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Comparative characterization of moringa, sesame and peanut seeds oils (Sudan)

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Abstract
This study was conducted to compare the yield percentage and physicochemical characteristics of *Moringa* seeds oil, with that of Sesame and Peanut seeds, to see the possibility of using *Moringa* seeds as a suitable and safe source of edible oil. *Moringa oleifera*, Sesame and Peanut Seeds were used after six months of storage. Seeds oils were extracted by n-hexane using cold and hot methods. Commercial oil samples for the three types of seeds were collected from the local markets in Khartoum State. PH- values, density, viscosity, refractive index, saponification value, peroxide value and acid value, were measured for the extracted and commercial oils. Sodium, potassium and calcium contents were determined for each oil sample. GC-MS characterization was carried for the different oils. The cold method extraction showed oil yields as 43% for *Moringa oleifera*, 41% for sesame and 44% for peanut whereas, that of hot method extraction were found to be (42%, 40%, and, 42%) respectively. GC-MS analysis showed different amounts of unsaturated fatty acids in *Moringa* oil especially oleic and linoleic acids. The main saturated acids were palmitic and stearic in the three types of oils. Peroxide values of the extracted and commercial *Moringa* oils were almost the same (hot 1.8, cold 1.9 and commercial 1.89 meqO_2/kg oil). GC-MS analysis also showed some differences between the extracted and commercial *Moringa oleifera* oils.

Keywords: *Moringa oleifera*, Oil yield, GC-MS, palmitic acid, edible oils

Introduction
Sudan is one of the main agricultural countries in Africa. The country still imports significant amounts of vegetable oils for edible purposes. Sudan produces oils mainly from Cotton, Peanut, Sesame, and Sunflower seeds. The gap between the local production and the actual needs is still large.

Moringa
Moringa oleifera (Moringaceae) is a fast-growing softwood tree indigenous to sub-Himalayan tracts of Northern India. It is one of 13 species within the same genus, and has become the most diffuse in tropical and subtropical areas at altitudes up to 2000 m (Alessandro Leone. et al., 2016) [3]. *Moringa oleifera* is a most widely known and utilized species (Naser E. and Ali S. 1973). In some parts of the world *Moringa oleifera* is referred to as (drumsticle tree) and horse radish, whereas, in other parts it is known as (kelor tree). *Moringa oleifera* is traditionally an important food commodity. It is leaves, flowers, seeds and roots are used as vegetables (Naser E. and Ali S.1973). A number of medicinal and therapeutic properties have been ascribed to various parts of the tree, including the treatment of ascites, rheumatism and venomous bites. Some parts of the plant have reported to show antitumor, antipyretic, antiepileptic, anti-inflammatory and anti-ulcer effects and the leaves were reported to be rich with vitamins A and C (Dahot M. 1988). Some recent studies reflect the possibility of using *M. oleifera* flowers, leaves, seeds, fruits, and barks as a potential source of solutions to the current challenges faced in treating cancer. They were described to be rich with a variety of bioactive compounds that, can act as antioxidants, antibiotics, anti-inflammatory and anti-cancer agents (Andy T. Y. Lau et al., 2021) [27]. Jinping Liu et al., (2019), reported 122 components in *M. oleifera* leaves, where the structure types included flavonoids, alkaloids, glyosides, organic acids, organic acid esters, iridoids, lignans, and steroids.
According to Guilin Chen et al., (2020) [26], *M. oleifera* leaves extracts exhibited strong antioxidant activities, where the main identified potential effective components were, kaempferol 3-O-rutinoside, quercetin 3-O-(600-malonyl-glucoside), kaempferol 3-O-glucoside, and quercetin derivative. Xiaona Fu et al., (2022) [25], who characterized a Bambara groundnut– *Moringa oleifera* leaf protein isolate complex (BAMOLP), described it as a good source of protein, rich with essential amino acids. It is especially higher in phenylalanine and histidine compared to whey, pea, brown rice, soy, hemp, and wheat protein and can therefore be used as an alternative in applications where those proteins are desired. The protein complex (BAMOLP) was also higher in threonine, phenylalanine, lysine, and leucine when compared to the FAO/WHO reference pattern. The flowers were reported to contain flavonoid pigments (Dahot M.1988). The seeds were erroneously reported as a promising source of edible oils which strongly resist rancidity (New Delhi, India, 1962). The tree can be cultivated in arid, semi-arid and hot areas with optimum temperatures between 25^{o}C and 35^{O}C (F. S. G Periva et al, 2018; HDRA 2002). It grows on soils with pH ranging from (5.0 to 9.0) but it prefers the neutral and well drained soils

(Crosly, 2007; F. S. G. Pereiva, 2018). According to F. S. G. Pereiva et al., (2018), the tree grows better in well-drained clay-sandy soils and tolerates clayey soils without stagnant water, and rapidly grows even in poor soils and less affected by drought. So it may easily be grown in poor third world countries, to produce useful oil, with economic benefits to the native population of the areas where the tree is cultivated (Starros Lalas and John Tasknis (2001). The tree begins to flower after eight months of planting (Fuglie, 2001). *Moringa olifeira* was also described as a very rapid growing tree in various climatic conditions as promising tree and has the potential to become a new source of oil for Malaysia (A. S. Mohammed et al, 2003). The species was described as a fast growing soft wood tree that can reach 12 meters in height and is indigenous to the Himalayan foot hills eg: Northern India, Pakistan and Nepal (Roloff, A. et al., 2009, Sharma, V. et al., 2011, Alessandro Leone et al; (2015). The environmental parameters such as annual precipitation, temperature, and soil type showed significant influence on the level of antioxidant activity and antioxidant content of *Moringa oleifera* cultivated in different locations (Ayonposi Bukola Olaoye, 2021) [12]. The tree is an important crop in many countries such as Ethiopia, Philippines, Sudan, Eastern Africa, Western Africa, South Africa, tropical Asia, Latin America, the Caribbean, Florida and islands of pacific (Fahey, 2005; F. S. G Pereira et al, 2018). S. S Ibrahim et al; (1974) [18] reported that, the oil content of *Moringa* seeds and oil properties show wide variations, depending on the species and the environmental conditions. *M. oliefera* trees may produce seeds as 2500 kg/ha, which yield about 1478kg of oil. Xiaona Fu et al., (2021) [25] reported that, the fatty acids of *Moringa oleifera* seeds oil are mainly composed of oleic acid (70.85%) and palmitic acid (8.98%), with unsaturated fatty acids content as high as (79.86%), refractive index (1.46), acid value (2.35 g KOH/kg oil), peroxide value (7.2 meq O_2/ kg oil), saponification value (189.84 g KOH/kg oil), and iodine value (66.78 g I_2/100 g oil). In a study carried by Karima Gharsallah et al., (2021) *Moringa oleifera* seeds from Tunisia was found to contain moisture as (7.78%), ash (3.1%), proteins (33.39%), fiber (3.9%), fat (41.7%), and total sugars as (10.13 %), whereas the seeds oil analysis showed the presence of oleic acid as a main fatty acid (73.4%) and the total phenolic content exhibited gallic acid as (102 mg eq/kg) in addition to caffeic, vanillic, and ferrulic acid coupled with Apigenin and Naringenin. The study concluded that *M. oleifera* seeds oil could potentially be utilized for industrial, cosmetic, pharmaceutical and medicinal applications.

Sesame

Sesame is one of the most important oil seeds worldwide (Kouc et al 2007) .The numerous varieties and ecotypes of Sesame adapted various ecological conditions, however, the cultivation of modern varieties is limited due to insufficient genetic information. Two studies that used morphological characters to group genotypes into clusters, find a wide diversity in Indian sesame genotypes (Ganesh et al, 1995, Patel et al. 1994). Multivariate analysis based on morphological characters provides genetic information that will allow the breeder to improve population by selecting from specific geographic regions (Souza et al. 1991).

Peanut

Peanut is widely grown as an important food crop and a source of edible oil for millions of people. It is a herbaceous plant of which there are different varieties such as Boro light, Boro red, Mokura, Campala, Gut and Ela (Anayser et al; 2009). Oil content of peanut was found to be different in quantity on relative proportion of fatty acids, geographic location, seasons and growing conditions (Aclyeyeye and Ajewde et al; 1992). Peanut seeds contain (44 to 56%) oil and (22 to 30%) protein on dry basis, as well as, vitamin K and B group (Savage and Keenon, 1994). Sesame and peanuts seeds were reported to be excellent sources of copper, magnesium, calcium, potassium, phosphorus, iron, zinc, molybdenum and selenium (Savage and Keenon, 1994). This rich assortment of minerals may result in many health benefits for human body.

Methodology

Moringa oleifera, Sesame and Peanut seeds were collected from Khartoum North market after six months of storage. The seeds were cleaned, dried and powdered by mechanical grinding to reduce the seeds sizes and to make them more accessible to the solvent. 500g of each type of seeds were accurately weighed and transferred to a Soxhlet system for oil extraction by n- hexane, using hot and cold methods. The physicochemical parameters of each extracted oil sample were measured using the appropriate technique. GC- MS analysis was carried for the extracted *Moringa*, sesame, and peanut oil samples as well as the commercial *Moringa* oil. All chemicals used were of analytical grade.

Results and Discussion

Table 1: Volumes of the extracted oils

Oil type	Mean volume of oil in the two methods
Moringa oleifera	235.9 ml
Sesame	222.35 ml
Peanut	236.96 ml

Table (1) showed the amount of oil extracted from 500g of *Moringa oleifera*, sesame and peanut seeds. The cold method extraction gave higher yield compared with hot method extraction.

This may be due to the increased ability of the polar solvent to overcome forces that bind lipids within the sample matrix (Lumely and Colwell, 1991). The oil yield showed that *Moringa Oleifera* seeds may be used as a good source of oil production.

Table 2: Physical proprieties of oil samples

Measured property	Type of oil samples								
	Moringa			Sesame			Peanut		
	Hot	Cold	Commercial	Hot	Cold	Commercial	Hot	Cold	Commercial
Refractive index	1.4655	1.3565	1.4549	1.4645	1.4624	1.3663	1.4665	1.422	1.2972
Viscosity	28.94	27.99	28.15	29.10	28.99	29.35	28.75	27.96	29.73
pH value	2.92	2.96	3.25	2.29	3.05	2.95	2.94	2.96	2.88
Density	0.90208	0.91157	0.91441	0.91077	0.90555	0.91455	0.90425	0.91332	0.90255
Boiling points/^{o}C	228	227	227	227	226	226	226	226	228

The measured physical parameters for *Moringa*, sesame, and peanuts oils showed no significant variations (Table. 2). The boiling points of the oils extracted by hot method for *Moringa oleifera*, sesame and peanut were, 228^{o}C, 227^{o}C and 226^{o}C respectively. These values were close to that, of oils extracted by cold method which were 227^{o}C, 227^{o}C and 226^{o}C. These results were in a good agreement with those of Standard Codex (2001).The pH values of the three oils extracted by the hot method have average values of 2.92, 2.29 and 2.94 respectively, indicating relatively high acidity. The refractive index (1.4655) for *Moringa* oil extracted by hot method was found to be within the reference range (1.4549-1.4665) and was not varied from sesame and peanut oils extracted by the same method, which, were (1.4645 and 1.4665).The variations of refractive index values for oils extracted by cold method may be attributed to the place of planting, depending on soil type or climatic factors. Refractive index, viscosity, pH value, density, and boiling points for the different types of oils were found to be almost identical. This may indicate high similarities between *Moringa*, Sesame, and Peanut oils. Therefore it may be concluded, that, from physical properties sight of view *Moringa oleivera* seeds oil can safely be used as edible oil. According to Xiaona Fu et al., (2021) [25], *Moringa oleifera* seeds oil was highly stable up to (305 °C) and due to these excellent physical and chemical properties it can be used as frying oil and might effectively contribute in cosmetic, pharmaceutical, and medicinal industries.

Table 3: Chemical properties of the different oils

Test	Type of oil samples								
	Moringa			Sesame			Peanut		
	Hot	Cold	Commercial	Hot	Cold	Commercial	Hot	Cold	Commercial
Iodine value	116	113	112	113	114	110	118	117	98
Peroxide value	1.8	1.9	1.89	2.0	1.8	1.9	2.0	2.2	2.0
Sap. Value	189.88	191.85	195.85	190.85	190.76	189.25	192.45	192.8	190.55
Acid value	5.77	5.75	5.25	5.86	5.80	5.11	5.91	5.92	4.59

The high iodine values may, suggest the presence of unsaturated fatty acids (table 3). *Moringa oleifera* oil gave an average of 114.5 Wij's for the two methods, compared with, 113.5 and 117.5 for sesame and peanut oils respectively. This may indicate the degree of instauration in the fatty acids of tri-acyl glycerol. These values could be used to quantify the amount of double bonds present in the oils, which signifies the susceptibility of oil to oxidation. The peroxide value of *Moringa* oil was (1.85*meq*O2 /kg oil), which fall in the accepted range (1.5 to 2.4), as reported by codex standards (2001). The peroxide values of sesame and peanut oil (1.9 and 2.1 *meq*O2/kg oil) were also found to be in a good agreement with those of *Moringa* oil and codex standards. Fluctuations of these values may be attributed to immaturity and storage effect on seeds. *Moringa* oil showed high oxidative rancidity as the results of the measured peroxide values indicate. The measured saponification values of *Moringa* oils (hot and cold methods) have an average of 190.87. The saponification values of sesame and peanut oils were 190.38 and 192.63 respectively. All these values were within the range (186 to 195), as reported by Codex Standards (2001). The acid value is an indication of the amount of fatty acids present in an oil sample. It is a reflection of pH value of the oil. If the acid value increases, the pH of the oil will decrease. The acid values of *Moringa*, Sesame and Peanut were found to be 5.77%, 5.86% and 5.91% respectively.

Table 4: Sodium, potassium and calcium contents of oil samples (ppm)

Mineral	Type of oil samples								
	Moringa			Sesame			Peanut		
	Hot	Cold	Commercial	Hot	Cold	Commercial	Hot	Cold	Commercial
Na	30.667	29.333	30.333	29.333	28.333	28.889	28.333	32.222	30.556
K	110.55	110.547	116.592	110.547	114.501	114.501	110.55	110.55	110.547
Ca	3.018	2.015	3.018	3.520	2.015	3.520	3.018	3.018	3.018

The three types of oils showed significantly high potassium and sodium content. The concentrations of the two elements (K and Na) were almost similar for the different oils. The commercial samples also showed almost similar potassium and sodium content as that of the extracted samples. The cold method extracted oils showed relatively low concentrations of the two elements, when compared with the hot extracted and the commercial oil samples (table 4). Calcium concentrations in the three oil types were low in comparison with that of potassium and sodium. *Moringa* and Sesame oils obtained by the cold extraction method showed identical calcium content (2.015ppm). The hot extracted and the commercial Sesame oil samples have the same calcium content (3.520ppm), as the highest calcium concentrations. The Peanut oil samples obtained by the two extraction methods and the commercial sample showed exactly similar calcium content (3.018ppm).

Table 5: Chemical constituents of the different oil samples (GC-MS analysis)

Chemical constituent	Type of oil samples					
	Moringa		Sesame		Peanut	
	Retention time/min	% area	Retention time/min	% area	Retention time/min	% area
Nonenal	16.090	0.1	16.350	0.07	16.180	0.2
Nonanal	16.389	0.05	-	-	16.394	0.17
Palmitic acid	41.072	9.8	37.747	13.62	37.672	11.36
Lauric acid	28.870	4.40	46.652	1.25	21.049	0.35
Stearic acid	45.494	2.95	39.375	0.17	41.138	3.67
Oleic acid	40.732	11.0	41.443	66.83	41.288	57.93
Arachidic acid	-	-	44.541	0.34	44.508	0.2
Oleic acid anhydride	45.422	3.14	45.422	3.14	-	-
Stearic acid anhydride	45.494	2.95	45.613	2.58	-	-
Sesamin	59.640	25.87	-	-	-	-
9,12 octadecadiconic	37.347	4.40	45.492	1.89	46.351	11.40
Linolic acid chloride	45.913	0.78	-	-	-	-
Bête-tocopherolsilane	46.283	3.10	-	-	-	-
Trimethyl phenyl silane	61.066	13.69	46.435	1.92	-	-
Linoleic acid	40.649	18.12	40.382	4.75	-	-
Diethyl methyl borine	-	-	42.533	1.13	55.268	0.58
Oleic acid chloride	-	-	-	-	45.5084	13.8
Stearic acid anhydride	45.494	2.95	45.613	2.58	-	-
Diethyl methyl	-	-	42.33	1.13	55.268	0.58

The extracted oils of *Moringa oleifera*, Sesame and Peanut were analyzed by GC-MS for qualitative and quantitative chemical composition (Table.5).The retention time and percentage area of the main fatty acids and the other chemical constituents were compared with those reported by the National Institute of Standards and Technology (NIST), with help of HPCHEM software and published mass spectra. Tables (5 and 6) show the chemical constituents of the extracted oil samples and commercial *Moringa* oil. Palmitic acid content was found to be (9.8%) in *Moringa*, (13.62%) in Sesame and (11.36%) in Peanut compared with (7.91%) in the commercial *Moringa* oil sample. Oleic acid content was (11.00%) in *Moringa*, (66.83%) in Sesame and (57.93) in Peanut. For the commercial *Moringa* oil, the Oleic acid content was found to be (68.49%). B. S. Ogunsina et al., (2021) reported Oleic acid as the major fatty acid in *Moringa* seeds oil (78–79%).

Stearic acid content was found to be (2.95%) in *Moringa oil*, (0.17%) in Sesame and (3.76%) in Peanut, where, it was (3.76%) in commercial *Moringa* oil. Arachidic acid was found to be (0.34%) in Sesame, (0.2%) in Peanut, and not detected in the extracted and the commercial *Moringa oils*. Lauric acid was (4.40%) in *Moringa*, (1.25%) in Sesame and (0.35%) in Peanut and not detected in the commercial *Moringa* oil. Linoleic acid content was (18.12%) in *Moringa*, (4.75%) in Sesame and not detected in Peanut oil. 9, 12-Octadecadienoic acid was (4.40%) in *Moringa*, (1.89%) in Sesame, (11.40%) in Peanut and (3.7%) in the commercial *Moringa* oil sample. Some chemical constituents were found in low amounts such as, stearic acid anhydride (2.95%) in *Moringa*, (2.58) in Sesame and not detected in Peanut. Nonenal and nonanal were found in very low percentages in some oil samples. Nonenal was not detected in both Sesame and commercial *Moringa* oils. Beta-tocopherol was found only in the extracted and commercial *Moringa* oils, as (3.10% and 0.49%) respectively, and not detected in Sesame and Peanut oil samples. Sesamin was detected only in the extracted *Moringa* oil as (25.87%), whereas some amounts of tri-methyl phenyl silane were measured as (13.69%) in Moringa and (1.92%) in Sesame oil. The main unsaturated fatty acids in the analyzed oil samples were oleic (C18:1) and linoleic acid (C18:2). The main saturated fatty acids were found to be, palamitic, lauric, and stearic acids (tables 5 and 6).

Table 6: Chemical constituents of Commercial Moringa sample using GC-Ms

Chemical constituent	Retention time/minute	area under the peak %	Height of the peak %
Octadecanoic acid	37.930	3.76	-
Octadecanoic acid	46.353	5.42	-

Heptanoic acid	49.521	0.49	-
Oliec acid	40.873	68.49	38.21
Stearic acid	41.092	3.76	9.47
Lauric acid	-	-	-
Palmitic acid	42.51	7.91	2.51
Oleic acid chloride	45.508	5.34	13.8
Archidic acid	-	-	-
Stearic acid anhydride	45.921	0.63	-
9-eicosadione	55.207	0.54	-
Hexadeconoic acid	43.291	0.92	-
Linoleic acid	46.521	0.59	20.09
9,12 Octadecanoic acid	37.930	3.76	-
Palmitic acid chloride	42.514	1.38	-
Beta-tocopherol	49.52	0.49	1.09
Diethyl methyl borane	56.700	3.27	-

The results showed by table (6) were in a good agreement with those reported by Nzilou et al; (2009). Palmitic acid was the main available saturated fatty acid in all oil samples. The highest oleic acid content was shown by Sesame oil as (66.830%) and Peanut oil as (57.93%), whereas the extracted *Moringa* oil sample showed unexpected oleic acid content as (11.00%) compared to that shown by the commercial *Moringa* oil sample which was found to be (68.49%). Another significant difference between the extracted *Moringa* oil and the commercial one, was their linoleic acid content, which was found to be (18.12%) in the hexane extracted oil sample and (0.59%) in the commercial *Moringa* oil sample as the lowest measured linoleic acid content. Surprisingly linoleic acid was not detected in the extracted Peanut oil sample. Sesame oil can be described as very rich with oleic and Palmitic acids. The two fatty acids were reported to account together for (85%) of the total fatty acids in Sesame oil (Nazikouet, et al; 2009, Egbekun and Ehieze et al; 1997).

Conclusion and Recommendations

The obtained results showed that, the oil of *Moringa oleifera* cultivated in Sudan can safely be used, for food preparation, cosmetics and industrial applications, depending on the measured physicochemical characteristics of the oil.

Moringa oleifera could be cultivated in large areas in Sudan, since the tree is rapidly growing even in poor soils, and not affected by drought (Sengupta and Gupta, 1970, Morton, 1991). *Moringa oleifera* can be grown in Sudan as a useful alternative source of edible oil production, because the tree can live for so many years when compared with the seasonal growing sesame, peanut, cotton and sunflower.

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