5	39.7	0.94	0.4	8.0	5.0	0.7	10.76
Walad / Khartoum-North	35.4	39.5	0.95	0.5	8.6	5.0	0.8	9.25
Normal /Khartoum	34.5	39.7	0.94	0.4	8.0	5.0	0.7	10.76
Walad /Khartoum	35.4	40.5	0.95	0.5	8.6	5.0	0.8	8.25
Normal /Umdourman	34.5	38.7	0.94	0.4	9.0	5.0	0.7	10.76
Walad /Umdourman	35.4	39.5	0.95	0.5	8.6	5.0	0.8	9.25
Commercial	33.5	40.7	0.94	0.4	8.0	5.0	0.7	10.76

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

Fatty acid composition of the sesame oils

Table (5) shows fatty acid composition of the sesame oils samples. The main unsaturated fatty acids of all sesame oil samples were found to be oleic acid which ranged between 38.7 and 40.7%. Linoleic acid was found between 33.5 and 35.4 %, while the linolenic acid ranged between 0.94 to 0.95%, also the palmitoleic acid ranged between 0.4 and 0.5%. The major saturated fatty acids in sesame oil were palmitic acid which was found between 8.0 to 9.0%, while stearic acid was recorded 5.0% to all samples oil, eicosenoic acid was recorded (o.7%) of Normal oil which were collected from all locations and commercial samples. All normal and walad oil of the three locations, showed no difference in the amounts of the major fatty acid composition between them, but they were lower than those reported by Weiss, (2000) in linoleic acid 46.3% while they were higher in oleic acid value 37.2%. Also Mariod *et al*., (2014) reported the same with palmitic, stearic and oleic acid which were (9.35, 5.08 and 39.1%) respectively. The variation in fatty acids composition was due to the difference in sesame seed species and the place of origin of the sesame seeds.

Sensory evaluation of sesame oil

Table (6) shows sensory evaluation of sesame oils extracted by different methods which were collected from different locations in Khartoum state, this experiment was to measure the taste, aroma, colour, flavour, and general acceptability. The obtained results of the taste, aroma, colour and general acceptability showed that there was no significant difference between normal Walad which were obtained from different locations in Khartoum State and the commercial oil.

Neither the location nor the oil types had no effect ($P \geq 0.05$) on the flavour of the sesame oil. It was observed that there was no significant difference found between flavour of normal sesame oil collected from Khartoum state and that brought from market which was extracted mechanically.

Sesame seed cake

Table (7) shows the result of oil residues in sesame seed cake samples , the results shows that Khartoum samples was significantly greater in remaining oil content (15.45%) than that of Khartoum North (14.97%) and Umdourman (14.78%). While the residue oil in the commercial cake sample was (8.12%). Also it was noticed that there was a significant difference between collected samples in oil content in all cakes when they were compared with commercial samples. Ravindran, (1990) observed that the solvent-processed meals contained lower oil (1%). This percentage of oil content in cakes was agreed with the findings of Mariod *et al*., (2014) who found that claimed cake from sesame percolation 1.068% and cake from sesame pressing 5.342%.

Sudan Journal of Science and Technology
Journal homepage:
http://jst.sustech.edu/

Table (6) Sensory evaluation of sesame oil types extracted by two extraction method .

Quality attribute	Camel Extraction						Mechanical extraction	lsd0.05	SE
	Khartoum North		Khartoum		Umdourman				
	Normal	Walad	Normal	Walad	Normal	Walad			
	Scores								
Taste	2.71^{ab} ±1.27	2.54^{ab} ±1.10	3.29^{a} ±1.12	2.79^{ab} ±1.14	2.67^{ab} ±1.09	2.46^{b} ±1.32	3.08^{b} ±1.25	0.6769*	0.2424
Aroma	2.42^{a} ±1.25	2.75^{a} ±1.15	2.92^{a} ±1.06	2.17^{a} ±1.13	2.33^{a} ±0.87	2.46^{a} ±1.47	2.79^{a} ±1.35	0.6824n.s	0.244
Colour	2.88^{a} ±1.26	2.54^{a} ±1.14	2.46^{a} ±1.18	2.63^{a} ±1.24	2.42^{a} ±1.14	2.25^{a} ±0.99	2.45^{a} ±1.14	0.6609n.s	0.32366
Flavour	2.63^{ab} ±1.06	2.63^{ab} ±1.01	3.04^{a} ±1.00	2.67^{ab} ±1.05	2.25^{b} ±0.99	2.08^{b} ±1.35	3.08^{a} ±1.28	0.6348*	0.2273
General acceptability	2.58^{a} ±1.14	2.79^{a} ±1.10	3.25^{a} ±0.94	2.58^{a} ±0.93	2.58^{a} ±0.88	2.33^{a} ±1.34	3.13^{a} ±1.36	0.8536n.s	0.3056

Values are mean ±SD
Mean(s) bearing different superscript(s) letters in a row are significantly different (P≤0.05).
1 = excellent, 2 = very good, 3 = good, 4 = acceptable, 5 = unacceptable

Table (7) Oil content in sesame seed cakes collected from Khartoum North, Khartoum, Umdourman and commercial samples:

Location	Khartoum North	Khartoum	Umdourman	Commercial	$Lsd_{0.05}$	SE
Sesame seed cake (%)	14.97^{b} ±0.00	15.45^{a} ±0.00	14.78^{c} ±0.00	8.12^{c} ±0.00	0.0006318*	0.0002

Values are mean ±SD. Mean(s) bearing different superscript(s) in a row are significantly different (P≤0.05).

Conclusion

- The study showed no evidence of superiority in physical, chemical and quality properties of the oil called Walad type over other types of sesame oil which were extracted by different pressing methods.

Recommendation

- It is recommended to use mechanical expression methods instead of traditional methods for oil extraction to avoid such great loss of oil in seed cakes.

References

1. AOAC, (2008). Official Methods of Analyses.15th Ed., Association of Official Analytical Chemists, Washington, DC.USA.
2. Brar, G.S. and Ahuja, K.L. (1979). Sesame: Its culture, genetics, breeding and biochemistry:.In: C.P. Malik, (ed). Annual Review of Plant Science. Kalyani Publishers, New Delhi. pp: 245-313.
3. CBOS (2018). 58th A nnual Report of the Central Bank of Sudan. Website: http://www.cbos.gov.sd.
4. Chung, C.H; Yee, Y.J; Kim, D.H; Kim, H.K. and Chung, D.S. (1995). Changes of lipid, protein, RNA and fatty acid composition in developing sesame (*Sesamum indicum L.*) seeds. Plant Science 109, 237-243.
5. Codex Alimentarius. (1999). Codex Standard for Named Vegetable Oils. International Food Standards Codex Standard, 210, 1-13.
6. FAO, (1996). Oil crops. Sudan: Country report to the FAO International Technical Conference on Plant Genetic Resources, p.13.
7. Gebrail,A., (2010) Physicochemical properties of sesame oil as related to adulteration. M. Sc. Thesis, Faculty of Agriculture, University of Khartoum, Sudan.
8. General directorate for planning and Agricultural economics, Statistics Department (2016). Ministry of Agriculture. Khartoum, Sudan.
9. Hirata, F; Fujita, K; Ishikura, Y; Hosoda, K; Ishikawa, T. and Nakamura, H. (1996). Hypocholesterolemic effect of sesame lignan in humans. Atherosclerosis. 122:135-136.
10. Mariod, A .A; Idris, Y. M. A; and Osman, N. M. (2014). Composition and stability of traditional processed sesame oil. Innovative Romanian Food Biotechnology, pp: 15-51.
11. Mohamed,H.M.A.and Awatif, I.I. (1998). The use of Sesame oil is an unsaponifiable matter as a natural antioxidant. Food Chemistry, volume 62(3) pp: 269-276.
12. Mohammed, N; Alyemeni, A.Y; Basahynd Sher, H. (2011). Physicochemical analysis and mineral composition of some sesame seeds (*Sesamum indicum* L.) grown in the Gizan area of Saudi Arabia. Journal of Medicinal Plants Research, 5(2): 270-274.
13. Nweke, F.N; Ubi, B.E. and Kunert, K.J. (2011). Determination of proximate composition and amino acid profile of Nigerian sesame (*Sesamum indicum* L.) cultivars. Nigerian Journal of Biotechnology. Volume 23, pp: 5- 12

14. Nzikou, J.M.; Matos, L.; Bouanga-kalou,G.; Ndangui,C.B.; Pambou-Tobi,N.P.G.; Kimbonguila,A. and Desobry,S. (2009). Chemical composition of the seeds and oil of sesame (*Sesamum indicum L.*) grown in Congo- Brazzaville. Advance Journal of Food Science and Technology, 1(1):6-11
15. Ravindran, V. (1990). Sesame meal. In: Nontraditional feed sources for use in swine production (Ed) P.A. Thacker, and R.N. Kirkwood. pp. 419-427. Butterworth Publishers, Boston.
16. Saydut, A. ; Duz, M. Z. ; Kaya, C. ; Kafadar, A. B. and Hamamci, C. (2008)("<549dd72d0cf2b803713a7d31 (2).pdf>,"). Transesterified sesame *(Sesamum indicum L.)* seed oil as a biodiesel fuel. Bioresource Technology, 99(14), 6656-6660.
17. SSMO, (2002) Sudanese Standard Meteorological Organization. Standard of sesame oil, Khartoum. Sudan.
18. Steel, R.D.G.; Torrie,T. H. and Dickey,D. A. (1997). Principles and procedures of statistics: in A Biometrical Approach. 3rd ed. Published by McGraw- Hill, New York, USA, P.666.
19. The Central Bank of Sudan (2016). Annual report book, Sudan.
20. Weiss E.A. (2000). Oil Seed Crop. 2nd Edition Blackwell Longman Group Ltd. USA. 131 - 164.
21. Yagoub, A.E.A; El Khier, M.K.S. and Ishag, K.E.A. (2008). Chemical composition and oil characteristics of sesame seed cultivars grown in Sudan. Research Journal of Agriculture and Biological Sciences volume: 4(6) pp: 761-766.
22. Yalegama, L.; Jayasekara, C.; Upali, S. and Abeygunawardhana, M. (2007). Organoleptic and chemical properties of coconut and sesame oils and their blends. Journal of the coconut research institute of Srilanka, 18: 67 – 76.