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Extraction and Comparative Evaluation on the Physicochemical Characteristics of Yemeni *Moringa oleifera* Seeds Oil

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ABSTRACT
Moringa oleifera is a versatile tree with nutritional, medicinal and environmental benefits making it a valuable resource for communities in many regions of the world. This study aimed to extracted oil from Yemeni *Moringa oleifera* seeds oil (YMOSO) using two methods (cold pressing and seoxhlet n-hexane). The yields of the oils were 16.12% and 28.34, % respectively. The yields of the oils were 16.12% % and 28.34% respectively. Where it was investigate the chemical and physical characteristics by two method cold press and soxhlet n-hexane showed of Yemeni *Moringa oleifera* seeds oil (YMOSO), including a free fatty acid (FFA) content of 1.12 % and 2.98 %, an acid value of 5.99±0.5 mg/g and 6.52±0.5 mg/g, an iodine value of 67.68±0.1 mg/g and 67.43±0.1 mg/g, a saponification value of 189.51±0.1 mg/g and 188.49±0.1 mg/g, a refractive index of 1.46±0.01 and 1.47±0.01 at 25 °,C a moisture content of 0.24±0.03% and 0.36±0.03%, a density of 0.90±0.05 g/ml and 0.89±0.05 g/ml at 25 °C, a specific gravity of 0.968±0.03 g/ml and 0.956±0.03 g/ml at 25 °C, and a viscosity of 48 and 47 cP at 25 °C respectively. the chemical components of the oil were determined using Fourier transform infrared (FTIR) spectroscopy and Gas Chromatography-Mass Spectroscopy (GS-MS).

CONTENTS

1. Introduction:

In recent years there has been increasying interest in exploring the various properties and potential applications of plant derived natural oils. Among these, Moringa seeds oil has attracted significant attention owing to its exceptional nutritional value, medicinal properties, and diverse industrial applications. Moringa is genus of the Moringaceae family, which includes 13 known species, including Moringa oleifera [1]. Moringa oleifera, the "marvel tree," is distributed worldwide in almost all tropical and subtropical regions, but is thought to be native to Afghanistan, Bangladesh, India, and Pakistan [2]. Moringa oleifera is a tree distributed in Yemen and some Asian and African countries [3]. Furthermore, Moringa oleifera exhibits rapid growth, with a lifespan ranging from approximately 1 to 3 months. It attains a height of 2.5 m and produces pods weighing around 120 g each. The length of the pods ranges from 45 to 50 cm, and a single tree

can yield a harvest of 1000 to 1200 pods [4]. In many studies`, Moringa oleifera seeds has been extracted in different ways and the results vary according to factors and climate. Abeer A. Idris and Azhari H. Nour et al. ,. GC-MS was used for determined fatty acid composition of Sudanese *Moringa oleifera* seeds oil and the yield was 42.87% [5]. GC-MS analysis identified thirty-six phyto-compounds amounting for 98.99% of the total oil in Tuna Sian seed oil [6]. In another study, Nigeria, oil yield 26.2%. The oil concentration was compared with those recorded a Kenya Extraction ratio 35.7% and India 38.3% [7]. In the study by seoxhlet extraction a yield of 28.75 ± 0.00% of oil while MAE gave a yield of 34.25 ± 0.00%. These data show that the solvent (petroleum ether) and extraction methods (MAE and SE) were suitable for the extraction of M. oleifera oil. This also indicates that petroleum ether has very good solubility for oil as well as excellent microwave irradiation properties[8].

In adddation, the physicochemical characteristics of oils play a crucial role in determining their suitability for different applications. Understanding the physicochemical properties of Moringa seeds oil is of paramount importance to unlocking its full potential and exploringe its applications in various industries, including food, pharmaceuticals, and cosmetics [9]. In this study, the physicochemical properties of Moringa oleifera seeds were as follows: acid value 6.35±0.12, saponification value 218.21±0.63, free fatty acid 3.16±0.05 and peroxide value 5.00±0.02 whereas for oil extracted with the maceration method was 7.51±0.03, specific gravity was 0.887±0.01, refractive index 1.457±0.01, and viscosity 57.20±0.01 [10]. In another study, the oil extraction xild and mater content of Moringa oleifera seeds were related , where the effect of seasonality, refining and drying, due to the reifying process analysis acid value of 1.82 ± 0.01, free fatty acid of 0.91 ± 0.01, iodine value of 62.14 ± 5.87, peroxide value of 0.00 ± 0.00, moisture content of 0.32 ± 0.04 [11]. The combination of compounds in the seeds of mature Moringa plants has been discovered to include a wide spectrum of components, including fatty acids, esters, amides, and vitamins. Among these compounds, the highest proportion was observed for fatty acids, which reached 29.52%. Alcohol followed with a proportion of 3.57%, while hydrocarbon compounds accounted for 1.84%. Ketones, stearate, adenines, and amides had successive levels of 1.71%, 0.13%, 0.04%, and 0.15% respectively. Additionally, vitamin E was present at a level of 0.27% [12].Thus, the extracted oil from Moringa oleifera seeds, which is called the oil ben, contain 70 percent of oleic acid, which is a monounsaturated fatty acid with 18 carbon atoms. Polyunsaturated fatty acids when compared to oleic acid we find that this (Oleic Acid) are stability on ppressing and superior an have industrial applications in the food industry such as storage for longer periods and cooking [13]. GC-MS analysis was completed performed to identify the phyto-chemicals present in the oil, with a total of thirty-six compounds accounting for 98.99% of the oil composition. Eleven groups classified these compounds with the highest intensity at 91.63%. cis, 6-octadecenoic acid, was presented for 70.68% of the oil composition. The triacylglycerol composition of MOSO was characterized by the predominance of glycerol trioleate (OOO) at 32.42±0.12%. Furthermore, thermogravimetric analysis revealed that MOSO exhibited significant thermal stability [14].

The aims of this studywas to investigate the Extraction and physicochemical characteristics of Yemeni Moringa seeds oil, to enhance our understanding of its composition, properties, and potential applications. The findings of this study have the potential to contribute to the broader knowledge of natural oils, facilitate their utilization in different industries, and explore their benefits in the fields of nutrition and healthcare. In addation, they were compared against GC-MS Analysis which revealed that the main fatty acids were in moringa seeds oil.

2. Materials And Methods

2.1. Sample Collection

Crude Yemeni Moringa oleifera seeds were obtained from Hadhramaut Governorate at the Agricultural Research Station in Wadi Hadramout - Al-Suwairi. The seeds samples were collected manually at the temperature 35°C during the harvest season in summer (June). They are typically harvested when they turn brown and begin to dry out on the tree. Once the seeds are separated from the tree, they must be cleaned to remove any impurities such as dirt, debris, or damaged seeds. This can be achieved by manually removing impurities . Subsequently it removed to access the kernel inside. Shelling can be performed manually by using a sharp tools. Once the seeds weare shelled, they are crushed or ground to break them down into smaller particles. This step increases the surface area of the seeds, facilitating subsequent oil extraction. It is known that the Moringa oleifera seeds classified has been classified according to experts from Agricultural Research Station in Wadi Hadramout. Figure 1. Photographs illustrate the stages of sample collection to extract Moringa oleifera seeds.

2.2 Chemicals and Reagent

All Chemicals were ethanol (99.8%), isopropanol (99.7%), Hydrochloric Acid (36.5%), Potassium Hydroxide (99%), Potassium Iodide (99.5%) and sodium thiosulfate (99%). The Wij's solutions, cyclohexane (99.7%), sodium Thiosulphate (99%), n-hexane (99%), Starch and Phenolphthalein.

2.3. Extraction method of oil

2.3.1. Extraction cold press

A total of 300 g of ground kernel seeds were exposed to water vapor (boiling water) and subsequently pressed using a screw pressing machine. The resulting oil was collected and stored at a 4˚C for subsequent analysis [15].

2.3.2. Extraction soxhlet in (n-hexane).

The extraction process of Moringa oleifera seed oil was extracted soxhlet using n-hexane as follows: 10 g of Moringa oleifera seeds were placed inside an extraction thimble. The thimble containing the seeds was then placed in a seoxhlet extractor. For extraction, 200 ml of n-hexane was used as the solvent. The seoxhlet process was carried out for 4 h at a temperature of 60 °C. After the extraction, the solvent was removed by evaporation. The produced vapour during the evaporation process were recycled by rotary evaporation. To eliminate any remaining traces of the solvent, the extracted oil was dried in an oven at a temperature of 50 °C for 4 hours [16] [17]. The results are expressed a ccording to the following equation:

$$\text{Fat content (\%)} = \frac{(\text{weight of flask + fat}) - (\text{weight of flask}) \times 100 \ldots..(1)}{\text{weight of sample}}$$

2.4. Physicochemical Characteristics

2.4.1. Determination of Free Fatty Acids (FFAs%) and Acid Value (AV):

Acid value and FFA percentage (as oleic acid) were determined according to Salimon et al. (2006) for free fatty acids [18]. Then, 50 ml of isopropanol and 0.5 ml phenolphthalein into a flask and addition of sodium hydroxide (NaOH, 0.1 N) of neutralized pink color occurs then 5 g Yemeni Moringa oleifera seeds oil (YMOSO) was added neutralized isopropanol then 40°C titrated. Then 1 ml of phenolphthalein was used as an indicator Equation 2:

$$\text{\% FFA as oleic acid} = \frac{28.2 \times N \times V}{W} \ldots\ldots\ldots(2)$$

Where, V is volume of NaOH solution used in (ml); N is normality of NaOH solution in Equivalent per liter (Eq/l); W grams is the weight of the sample in

Acid value = % FFA as Oleic Acid × 2.81 …..(3),

where, 2.81 is the conversion factor of oleic acid.

2.4.2. Determination of Iodine Value (IV).

The IV of Yemeni Moringa oleifera seeds oil (YMOSO) was calculated by [19] .The 0.5 g of Yemeni Moringa seeds oil (YMOSO), followed by the addition of 15 ml of cyclohexane. Next, 25 ml of Wijs solution was placed in a tight flask and , the mixture was shaken gently and placed in the dark for 60 min. Twenty milliliter of 10%potassium iodide (KI) solution and 150 ml of distilled water were added to the mixture with continuous of titration by sodium thiosulphate (0.1N Na2S2O3) until by iodine color [19][20]. The blank was treated under the same conditions. The iodine value was determined using equation 4 as follows:

$$\mathbf{I.V} = \frac{\mathbf{12.69 \times N(V_b - V_s)}}{\mathbf{W}} \text{……..(4)}$$

2.4.3. Determination of Saponification Value.

To estimate the saponification result of the Yemeni Moringa oleifera seeds oil (YMOSO), a 2 g sample of the oil was combined with 15 mL of 0.1 N (KOH) solution. The resulting mixture was then placed in flask equipped with a glass joint. A condenser was attached to the glass joint to set up the reflux system. The mixture was heated under continuous stirring for 60 min. in a water bath. After the heating period, 0.5 mL of a 1% phenolphthalein solution was added to the mixture as an indicator. A 0.1 mol/L (HCl) was used for titration . A Blank titration was performed as a reference [20] [32]. The saponification value was calculated using Equation 5:

$$\mathbf{S.V} = \frac{56.1 \times N(V_b - V_s)}{W} \text{…….(5)}$$

where, Vb = ml of blank; Vs = ml of titrant; W = weight (g) of the sample; and N = normality of the KOH Eq/l.

2.4.4. Refractive Index

The Refractive Index of Yemeni Moringa oleifera seeds oil (YMOSO) at temperature 25°C as explained by Salimon and Ahmed [21] using a refractometer model (TAGO Co. Ltd. Series No.1211), connected to a Japanese Digital Thermometer Model (DTM-1T) at 26.5°C.

2.4.5. Moisture Content

The moisture Content of Yemeni Moringa oleifera seeds oil (YMOSO) was estimated using a moisture Analyzer model and MX-50. Approximately 5 g of the sample was weighed in a moist dish and dried in a moisture analyzer for 30 min. at 101°C [22].

2.4.6. Viscosity

The Viscosity was measuread in cP (centipoises) directly from the viscometer, which was maintained for 1 min. and 100 rpm at room temperature of Yemeni Moringa oleifera seeds oil (YMOSO). at temperature 25°C the Brookfield model RV DV-I+ (U.S.A) [23] [33].

2.4.7. Density and Specific Gravity

The Density of Yemeni Moringa oleifera seeds oil (YMOSO). This was measured using a delicate balance. The weight of one millilitre of Yemeni Moringa oleifera seeds oil (YMOSO), placed on a balance was recorded at room temperature.The Lund relationship, were used to determined specific gravity at temperature 25°C [24].

2.4.8. Fourier Transform Infrared Spectroscopy Analysis of Yemeni Moringa oleifera seeds oil

(YMOSO) Analysis of Yemeni Moringa oleifera seeds oil (YMOSO) was determined by method [25]. (Perkin Elmer Spectrum GX spectrophotometer- in Malysia) in the range of 500−4000 cm-1 to derected specific was used to measure functional groups of the Yemeni Moringa oleifera seeds oil (YMOSO). The sample was covered with NaCl cells (25 mm ID × 4 mm thickness) and used for analysis. 2.4.9. Gas Chromatography - Mass Spectrophotometer (GC-MS) Analysis The analysis of the Yemeni Moringa oleifera seeds oil (YMOSO) was coupled with a gas Chromatography-Mass

Spectrophotometer. (Shimadzu Japan- in Malysia) (25 m × 250 µm ×0.25µm). The initial temperature was set at 60°C, heated at a rate of 3°C/min. to 280°C,with 1 µL sample was injected. The ion source temperature and interface seting to 200°C and 250°C respectively with solvent time of 3 min. The identification of various components was based on a comparison of their mass spectra with those of the Nist Library mass

Figure.1: photos illustrate of stages of sample collection to extraction Moringa oleifera seeds

spectra database and mass spectra from the Literature [26]. the electron impact (EI) ionization mode was 70ev and linear.

3. Results And Discussion

3.1 Oil Extraction of Moringa seeds Oil Table 1. shows the crude extraction of oil from Yemeni Moringa oleifera seeds oil (YMOSO) using two methods cold pressing and seoxhlet extraction with n-hexane. The yields of the oils were 16.12 and 28.34%, respectively. This extraction yield is consistent with findings reported in other countries, indicating that the extraction efficiency of Yemeni Moringa oleifera seeds oil (YMOSO) using the cold press method and soxhlet with n-hexane is comparable across different regions [27] [28] [30].

3.2 Physicochemical Characteristics of Moringa seeds Oil Table 1. shows the present study focused on investigating the chemical and physical properties of Yemeni Moringa oleifera seeds oil (YMOSO). The data revealed that The oil was light yellow in color and had a favorable odor. The value of free fatty Acid % for (YMOSO) is 1.12 % of the oil obtained using cold press method and 2.98% of the oil obtained using soxhlet with n-hexane. FFA is an important quality parameters in the (YMOSO), referring to oil deterioration [27]. The result shows that the acid value (AV) was to be 5.99±0.5 mg/g using cold press method and 6.52±0.5 mg/g using soxhlet with n-hexane NaOH/g oil for (YMOSO). The iodine value (I.V) of the (YMOSO) was 67.68±0.1 mg/g using cold press method and 67.43±0.1 mg/g using soxhlet with n-hexane. The value determined saponification value (S.V) of (YMOSO) as 189.51±0.1 mg/g g using cold press method and 188.49±0.1 mg/g using soxhlet with n-hexane KOH/g and was also suitable with the range of oil specifications [16] [20]. A high saponification value indicate a high proportion of lower fatty acids as reported by IT. Therefore , the quantity of oil was controlled by the soap value. In this study, the refractive index of (YMOSO) is 1.46±0.01 using cold press method and 1.47±0.01 using soxhlet with n-hexane at 25°C has a high number of carbon atoms in their Fatty Acid composition. The value was determined of moisture content of (YMOSO) where determine to be 0.24±0.03% using cold press method and 0.36±0.03% using seoxhlet with n-hexane at 101°C. These are shown in table1. The Density of the sample also showed a slight difference and was in the range of 0.90±0.05 g/ml using cold press method and 0.89±0.05 g/ml using soxhlet with n-hexane at 25°C for (YMOSO) and the specific gravity of (YMOSO) was 0.968±0.03 g/ml using cold press method and 0.956±0.03 g/ml using soxhlet with n-hexane at 25°C. Therefore, the data for viscosity at 25°C exhibited the highest resistance of (YMOSO) to flow with viscosity of 48 cP using cold press method and 47 cP using seoxhlet with n-hexane [11] [27].

Table 1: Extraction and Physicochemical properties of YMOSO

Components	Units	Experimental Values(cold press)	Experiment-al Values(soxhlet with n-hexane)
Oil content	%	16.12	28.34
FFA (as oleic acid)	%	1.12	2.98
Acid value (AV)	mg NaOH/g	5.99±0.5	6.52±0.5
Iodine value (IV)	g/100 g	67.68±0.1	67.43±0.1
Saponification value (SV)	mg KOH/g	189.51±0.1	188.49 ±0.1
Refractive index	-	1.46±0.01	1.47±0.01
Moisture content	%	0.24±0.03	0.36±0.03
Density	g/ml	0.90±0.05	0.89±0.05
Specific gravity	g/ml	0.968±0.03	0.956±0.03
Viscosity	cP	48	47

The chemical structure of the Yemeni Moringa oleifera seeds oil (YMOSO) extracted by two methods cold press and seoxhlet n-hexane was verified by FTIR. Notably, the FTIR spectrum of vegetable oils, including YMOSO, is often dominated by peaks corresponding to the triacylglycerol (TAG) molecules, as depicted in Figures 2. Table 2 presents the characteristic peaks associated with the main functional groups in the YMOSO sample. Additionally, Figure 3 and 4 displays the infrared spectra of the YMOSO samples within the range of 4000 to 600 cm -1, allowing for a comprehensive analysis of its molecular characteristics. Because of the resemblance of the chemical structure, the FTIR spectrum of each of the extracted YMOSO by cold pressing and seoxhlet n-hexane exhibited a similar pattern. Generally, FTIR produced significant peaks of carbonyl stretching vibrations (C=O) of ester at 1742 cm-1 and 1739 cm-1 of extracted YMOSO by cold press and the extracted YMOSO by seoxhlet n-hexane respectively as shown in Figures 3 and 4. C-O ester group stretching was notable at 1165 cm-1 and 1162 cm-1 in extracted YMOSO by cold press and the extracted YMOSO by soxhlet n-hexane, spectrum respectively. Furthermore, the hydroxyl (OH) stretching vibrations of alcohol or free fatty acids that initially existed in extracted YMOSO by cold press and the extracted YMOSO by soxhlet n-hexane spectrum (3000-3500 cm-1). The peaks in the bands at 2925-2854 cm-1 and 2921 - 2853 cm-1 represent -the CH3 and -CH2 groups of YMOSO extracted by cold press and seoxhlet n-hexane respectively.

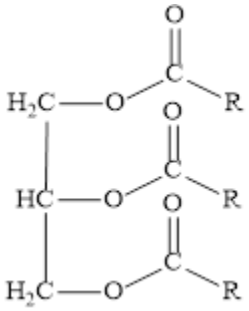


Figure. 2: Structure of triacylglycerol

Table 2: The functional groups of YMOSO regarding the main wavenumber in the FTIR

Functional Group	Wavenumber (cm^{-1})a	Wavenumber (cm^{-1})b
-OH stretching vibration	3495	3506
C = C bending vibration (aliphatic)	3011	3008
C-H stretching vibration (aliphatic)	2925,2854	2921,2853
C = O stretching vibration (ester)	1742	1739
C-H scissoring and bending for methylene	1463	1463
=C–H (cis) Unsaturated	1417	1418
-CH3 sym deformation	1377	1377
-C-O-Stretching vibration(ester)	1238−1165	1240−1162
C-H group vibration (aliphatic)	722	725
a : YMOSO, extracted by cold press, b: YMOSO, extracted soxhlet with n-hexane press		

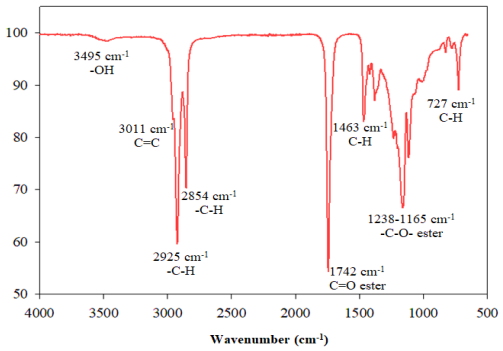


Figure. 3: The main wavenumber in the FTIR of YMOSO, extracted by cold press

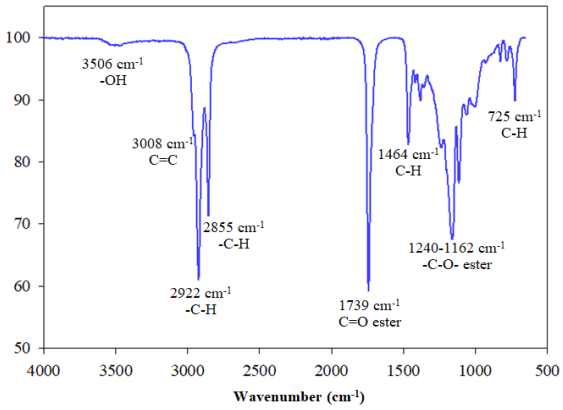
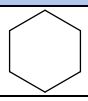
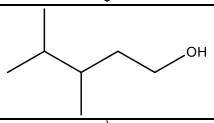
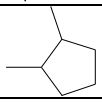
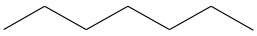
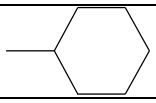
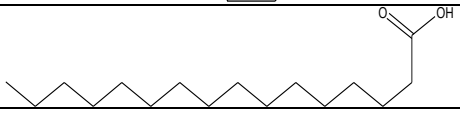


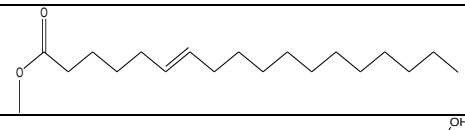
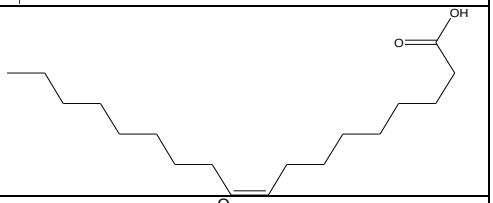
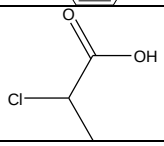
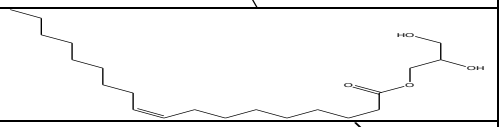
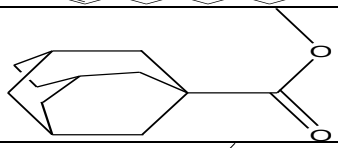
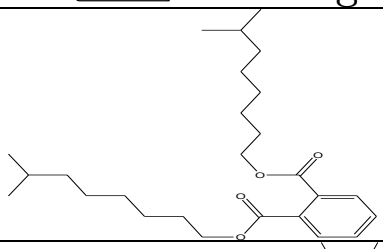
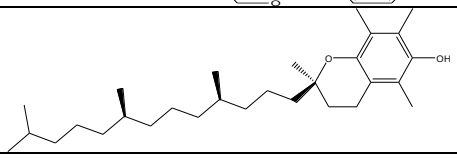
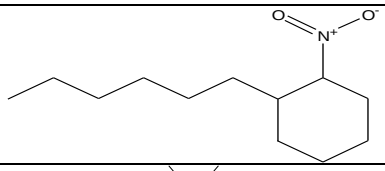
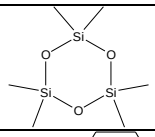
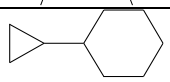
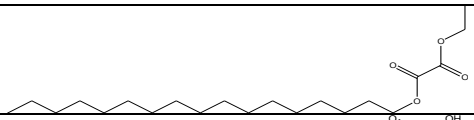
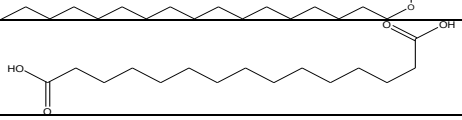
Figure. 4: The main wavenumber in the FTIR of YMOSO, extracted Soxhlet with n-hexane press

3.4. GC-MS Analysis of YMOSO

The conducted analysis using GC-MS revealed the presence of more than 20 compounds in the extracted oil obtained from Moringa oleifera seeds by two methods cold press and soxhlet n-hexane as shown in Table 3 and ,4 respectively.Among these compounds, eight major components were identified in the extracted Yemeni Moringa oleifera seeds oil cold press and seoxhlet n-hexane, and their respective peak percentage areas are presented in Table 3 and ,4 respectively. The predominant compounds were found to be 6-Octadecenoic acid, methyl ester, (21.21 and 19.17 %) from the total peak area, followed by oleic acid, (16.97 and 19.60 %), n-Hexadecanoic acid (5.58 and 6.91%), 2- Chloropropionic acid (7.78 and 5.5 %), cyclohexane (4.01 and 4.07%), myristoyl chloride (2.34 and 2.32%), Tricyclo[4.3.1.1(3,8)]undecane-1- carboxylic acid, methyl ester (2.02 and 1.1 %) and phthalic acid, bis(7-methyloctyl) ester (2.13 and 1.11 %) respectively.

Table 3: Compounds present in YMOSO, extracted by cold press method using GC-MS analysis

No	Name of compounds	RT (min)	Peak Area %	Molecular formula	Structure
1	Cyclohexane	2.181	4.01	C_6H_{12}	
2	1-Pentanol, 3,4-dimethyl-	2.252	1.12	$C_7H_{16}O$	
3	Cyclopentane, 1,2-dimethyl-	2.334	1.24	C_7H_{14}	
4	Heptane	2.393	1.10	C_7H_{16}	
5	Cyclohexane, methyl-	2.575	1.75	$C_6H_{11}CH_3$	
6	n-Hexadecanoic acid	17.709	5.58	$C_{16}H_{32}O_2$	

7	6-Octadecenoic acid, methyl ester	19.374	21.21	$C_{19}H_{36}O$	
8	Oleic Acid	19.404	16.97	$C_{18}H_{34}O_2$	
9	2- Chloropropionic acid	19.586	7.78	$C_3H_5ClO_2$	
10	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21.721	0.90	$C_{21}H_{42}O$	
11	Tricyclo[4.3.1.1(3,8)]undecane-1-c arboxylic acid, methyl ester	24.100	2.02	$C_{12}H_{18}O_2$	
12	Phthalic acid, bis(7-methyloctyl) ester	24.103	2.13	$C_{26}H_{42}O_4$	
13	Vitamin E	27.211	0.85	$C_{29}H_{50}O$	
14	1-Hexyl-2-nitrocyclohexane	20.345	1.19	$C_{12}H_{23}NO_2$	
15	Cyclotrisiloxane, hexamethyl-	3.487	1.04	$C_6H_{18}O_3Si_3$	
16	Cyclohexane, cyclopropyl-	19.292	0.41	C_9H_{16}	
17	Oxalic acid, allyl octadecyl ester	20.345	0.49	$C_{23}H_{42}O4$	
18	1,15-Pentadecanedioic acid	20.668	2.44	$C_{15}H_{28}O_4$	

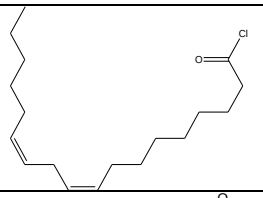
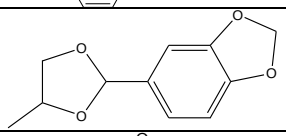
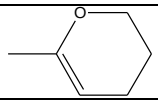
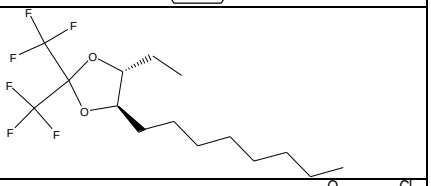
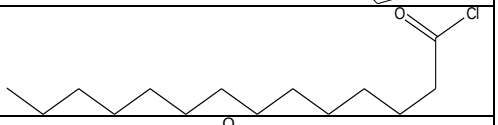
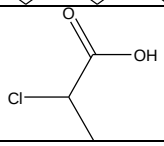
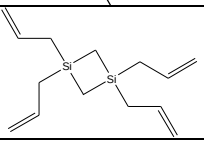
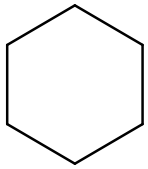
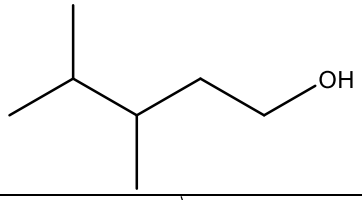
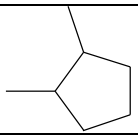
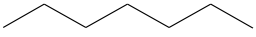
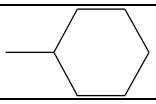
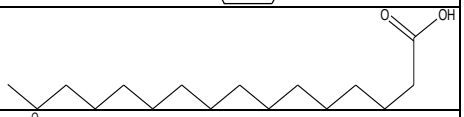
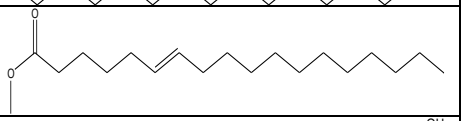
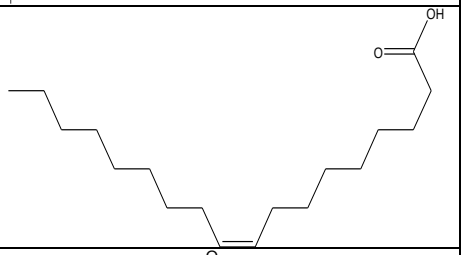
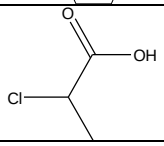
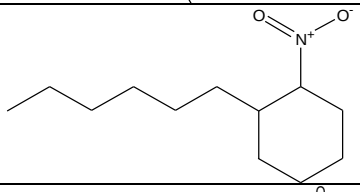
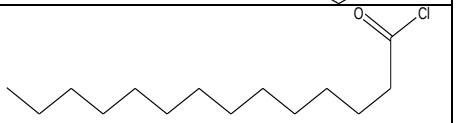
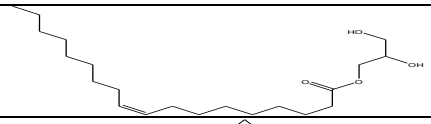
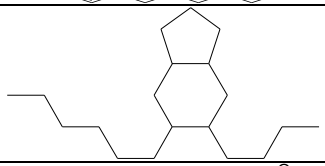
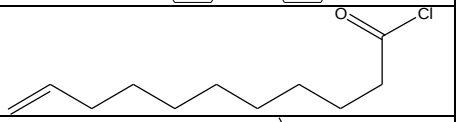
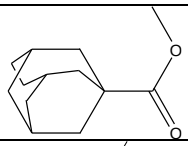
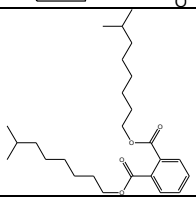
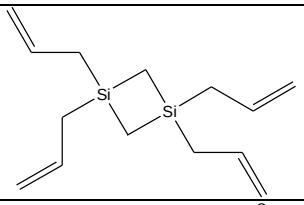
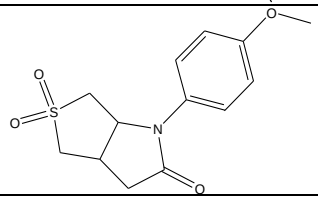
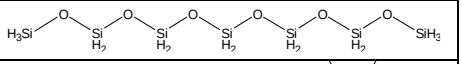
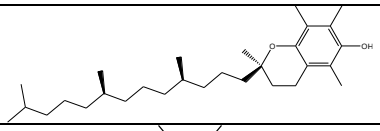
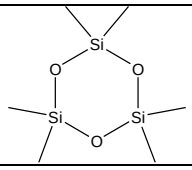
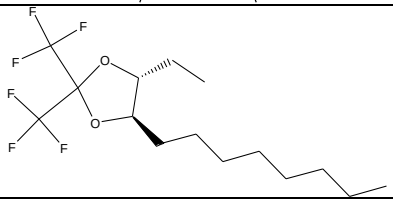
19	9,12-Octadecadienoyl chloride, (Z,Z)-	22.056	0.9	$C_{18}H_{31}ClO$	
20	1,3-Benzodioxole, 5-(4-methyl-1,3-dioxolan-2-yl)-	27.038	2.19	$C_{11}H_{12}O_4$	
21	2H-Pyran, 3,4-dihydro-6-methyl-	22.327	2.02	$C_6H_8O_2$	
22	1,3-Dioxolane, 4-ethyl-5-octyl-2,2-bis(trifluoromethyl)-,trans-	27.260	0.40	$C_{15}H_{24}F_6O_2$	
23	Myristoyl chloride	20.701	2.34	$C_{14}H_{27}ClO$	
24	2- Chloropropionic acid	19.586	5.50	$C_3H_5ClO_2$	
25	1,1,3,3-Tetraallyl-1,3-disilacyclo butane	26.032	0.43	$C_4H_4C_{l4}$	

Table 4: Compounds present in YMOSO, extracted by n-hexane using GC-MS analysis

No	Name of compounds	RT (min)	Peak Area %	Molecular formula	Structure
1	Cyclohexane	2.187	4.07	C_6H_{12}	
2	1-Pentanol, 3,4-dimethyl-	2.334	1.26	$C_7H_{16}O$	
3	Cyclopentane, 1,2-dimethyl-	2.334	1.26	C_7H_{14}	
4	Heptane	2.393	1.12	C_7H_{16}	

5	Cyclohexane, methyl-	2.575	1.76	$C_6H_{11}CH_3$	
6	n-Hexadecanoic acid	17.715	6.91	$C_{16}H_{32}O_2$	
7	6-Octadecenoic acid, methyl ester	19.027	19.17	$C_{19}H_{36}O$	
8	Oleic Acid	19.403	19.60	$C_{18}H_{34}O_2$	
9	2- Chloropropionic acid	19.586	5.50	$C_3H_5ClO_2$	
10	1-Hexyl-2-nitrocyclohexane	20.345	1.16	$C_{12}H_{23}NO_2$	
11	Myristoyl chloride	20.668	2.32	$C_{14}H_{27}ClO$	
12	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21.715	0.86	$C_{21}H_{42}O$	
13	1H-Indene, 5-butyl-6-hexyloctahydr o-	22.062	0.31	$C_{19}H_{36}$	
14	10-Undecenoyl chloride	22.333	1.19	$C_{11}H_{19}ClO$	
15	Tricyclo[4.3.1.1(3,8)]undecane-1-c arboxylic acid, methyl ester	24.003	1.10	$C_{12}H_{18}O_2$	
16	Phthalic acid, bis(7-methyloctyl) ester	24.103	1.11	$C_{26}H^{42}O_4$	

17	1,1,3,3-Tetraallyl-1,3-disilacyclo butane	26.032	0.43	$C_4H_4Cl_4$	
18	1-(4-Methoxy-phenyl)-5,5-dioxo-hex ahydro-5.lambda.(6)-thieno[3,4-b]p yrrol-2-one	27.038	1.37	$C_{13}H_{15}NO_4S$	
19	Heptasiloxane	27.144	0.62	O_6Si_7	
20	Vitamin E	27.203	0.79	$C_{29}H_{50}O$	
21	Cyclotrisiloxane, hexamethyl-	27.915	0.71	$C_6H_{18}O_3Si_3$	
22	1,3-Dioxolane, 4-ethyl-5-octyl-2,2-bis(trifluoromethyl)-,trans-	27.252	0.32	$C_{15}H_{24}F_6O_2$	

4. Conclusion

This study demonstrated that Yemeni Moringa seeds oil exhibited physicochemical properties comparable to Those of Moringa oleifera seeds oil obtained from other countries. GC-MS analysis revealed the presence of dominant fatty acids, namely lauric acid, myristic acid, and oleic acid, in Moringa oleifera oil. The triacylglycerol composition of Moringa oleifera oil showed a higher proportion of saturated TAGs and a lower proportion of unsaturated TAGs. The FTIR analyses of Moringa oleifera oil demonstrated positive results, with strong absorption observed at the ester carbonyl peak, specifically at 1750 cm-1 and 1243 cm-1. Understanding the pattern of interactions within triacylglycerol molecules could be beneficial for various industries and medical treatments, offering insights into their functional properties and potential applications[34] .

Acknowledgments

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5. References

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