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Comparative GC-MS Analysis of the Chemical Composition of *Carthamus tinctorius* Oils from Different Regions of Algeria and Syria

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Abstract. The chemical compositions of safflower seed oils were characterised by gas chromatography coupled with mass spectrometry (GC/MS) analysis. The oils were collected from Tiaret in Algeria and Haleb in Syria. The investigation discovered a wide range of chemicals including esters, ketones, alcohols, aldehydes, hydrocarbons, acids, halogenated compounds, alkenes, cyclic ketones, polycyclic and aromatic compounds, as well as other oxygenated compounds. The Tiaret sample contained various compounds including esters such as Cyclopropanetetradecanoic acid and 2-octyl-, methyl ester, ketones like 2-Pentanone and 4-hydroxy-4-methyl-, alcohols like α-Cadinol and τ-Cadinol, and hydrocarbons. The Haleb sample contains hexanoic acid, hexanal, 6-methylheptanol, 1-hexanol, and hydrocarbons such as hexadecane. Analysis of the GC/MS data reveals that the chemical composition of safflower seed oils might vary considerably across different locales. The samples from Tiaret ITGC and Haleb were discovered to have hexanal, a chemical associated with lipid oxidation, in equal concentrations. This suggests that the seed processing or freshness levels at the two locations were equal. The existence of different concentrations of chemicals such as 1,-hexanol and 2,4-decadienal in the samples indicates that there might be variations in the methods used for processing after harvesting or the climate conditions in different regions. When evaluating the composition and quality of safflower seed oils, it is crucial to take into account geographical variations and agricultural practices, as illustrated in the study. Additional investigation is required to comprehend the influence of these constituents on the nutritional composition and sensory attributes of safflower oils.

Introduction

Safflower, scientifically known as *Carthamus tinctorius*, is an herbaceous plant that grows annually. Buyukkurt et al. (2021) classify it as a member of the *Carthamus* genus, as well as either the Compositae or Asteraceae families.

Safflower, or *Carthamus tinctorius*, is a species of perennial herb in the family Compositae. Central Asia and East Asia host a wide distribution of this herb (Liu et al., 2023). *C. tinctorius* is the sole cultivated species, however there used to be up to 25 species associated with the *Carthamus* genus. Recent research over the past 20 years has shown evidence that there are around 15 different species in the *Carthamus* genus. The uncertainty surrounding this genus primarily arose from the restricted morphological observations, such as the presence of prickly leaves or cypselas. Molecular biology facilitated the distinction between *Carthamus* species (Hall III, 2016).

Due to its high tolerance to drought and salinity, *Carthamus tinctorius* can be cultivated in several regions worldwide, including India, Mexico, America, Spain, Australia, and China (Zhou *et al*., 2014).

The oilseed plant *Carthamus tinctorius*, also known as safflower, belongs to the Asteraceae family. It grows herbaceously and stands out for its diminutive size. Safflower exhibits resilience in demanding edaphoclimatic conditions, namely in semi-arid environments characterised by scant rainfall and elevated air temperatures (Silva *et al*., 2021).

Safflower, scientifically known as *Carthamus tinctorius*, is cultivated by the Asteraceae family for its oil-rich seeds. The plant exhibits an herbaceous growth habit and is rather little in size. Safflower is known for its capacity to endure difficult soil and climatic conditions, especially in semi-arid regions with limited rainfall and high temperatures (Silva *et al.*, 2021).

Safflower seeds boast a protein content ranging from 14% to 23%, with thin-hulled cultivars containing 11% fiber, while thick-walled cultivars contain 34% fiber. This makes safflower seeds an excellent protein source for animal diets (Hall III, 2016).

Safflower is renowned for its capacity to improve blood circulation, eliminate blood stasis, induce menstruation, and reduce pain. Safflower is primarily utilized medicinally for treating injuries, joint pain, postpartum abdominal pain and masses, dysmenorrhea, amenorrhoea, and blood stasis problems. We reference both Asgarpanah and Kazemivash (2014) and Zhou *et al*. (2014), as well as Tonguç *et al,* (2023).

Safflower possesses wide-reaching medical functions and pharmacological effects on cardiovascular and cerebrovascular system, protective effect on endothelial cells, Anticoagulant and antithrombotic activities, anti-fibrotic and anti-inflammatory effects,

antioxidant activity, modulating immune system. (Zhou *et al*., 2014; Asgarpanah and Kazemivash; 2014) Santana *et al* (2017). The safflower, as reported by Qian *et al*. (2022), consisted of a grand total of 141 constituents. There were 66 flavanols/flavones and their O-glycosides, 11 flavanones and their O-glycosides, 6 organic acids (mostly caffeic acid and p-coumaric acid), 1 polyacetylene, and 16 other chemicals that couldn't be identified.The flower petals and the meal component of the seed contain the majority of the phenolic chemicals in safflower (Hall III, 2016).

This plant is primarily farmed for its seed, which serves as a valuable source of culinary oil and also utilized as birdseed. People cultivated this crop for its blooms, which they used to colour and flavour dishes and produce dyes. The rich content and high nutritional value of its edible oil have made it an increasingly important crop in certain regions, such as Turkey and Iran (Asgarpanah and Kazemivash, 2014).

Safflower (*Carthamus tinctorius*) is a favourable option as an oilseed. Safflower oil has a fatty acid profile that consists of fourteen different fatty acids. Safflower oil has 9.61% saturated fatty acids and 90.33% unsaturated fatty acids in its composition. Monounsaturated fatty acids comprise 14.07% of the unsaturated fats, while polyunsaturated fatty acids constitute 76.26%. The oil contains a high quantity of linoleic acid, which makes up 76.22 percent of the total lipids. Katkade *et al*. (2018) reported that oleic acid constitutes around 13.75 percent of the oil and ranks as the second most prevalent fatty acid. Palmitic acid distinguished itself from the other saturated fatty acids due to its remarkably high concentration of 6.02%. Katkade *et al*. (2018) determined that the tocopherol content of safflower oil was 513.8 mg/kg.

The oil content and composition of the crop can be influenced by the edaphoclimatic circumstances in which it is grown (Hall III, 2016). Oilseeds play a significant role in the global commerce of agricultural products, contributing to the economy. Pasandi *et al.*, (2018):

The oil milling industry places great significance on determining the oil content of seeds, as the financial assessment of the oilseed trade depends on this factor. The price of the raw material is contingent upon its oil content (Matthäus and Brühl, 2001). The study conducted by Pérez *et al*. (2022) demonstrated that the addition of safflower oil to the diet of rats undertaking swimming training and consuming a high-fat diet resulted in a decrease in abdominal fat.

The objective of this study is to analyse the oil components collected from three different areas in Syria and Algeria using gas chromatography-mass spectrometry (GC-MS). The purpose of this comparison is to shed light on how these three ecotypes are similar and different, allowing us to better comprehend their individual traits and possible advantages.

2. Experimental

2.1. Materials

In order to carry out our work, three different samples of *Carthamus Tinctorius* seeds were chosen: • Halab sample comes from Syria; • Sample cultivated at the Technical Institute of Large Crops (ITGC) station in Sebain, Tiaret; • Wild sample harvested from the steppe of Tiaret. Geographical and climatic characteristics of these regions are markedly different (Table 1).

Table 1. Geographical and climatic characteristics of the Studied Regions

	Latitude	Longitude	Altitude	Pluviométrie	T° min	T° Max
Tiaret	35,37	1,32	760	400	10	32
ITGC Tiaret	35,40	1,28	800	450	8	35
Haleb	36,20	37,17	380	250	5	40

2.2. Extraction procedure

Weigh 25g of plant material (seeds) for each sample. This amount of plant material should be ground and placed in special porous cartridges for the Soxhlet (permeable for solvents). Then, these cartridges are placed in the Soxhlet. • The solvent is brought to a boil and then condensed with the ball condenser, during its boiling it will pass through the cartridge several times until the color becomes transparent. • The entire mixture (condensed solvent and extracted essential oil) should be recovered. Then, it should be placed in a rotary evaporator to separate the oil and recycled solvent. • The obtained oil is put into hermetically sealed tubes and wrapped in aluminum foil. Its storage is done at room temperature +4°C. The operating conditions used for gas chromatography analysis for our three samples are as follows: • Column temperature: 55.0°C • Injection temperature: 250.00°C • Injection mode: Split • Flow control mode: Linear velocity • Pressure: 24.4 kPa • Total flow rate: 17.7 mL/min • Column flow rate: 0.77 mL/min • Linear velocity: 35.0 cm/sec • Purge flow rate: 1.5 mL/min • Split ratio: 20.0 • Ion Source temperature: 200.00°C • Interface temperature: 250.00°C.

2.3. GC–MS analysis

Gas chromatography coupled with mass spectrometry was performed at the biotechnology laboratory of the University of Jijel. Gas chromatography coupled with mass spectrometry (GCMS type QP2010- Shimadzu) is equipped with an injector maintained at 250°C, where 1 µL of sample is put in "split" mode (1:50 ratio). The molecules of the injected extracts are fragmented at the column outlet by electron impact (EI - 70 ev). • The mobile phase (Helium) has a flow rate of 0.8 mL/min. • The stationary phase consists of a column (DB-1; 30 m x 0.25 mm x 0.25 µm) involved in a 30-min program with a temperature range between 50 and 250°C. We used the same system established by Berkov et al., 2008; However, the temperature programming was slightly modified, increasing by 10°C/min in an interval of 50-250°C, followed by a 10-min plateau at 250°C. The interface temperature is 300°C, and that of the EI

(Electronic Impact) source is 200°C. The "full scan" mode is started from 4.1 to 33 min to detect fragments of m/z ratio between 100 and 350. Mass spectra are obtained, where each peak corresponds to an m/z ratio fragment of a molecule eluted at time t.

2.4. Statistical treatment of the seed oil

Figure 1 shows the typical total GC-MS chromatograms of oil compounds extracted from safflower samples. Figure 1 exhibits the outcomes of samples obtained from Tiaret (No. 1), ITGC (No. 2), and Haleb (No. 3). The MS data were cross-referenced with the Xcalibur NIST library to identify the TIC peaks and ascertain the chemical compositions of the seed oil. Concurrently, the proportionate content of each compound was determined by dividing the peak area of each component by the total area of all peaks in the Total Ion Chromatogram (TIC). The results are presented in Table 1, 2, and 3, accordingly.

2.5. Statistical analyses

The statistical analyses were conducted using SAS software version 9, with a significance level set at 95%. To examine differences between sampling regions and components present in different chemical families, the PROC GLM procedure was employed. Additionally, variability of chemical components within each family was estimated using the PROC Boxplot procedure.

3. Results

Oil yield: The variation in oil seed yield among the varieties used is remarkable. Indeed, the results demonstrate a very high yield displayed by the Halab variety at 35.76%, followed by an average yield produced by the variety cultivated at ITGC at 26.16%, and finally a low yield presented by the wild variety at 16.16% (Fig. 1).

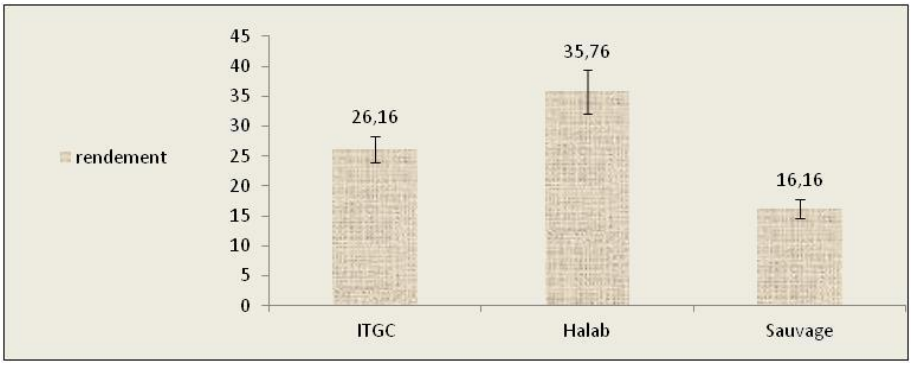

Figure 1: Oil Yield Comparison of Tiaret, Tiaret ITGC, and Haleb Samples

The results of this study (Fig.2, Fig.3, and Fig. 4) are consistent with several previous studies on the chemical composition of seed oils from *Carthamus tinctorius* from different regions. A study conducted in India shown that the chemical composition of seed oils derived from *Carthamus tinctorius* had substantial variations based on their geographical origin (Rath *et al*., 2011). Furthermore, a research conducted in Egypt revealed notable disparities in the chemical makeup of essential oils derived from

Carthamus tinctorius originating from various geographical regions (Hamdan *et al.*, 2013).

The table 2 provides the composition of safflower seed oil from Tiaret. It lists various peaks along with their retention times, areas, percentages, heights, compound names, and base mass-to-charge ratios. The composition includes a variety of compounds such as acids, ketones, alcohols, and hydrocarbons. Notable components include cyclopropanetetradecanoic acid, 2-octyl-, methyl ester, 2-pentanone, 4-hydroxy-4-methyl-, and 1-hexanol. These compounds contribute to the overall chemical profile of the safflower seed oil.

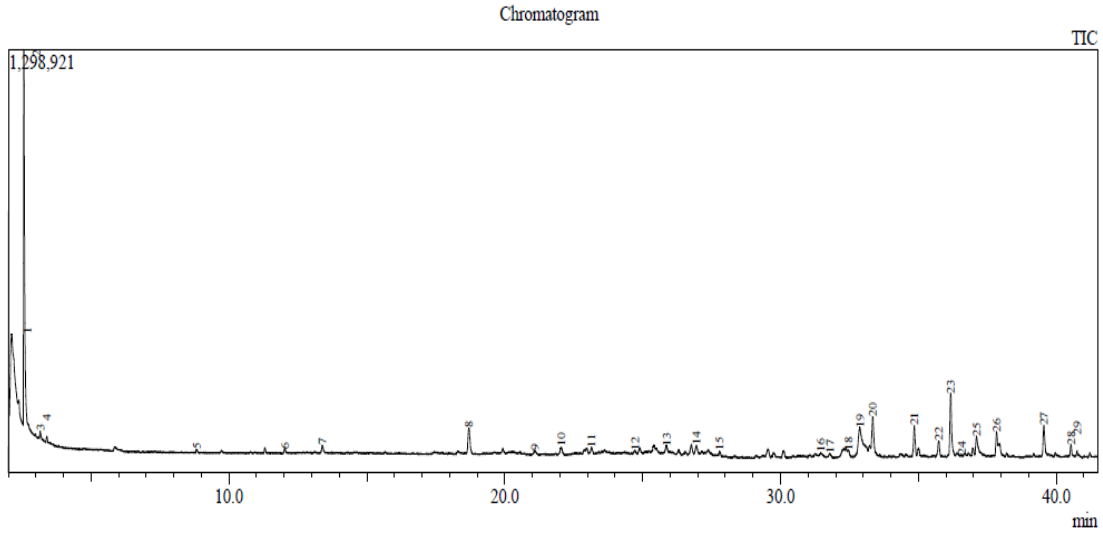

Figure 2: GCMS spectrum of *Carthamus Tinctorius* seed oil from Tiaret.

Table 2: Composition of Tiaret Safflower Seed Oil.

peak	R.Time	Area	Area%	Height	Name	Base m/z
1	2.113	2658991	23.22	254406	Cyclopropanetetradecanoic acid, 2-octyl-, methyl ester	43.00
2	2.561	2942710	25.70	1154670	2-Pentanone, 4-hydroxy-4-methyl-	43.00
3	3.155	69842	0.61	23540	1-Hexanol	56.00
4	3.395	47240	0.41	18439	Styrene	104.05
5	8.824	38070	0.33	10355	Bicyclo[2.2.1]heptan-2-one, 1,3,3-trimethyl-	81.10
6	12.030	49467	0.43	13528	Ethanone, 1-(2-furanyl)-	95.10
7	13.383	103922	0.91	23525	2-Caren-10-al	79.00
8	18.696	414466	3.62	79069	3-Cyclohexene-1-methanol, .alpha.,.alpha.,4-trimethyl-, acetate	121.10
9	21.092	52767	0.46	12184	1,3,6-Heptatriene, 2,5,5-trimethyl-	81.05
10	22.049	83563	0.73	19476	1,6-Cyclodecadiene, 1-methyl-5-methylene-8-(1-methylethyl)-, [s-(E,E)]-	105.15
11	23.143	95823	0.84	20467	Cycloisolongifolene, 8,9-dehydro-	159.10
12	24.725	52460	0.46	12655	Adamantane, 1-(2-bromoethenyl)-	161.20

13	25.872	120503	1.05	22597	1,6-Cyclodecadiene, 1-methyl-5-methylene-8-(1-methylethyl)-, [s-(E,E)]-	161.20
14	26.953	116298	1.02	24271	Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-, (1S-cis)-	161.20
15	27.786	41495	0.36	12208	Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	119.10
16	31.459	63054	0.55	11783	Butane, 2-iodo-3-methyl-	71.05
17	31.793	34181	0.30	8533	.alpha.-Cubebene	161.15
18	32.461	100142	0.87	21000	1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a.beta.,7b.alpha.)]-	133.10
19	32.880	861193	7.52	90578	.tau.-Cadinol	161.20
20	33.347	709397	6.19	124538	.alpha.-Cadinol	95.10
21	34.855	385119	3.36	94139	2,5,5,8a-Tetramethyl-4-methylene-6,7,8,8a-tetrahydro-4H,5H-chromen-4a-yl hydroperoxide	43.00
22	35.736	206866	1.81	48601	1-Cyclohexanone, 2-methyl-2-(3-methyl-2-oxobutyl)	153.10
23	36.172	904610	7.90	195574	2H-Cyclopropa[a]naphthalen-2-one, 1,1a,4,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-, (1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)	203.10
24	36.567	46516	0.41	7545	1,6-Anhydro-.beta.-D-glucofuranose	73.10
25	37.109	366255	3.20	60622	trans-Z-.alpha.-Bisabolene epoxide	83.05
26	37.835	297967	2.60	76210	2H-Pyran, 2-(7-heptadecynyloxy)tetrahydro-	43.00
27	39.553	405408	3.54	92910	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	149.05
28	40.538	133361	1.16	36692	9-(3,3-Dimethyloxiran-2-yl)-2,7-dimethylnona-2,6-dien-1-ol	81.10
29	40.757	49445	0.43	18326	3-Decyn-2-ol	43.00

The table 3 delineates the compositional analysis of safflower seed oil originating from Tiaret (ITGC). It enumerates distinct chromatographic peaks, providing respective retention times, areas, percentages, heights, compound nomenclatures, and base mass-to-charge ratios. The constituents encompass a spectrum of chemical classes such as aldehydes, hydrocarbons, acids, ketones, and alcohols. Prominent constituents featured in this analysis include hexanal, octane, 2-pentanone, 4-hydroxy-4-methyl-, hexanoic acid, and benzyl chloride. These identified compounds collectively contribute to delineating the comprehensive chemical profile of safflower seed oil from Tiaret (ITGC).

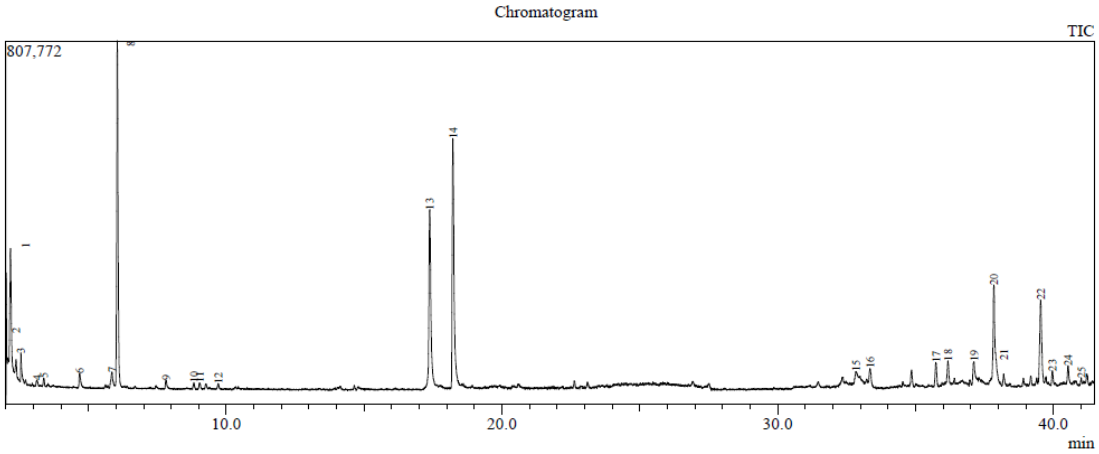

Figure 3: GCMS spectrum of *Carthamus Tinctorius* seed oil from ITGC Tiaret. .

Table 3: Composition of Tiaret (ITGC) Safflower Seed Oil.

Peak	R.Time	Area	Area%	Height	Name	Base m/z
1	2.173	931288	7.61	264505	Hexanal	44.00
2	2.376	84371	0.69	34297	Octane	43.05
3	2.553	166549	1.36	64006	2-Pentanone, 4-hydroxy-4-methyl-	43.00
4	3.135	51768	0.42	13378	1-Hexanol	56.00
5	3.382	51581	0.42	18043	1,3,5,7-Cyclooctatetraene	104.05
6	4.679	126172	1.03	30560	(S)-(+)-5-Methyl-1-heptanol	55.00
7	5.855	175436	1.43	34309	Hexanoic acid	59.95
8	6.049	2693131	22.01	768220	Benzyl chloride	91.05
9	7.811	53860	0.44	17013	3-Undecene, 9-methyl-, (E)-	55.00
10	8.825	46931	0.38	14716	Bicyclo[2.2.1]heptan-2-one, 1,3,3-trimethyl-	81.10
11	9.033	51758	0.42	14028	1,5-Heptadiene-3,4-diol	71.00
12	9.710	39598	0.32	11908	1-Hexanol, 3-methyl-	55.00
13	17.380	1926165	15.74	391738	2,4-Decadienal, (E,E)-	81.00
14	18.220	2521523	20.61	550727	2,4-Decadienal, (E,E)-	81.00
15	32.839	112623	0.92	20744	Octane, 2-bromo-	57.05
16	33.349	174888	1.43	36866	1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-, [1S-(1.alpha.,4.alpha.,4a.beta.,8a.beta.)]-	95.10
17	35.736	220009	1.80	53883	1-Cyclohexanone, 2-methyl-2-(3-methyl-2-oxobutyl)	153.10
18	36.175	219716	1.80	54445	2H-Cyclopropa[a]naphthalen-2-one, 1,1a,4,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-, (1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)	203.10
19	37.116	216202	1.77	46027	trans-Z-.alpha.-Bisabolene epoxide	83.05
20	37.842	1047399	8.56	211490	1-Heptatriacotanol	43.00
21	38.198	109979	0.90	27593	1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-, [1R-(1.alpha.,4.beta.,4a.beta.,8a.beta.)]-	159.10

22	39.537	955075	7.81	186592	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	149.05
23	39.964	91904	0.75	29296	1,4-Methano-1H-cyclohepta[d]pyridazine, 4,4a,5,6,7,8,9,9a-octahydro-10,10-dimethyl-	107.05
24	40.533	134818	1.10	38667	9-(3,3-Dimethyloxiran-2-yl)-2,7-dimethylnona-2,6-dien-1-ol	81.05
25	41.011	32391	0.26	14369	1,4-Methano-1H-cyclohepta[d]pyridazine, 4,4a,5,6,7,8,9,9a-octahydro-10,10-dimethyl-	79.00

The table 4 presents the detailed composition of safflower seed oil from Haleb (Syria). It lists various chromatographic peaks along with their respective retention times, areas, percentages, heights, compound names, and base mass-to-charge ratios. It reveals a diversity of compounds including aldehydes, hydrocarbons, acids, ketones, and alcohols. A total of 43 components are identified, with notable ones including hexanal, hexanoic acid, benzyl chloride, and 2,4-decadienal. These compounds collectively contribute to the distinctive chemical composition of safflower seed oil from Haleb, Syria.

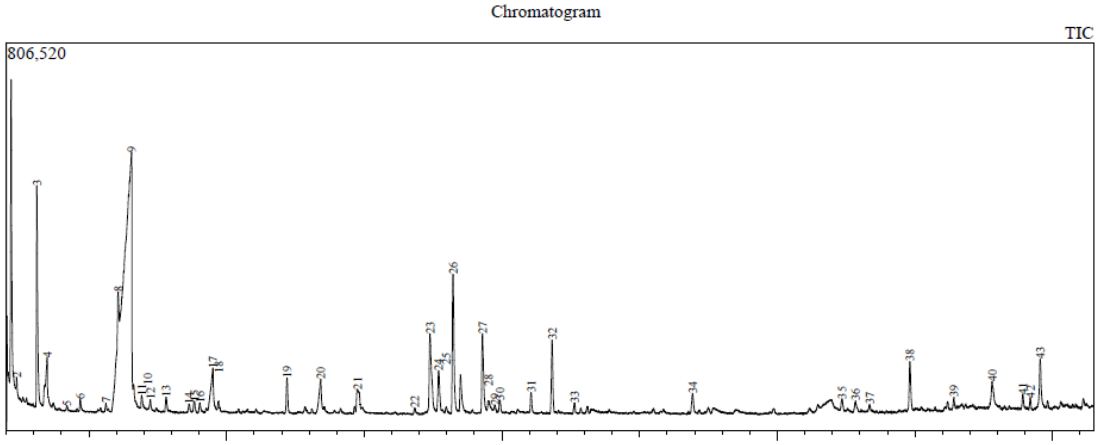

Figure 4: GCMS spectrum of *Carthamus Tinctorius* seed oil from Haleb Syrie.

Table 4: Composition of Haleb (SYRIE) Safflower Seed Oil.

Peak#	R.Time	Area	Area%	Height	Name	Base m/z
1	2.174	1654744	6.86	633466	Hexanal	44.00
2	2.377	48061	0.20	29970	Heptane, 2,4-dimethyl-	43.05
3	3.109	1344793	5.57	459979	1-Hexanol	56.05
4	3.482	405789	1.68	100296	Pentanoic acid	60.00
5	4.195	29523	0.12	9108	1-Hexanol	56.00
6	4.681	81953	0.34	24965	1-Hexene, 3,5-dimethyl-	41.00
7	5.617	54085	0.22	17857	1-Hexen-3-ol	57.00
8	6.062	1833456	7.60	248011	Benzyl chloride	91.05
9	6.547	9669256	40.06	535245	Hexanoic acid	60.00
10	6.625	220868	0.92	49996	Acetic acid, hexyl ester	43.00
11	6.914	102777	0.43	26046	2(3H)-Furanone, 5-ethyldihydro-	85.00

12	7.230	68222	0.28	21350	3,5-Octadien-2-ol	55.00
13	7.803	106939	0.44	29864	1,5-Pentanediol, 3-methyl-	55.00
14	8.635	63669	0.26	16861	Cyclooctyl alcohol	57.00
15	8.826	94286	0.39	22561	1-Hexene, 3,3,5-trimethyl-	81.05
16	9.031	71537	0.30	19094	Butane, 1-bromo-2-methyl-	71.00
17	9.500	614877	2.55	88608	Heptanoic acid	60.00
18	9.710	85938	0.36	21087	Heptanal	57.00
19	12.193	265581	1.10	73429	Naphthalene	128.05
20	13.419	442413	1.83	70661	Pentane, 2,4-dimethyl-	59.95
21	14.750	315489	1.31	45443	1-Undecanol	55.00
22	16.834	47710	0.20	12333	4-Nonanone	71.05
23	17.387	940069	3.89	161812	2,4-Decadienal, (E,E)-	81.00
24	17.700	408085	1.69	86702	Hexanoic acid, pentyl ester	70.05
25	17.977	71603	0.30	13042	Pentandioic acid, (p-t-butylphenyl) ester	135.10
26	18.222	1231768	5.10	290101	2,4-Decadienal, (E,E)-	81.00
27	19.291	771874	3.20	165548	2(3H)-Furanone, dihydro-5-pentyl-	85.00
28	19.517	175468	0.73	26040	3-Heptanone, 4-methyl-	57.00
29	19.734	89742	0.37	16326	Phenol, 2-methoxy-4-(1-propenyl)-, (Z)-	164.10
30	19.919	108040	0.45	26332	3-Cyclohexene-1-methanol, .alpha.,.alpha.,4-trimethyl-, acetate	121.10
31	21.058	155298	0.64	42256	Octadecanoic acid, 2-oxo-, methyl ester	43.00
32	21.820	545308	2.26	152064	Hexanoic acid, hexyl ester	43.05
33	22.636	80210	0.33	21919	1-Heptanol, 6-methyl-	69.00
34	26.925	195411	0.81	41697	9-Octadecene, (E)-	191.10
35	32.351	109899	0.46	24744	1-Tridecene	83.00
36	32.842	123364	0.51	23793	Hexadecane	57.05
37	33.355	53157	0.22	14145	1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-, [1S-(1.alpha.,4.alpha.,4a.beta.,8a.beta.)]-	95.10
38	34.815	433204	1.79	103232	2,2,6,7-Tetramethyl-10-oxatricyclo[4.3.0.1(1,7)]decan-5-one	165.10
39	36.415	74161	0.31	23431	Sulfurous acid, 2-ethylhexyl isohexyl ester	57.05
40	37.801	294393	1.22	51513	Tetradecanoic acid	73.00
41	38.911	100023	0.41	29363	1-Tridecene	97.10
42	39.185	82279	0.34	25649	Undecane, 3,8-dimethyl-	57.00
43	39.548	473120	1.96	101409	Phthalic acid, butyl tetradecyl ester	149.00

The table 5 compares the chemical composition of different samples from Tiaret in Algeria and Haleb in Syria. It shows significant differences in the presence of various components such as aldehydes, alcohols, acids, ketones, and hydrocarbons. For example, the Haleb sample is rich in hexanoic acid, while the Tiaret ITGC sample contains notable amounts of aldehydes and halogenated hydrocarbons. These variations could be influenced by environmental or production factors specific to each region.

Table 5: Composition chimique comparative des échantillons de Tiaret (Algérie) Tiaret ITGC (Algérie) et d'Alep (Syrie)

Chemical Family	Common Component	Tiaret (%)	Tiaret ITGC (%)	Haleb (Syrie) (%)
Aldéhydes	Hexanal	0.00	7.61	6.86
Alcools	1-Hexanol	0.61	0.74	5.69
Acides	Hexanoic acid	0.00	1.43	44.01
Ketones	2-Pentanone, 4-hydroxy-4-methyl-	25.70	1.36	0.00
Hydrocarbures	Octane	3.31	0.69	0.00
Esters	1,2-Benzenedicarboxylic acid, ester	3.54	7.81	0.00
Alcools	3-Cyclohexene-1-methanol, acetate	3.62	0.00	0.00
Aldehydes	2,4-Decadienal, (E,E)-	0.00	36.35	8.99
Hydrocarbures halogénés	Benzyl chloride	0.00	22.01	5.39

Taking into account only the families that were consistently present across the three geographic origins of the seed oil of the species in question, no significant differences were found among the three localities (DF = 2; F value = 2.62; P = 0.09), nor among the percentages of components per common chemical family (DF = 4; F value = 1.30; P = 0.30), nor among the chemical families within each region (DF = 7; F value = 0.45; P = 0.86), with an R2 value of 0.40. Consequently, according to these statistical analyses, the difference among these three localities, in terms of chemical composition, primarily manifests as a significantly different total richness of certain oils compared to others. The total richnesses in chemical families per locality are 5, 11, and 16 families for ITGC Tiaret, Tiaret, and Haleb respectively.

We examined the variability of components only for families consistently present across the three localities. According to the obtained results, the highest variability was observed for the two families, Ketones and Esters, in favor of the Tiaret (ITGC) region (Fig. 5).

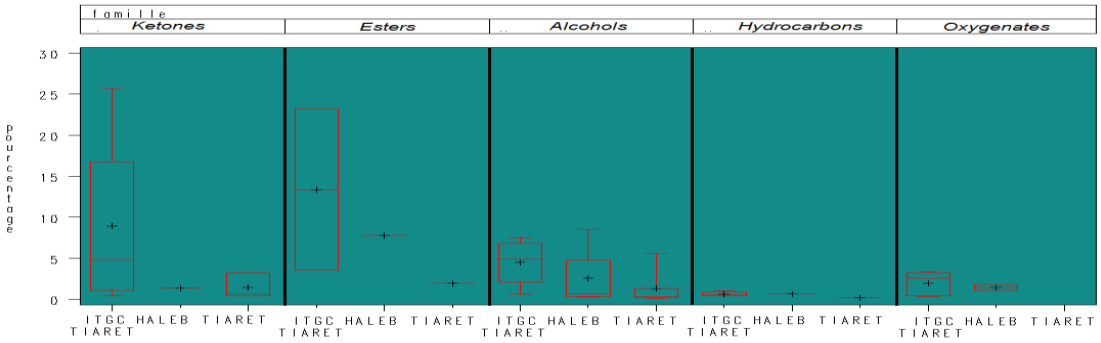

Figure 5: Study of variability in component percentages chemical families identified in safflower seed oils from different geographic origins.

Discussion

Gas chromatography coupled with mass spectrometry (GC/MS) analysis is a widely used technique for the identification and investigation of intricate chemical constituents in various substances, such as extracts derived from vegetable oils. By combining information on the retention time of the compounds and their fundamental mass-to-charge ratio, this method enables the detection and measurement of various chemical compounds in the analyzed materials.

The study of safflower seed oils from two separate locations, Tiaret (Algeria) and Haleb (Syria), has led to the identification and classification of several chemical compounds according to their chemical families. Among the various kinds of molecules found in the results are esters, ketones, alcohols, aldehydes, hydrocarbons, acids, halogenated compounds, alkenes, polycyclic compounds, aromatic compounds, and cyclic ketones. Additives and modifiers also come in a wide variety of forms.

Esters, such as cyclopropanetetradecanoic acid, bis (2-methylpropyl) ester of benzene dicarboxylic acid, and butyltetradecyl phthalate, are frequently present in vegetable oils and may contribute to their sensory and functional properties (Gunstone, 2011). These are volatile chemicals called ketones, like 2-pentanone-4-hydroxy-4-methyl and 2H-cyclopropa[a]naphthalen-2-one. They can affect the smell and taste of vegetable oils (Ghosh & Preussmann, 2018) Atole *et al*, (2018). Alcohols, such as 1-hexanol and tau-cadinol, may contribute to the stability and shelf life of vegetable oils.

According to Gunstone (2011), aldehydes function as natural antioxidants. Aldéhydes such as hexanal and 2,4-decadienal are volatile compounds that can contribute to the aroma and taste of vegetable oils but can also serve as indicators of the quality and freshness of the oil (Frankel, 2010). Hydrocarbons such as naphthalene and pentane are nonpolar compounds found in vegetable oils and can be involved in thermal degradation or oxidation processes (Frankel, 2014). Fatty acids, such as hexanoic acid and octadecanoic acid, are major components of vegetable oils and can alter their nutritional properties and oxidation stability (Gunstone, 2011).

The chemical contents of vegetable oils can vary due to various factors, such as cultivar, growth circumstances, climate, and agricultural practices (Gunstone, 2011). This variation is worth mentioning.

Important chemicals are found in the Tiaret sample. These include esters like Cyclopropanetetradecanoic acid, 2-octyl-, methyl ester, ketones like 2-Pentanone, 4-hydroxy-4-methyl-, alcohols like α-Cadinol and ϱ-Cadinol, and hydrocarbons like Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-. The Haleb sample contained a diverse array of compounds. The compounds mentioned include

hexanoic acid (an acid), hexanal (an aldehyde), 6-methylheptanol and 1-hexanol (alcohols), and hexadecane (a hydrocarbon). These main components may significantly influence the sensory, nutritional, and functional qualities of safflower oils from different locations.

Various factors, including different cultivars, growth circumstances, and specialized agricultural practices in each region, can also impact the variety of chemical compounds found in each sample. Hasan *et al*, (2020).

After analyzing the GC/MS results of safflower seed oils obtained from Tiaret (Algeria), Tiaret ITGC (Algeria), and Haleb (Syria), it is clear that the chemical composition of the samples varies significantly. Environmental conditions, agricultural techniques, and genetic differences in the safflower varieties grown in various regions can account for various variances.

The concentrations of hexanal compound in the ITGC and Haleb samples are approximately same (Tiaret: 0.00%, ITGC: 7.61%, Haleb: 6.86%). It is associated with the oxidation of lipids. This suggests that the degree of freshness or seed processing in various locations is comparable. There were notable variations in the concentrations of 1-hexanol among the samples collected from Tiaret (0,61 %), ITGC (0,74 %), and Haleb (5,69 %). These differences may indicate changes in the methods used to process crops after harvesting or the weather conditions in the regions being studied.

The Haleb sample exhibited a significantly higher concentration of hexanoic acid (44,01 %) compared to the Tiaret ITGC sample (1,43 %) and the Tiaret sample (0,00 %). This implies that the lipids might be undergoing accelerated degradation or that the composition of fatty acids in the safflower varieties cultivated in this region is undergoing alterations. Furthermore, the Tiaret, ITGC, and Haleb samples all exhibit trace levels of octane (Tiaret: 3,31 %, ITGC: 0,69 %, Haleb: 0,00 %). This suggests that the purification process and environmental conditions are likely to be comparable among these samples.

This study emphasises the need to take regional variations and agricultural methods into account when evaluating the quality and content of safflower seed oils. Additional research is required to fully comprehend the influence of these factors on the nutritional and sensory characteristics of safflower oils. The offered current references corroborate these findings and establish a foundation for further research on the subject.

The GC/MS study of safflower seed oils from both Haleb and Tiaret demonstrates a diverse range of chemical constituents. Different molecules present in vegetable oils have distinct impacts on their flavour, nutritional content, and suitability for various uses. This analytical method offers useful insights for comprehending and assessing vegetable oils for many commercial and home uses.

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