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Study of the chemical content of organic extracts of the Syrian plant *Artemisia herba-alba* using GC-MS technology

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CHRONICLE

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ABSTRACT

Artemisia herba-alba is a perennial herbaceous plant belonging to the Asteraceae family. It is used in folk medicine to treat many nervous and digestive disorders, as well as diabetes. It possesses antioxidant, antifungal and anti-inflammatory properties. The chemical composition of the organic extracts obtained from the leaves of the Syrian *Artemisia herba-alba* plant was analysed using a Soxhlet extraction device and three solvents with varying degrees of polarity (petroleum ether, chloroform and ethyl acetate). The chemical constituents of the three extracts were determined using GC/MS technology. In the petroleum ether extract (Ah_1), 38 compounds were identified, while the chloroform extract (Ah_2) contained 39 compounds, and the ethyl acetate extract (Ah_3) contained 45 compounds. The most significant compounds in the Ah_1 extract were longiverbenone (23.9%), heneicosane (18.2%), 3,3,6-trimethyl-1,5-heptadien-4-one (16.5%), caryophyllene oxide (5.8%), and octacosane (4.6%). In the Ah_2 extract, the main constituents were dioctyl hexanedioate (13.2%), (Z,Z) 9,12-octadecadienoyl chloride (7.3%), and (-)-spathulenol (7.1%). The primary compounds in the Ah_3 extract were pentanoic acid (9.5%), geranyl isovalerate (9.3%), 2-butyl-1-octanol (7.5%), and 1-heptadecene (6.4%).

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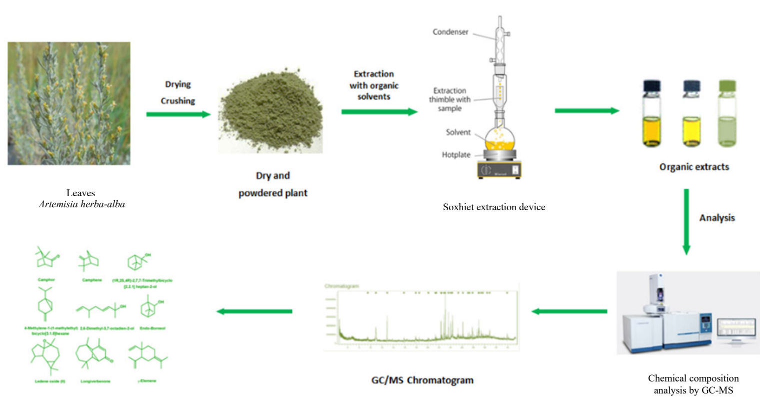

Graphical abstract

1. Introduction

Artemisia herba-alba is a silver-green, perennial plant from the Asteraceae family, [1] which reaches a height of 20-40 cm and is widespread in North Africa, the Arabian Peninsula and large parts of Europe. [2] The A. herba-alba plant has biological activity. It is antimicrobial, [3] anti-inflammatory, [4] antioxidant, [5] antidiabetic, [6] anticancer [7] and leishmaniostatic.

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[8] In folk medicine, it is used to treat stomach complaints such as diarrhoea and abdominal cramps. [9] It is also used to treat neurological disorders such as Alzheimer's disease and epilepsy, [10] arterial hypertension and diabetes, [11,12] hair loss, [13] poisoning and to treat external wounds. [14] Previous chemical studies have shown that this plant is rich in terpenoids, coumarins, flavonoids, caffeic acids and sterols. [15]

The chemical composition of the petroleum ether extract of the Egyptian plant *Artemisia herba-alba* was analysed and the results of GC-MS analysis showed that the extract contained the compounds tricyclo[6,8,9]hexadeca-3,16-dione (22.98%), 2,5,5-trimethy-1-hexene-3-yne (21.2 %), dihydrocarvyl acetate (6.73 %), ethyl (*E*)-cinnamate (4.16 %), 4,7,7-trimethyl bicyclo[2.2.1]heptan-2-one semicarbazone (3.77 %), (-)-3-alpha acetoxy-5-etienic acid (1.74 %), camphor (1.17 %). [16] The methanol and ethanol extracts of the plant leaves contained 24 and 20 compounds, respectively, the major compounds of the methanol extract being: (Z) 9-octadecanamide (28.687%), phytol (12.611%) and palmitoleamide (12.304%). The ethanol extract are: (Z) 9-octadecanamide (25.687%), dodecanamide (16.142%) and camphor (14.494%). [17] The chemical composition of the ethanolic extract of the Moroccan plant *Artemisia herba-alba* was investigated and the results of GC-MS analysis showed that the ethanolic extract contained 21 compounds of monoterpenes and sesquiterpenes. The most important compounds were: Camphor (17.5%), alpha-thujone (4.25%), β-thujone (4%). [18] Due to the lack of chemical studies related to *Artemisia herba-alba* plant and the lack of chemical studies in Syria, the research aimed to investigate the chemical composition of the organic extracts using three solvents with different degrees of polarity (petroleum ether, chloroform, ethyl acetate) of the leaves of *Artemisia herba-alba* plant using GC-MS technology.

2. Results and Discussion

The petroleum ether extract was obtained with a pale green color and a yield of 1.9% of the dry weight of the plant. The GC/MS chromatogram of the petroleum ether extract (Ah_1) of the *Artemisia herba-alba* plant **(Fig. 1)** shows the presence of 38 different compounds, representing 98.7% of the total composition of the extract, with nonpolar compounds (Aliphatic hydrocarbons, terpenes) dominating the extract.

Table 1. Chemical components of petroleum ether extract (Ah_1) of the leaves of *Artemisia herba-alba* by GC-MS

No.	Compound name	Molecular formula	Class	Mw (g/mol)	R_t	Area %
1	5-(1,2-Propadienyloxy)-2-pentanone	$C_8H_{12}O_2$	O	140.18	9.20	1.2
2	3,4-Dimethyl-2-hexanone	$C_8H_{16}O$	O	128.21	9.65	0.3
3	Camphene	$C_{10}H_{16}$	HM	136.23	10.22	1.3
4	4-Methylene-1-(1-methylethyl) bicyclo[3.1.0]hexane	$C_{10}H_{16}$	HM	136.23	10.86	1.4
5	2,6-Dimethyl-3,7-octadien-2-ol	$C_{10}H_{18}O$	OM	154.25	11.18	0.6
6	(1R,2S,4R)-2,7,7-Trimethylbicyclo [2.2.1] heptan-2-ol	$C_{10}H_{18}O$	OM	154.25	11.97	0.7
7	3,3,6-trimethyl-1,5-heptadien-4-one	$C_{10}H_{16}O$	OM	152.23	12.41	16.5
8	3,6,6-trimethyl-2-norpinanol	$C_{10}H_{18}O$	OM	252.35	12.86	0.7
9	3-Methyldecane	C_9H_{20}	AH	128.25	13.22	0.4
10	Camphor	$C_{10}H_{16}O$	OM	152.23	14.08	2.1
11	Endo-borneol	$C_{10}H_{18}O$	OM	154.25	14.53	1.5
12	3-Methyl octane	C_9H_{20}	AH	128.25	15.07	0.6
13	2,6-Dimethyloctane	$C_{10}H_{22}$	HM	142.28	15.95	0.5
14	Tridecane	$C_{13}H_{28}$	AH	184.36	16.35	1.0
15	Cis-thujopsene	$C_{15}H_{24}$	HS	204.35	17.33	1.1
16	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2-butenal	$C_{14}H_{22}O$	O	206.32	18.74	0.1
17	Humulenol-II	$C_{15}H_{24}O$	OS	220.35	20.04	0.2
18	Ledene oxide (II)	$C_{15}H_{24}O$	OS	220.35	20.23	0.5
19	Acorenone β	$C_{15}H_{24}O$	OS	220.35	20.51	0.3
20	Longiverbenone	$C_{15}H_{22}O$	OS	218.33	21.08	23.9
21	((4aS,8S,8aR)-8-Isopropyl-5-methyl-3,4,4a,7,8,8a-hexahydro naphthalen-2-yl) methanol	$C_{15}H_{24}O$	OS	220.35	21.70	0.3
22	Tridec-2-yn-1-yl undec-10-ynoate	$C_{24}H_{40}O_2$	O	360.6	21.98	0.7
23	γ-Elemene	$C_{15}H_{24}$	HS	204.35	22.14	1.4
24	t-Butyl-(2-[3-(2,2-dimethyl-6-methylenecyclohexyl)-propyl]-[1,3]dithian-2-yl) dimethyl silane	$C_{22}H_{42}S_2Si$	O	398.8	22.26	0.3
25	(5Z, 8Z, 11Z, 14Z) Methyl eicosatetraenoate	$C_{21}H_{34}O_2$	O	318.49	22.72	0.8
26	Trans-Z-α-bisabolene epoxide	$C_{15}H_{24}O$	OS	220.35	23.06	0.7
27	1,8-Dimethyl-8,9-epoxy-4-isopropyl spiro [4.5] decan-7-one	$C_{15}H_{24}O_2$	OS	236.35	23.30	0.7
28	Cis-Z-α-bisabolene epoxide	$C_{15}H_{24}O$	OS	220.35	23.60	4.4
29	Caryophyllene oxide	$C_{15}H_{24}O$	OS	220.35	24.11	5.8
30	2,3-Dihydroxypropyl (9Z,12Z,15Z) octadecatrienoate	$C_{21}H_{36}O_4$	O	352.5	25.38	0.6
31	4-(1,5-Dihydroxy-2,6,6-trimethylcyclohex-2-enyl)but-3-en-2-one	$C_{13}H_{20}O_3$	O	224.30	25.55	0.4
32	Octadecamethyl cyclononasiloxane	$C_{18}H_{54}O_9Si_9$	O	667.4	26.33	0.2
33	Nonadecane	$C_{19}H_{40}$	AH	268.51	30.11	3.4
34	1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15-Hexadecamethyl octasiloxane	$C_{16}H_{48}O_7Si_8$	O	577.2	30.37	0.5
35	Heptadecane	$C_{17}H_{36}$	AH	240.47	30.81	0.3
36	Heneicosane	$C_{21}H_{44}$	AH	296.6	31.59	18.2
37	Eicosyl vinyl carbonate	$C_{23}H_{44}O_3$	O	368.6	31.64	0.5
38	Octacosane	$C_{28}H_{58}$	AH	394.8	33.42	4.6
Total identified compounds						**98.7**
		No. of compounds	**Compound symbol**			
	Monoterpenes					**25.3**
	Hydrocarbon	3	HM			3.2
	Oxygenated	5	OM			22.1
	Sesquiterpenes					**39.3**
	Hydrocarbon	2	HS			2.5
	Oxygenated	10	OS			36.8
	Aliphatic Hydrocarbons	7	AH			**28.5**
	Other oxygenated compounds	12	O			**5.6**

The petroleum ether extract (Ah_1) consists mainly of 12 compounds of hydrocarbon and oxygen sesquiterpenes (39.3%), eight compounds of hydrocarbon and oxygen monoterpenes (25.3%) and aliphatic hydrocarbons (28.5%). The most abundant compound obtained was the sesquiterpene longiverbenone (23.9%), followed by the aliphatic hydrocarbon heneicosane (18.2%), the monoterpenoid 3,3,6-trimethyl-1,5-heptadiene-4-one (16.5%), the sesquiterpene compound caryophyllene oxide (5.8%), the hydrocarbon compound octacosane (4.6%), cis-Z-α-bisabolene epoxide (4.4%) and nonadecane (3.4%). The remaining compounds were camphor (2.1%), 4-methylene-1-(1-methylethyl) bicyclo[3.1.0]hexane (1.4%), γ-elemene (1.4%) and camphene (1.3%). Traces of compounds were present in amounts less than 1.2%. **Table 1** shows the chemical composition of the petroleum ether (Ah_1) extract of the leaves of *Artemisia herba-alba* by GC/MS. **Fig. 1** shows the GC-MS chromatogram of petroleum ether extract (Ah_1) of the leaves of *Artemisia herba-alba*. **Fig. 2** shows the main chemical formulas of the petroleum ether (Ah_1) extract.

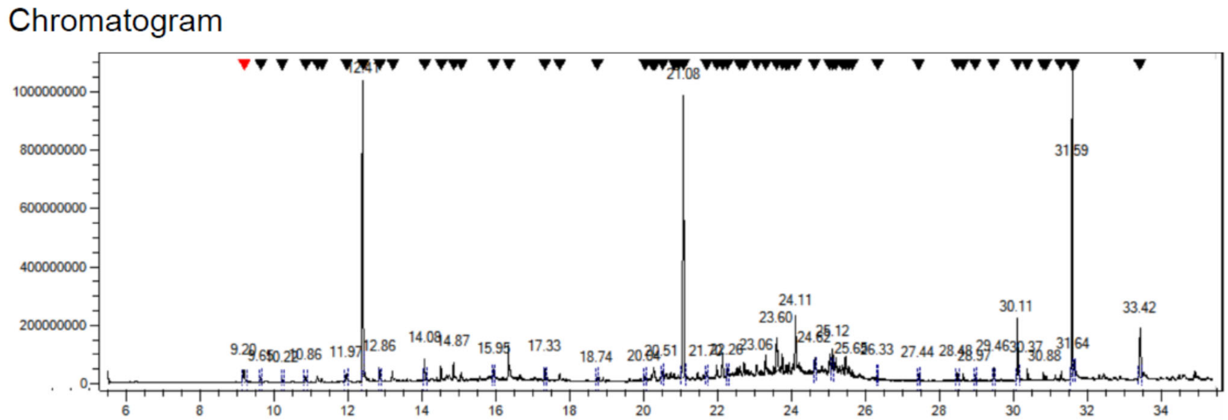

Fig. 1. GC-MS chromatogram of petroleum ether extract (Ah_1) of the leaves of *Artemisia herba-alba*

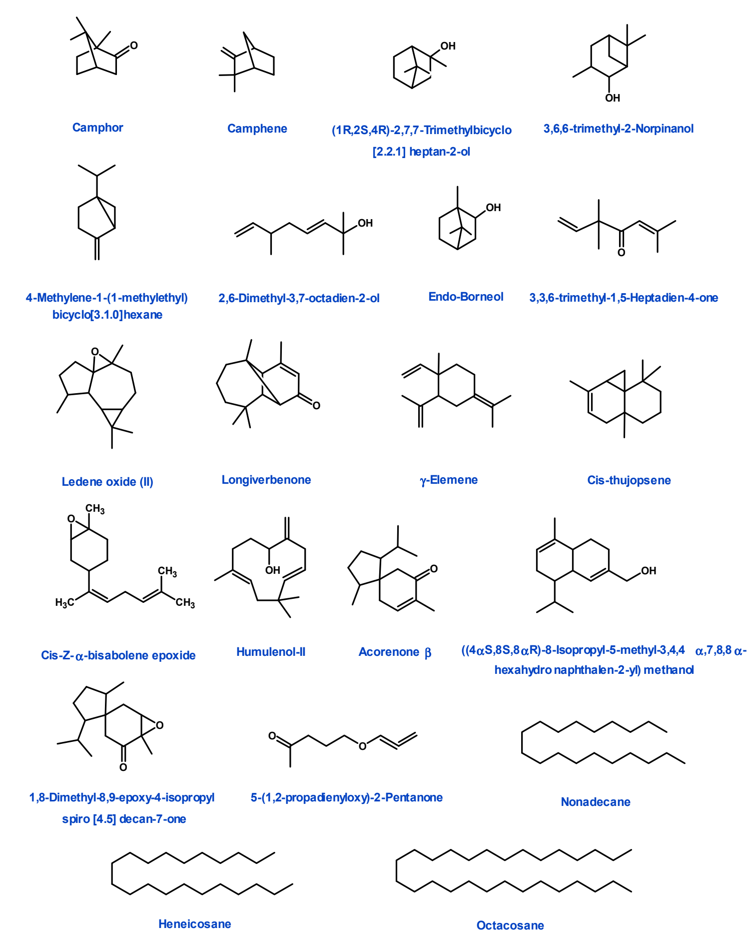

Fig. 2. The main chemical formulas of the petroleum ether extract (Ah_1)

The chloroform extract was obtained in a dark green color with a yield of 2.3 % of the dry weight of the plant. The GC/MS chromatogram of the chloroform extract (Ah_2) of the *Artemisia herba-alba* plant (**Fig. 2**) revealed 39 different compounds, accounting for 99.7 % of the total composition of the extract. The chloroform extract (Ah_2) consists mainly of six compounds of aliphatic and aromatic hydrocarbons (16.7%), five compounds of monoterpene (13.1%), five compounds of sesquiterpenes (12.4%), and seven compounds of ester derivatives (28.8%), in addition to oxygenated compounds in small percentages. The most abundant compound obtained was the ester compound dioctylhexanedioate (13.2%), followed by (Z,Z) 9,12-octadecadienoyl chloride (7.3%), (-)-spathulenol (7.1%), n-butyl methacrylate (7.0%), 2-butoxyethyldodecanoate (6.1%), heptacosane (5.8%), isopinocarveol (5.2%), styrene (5.0%), (-)-myrtenol (4.3%), 1-propyl-3-(propen-1-yl) adamantine (4.2%), and 3,7,11-trimethyl-1-dodecanol (2.8%). The remaining compounds were present in trace amounts, less than 2.5%. **Table 2**. shows the chemical composition of the chloroform extract (Ah_2) of the leaves of *Artemisia herba-alba* using GC/MS. **Fig. 3** shows the GC-MS chromatogram of the chloroform extract (Ah_2) of the leaves of *Artemisia herba-alba*, and **Fig. 4** shows the main chemical formulas of the chloroform extract (Ah_2).

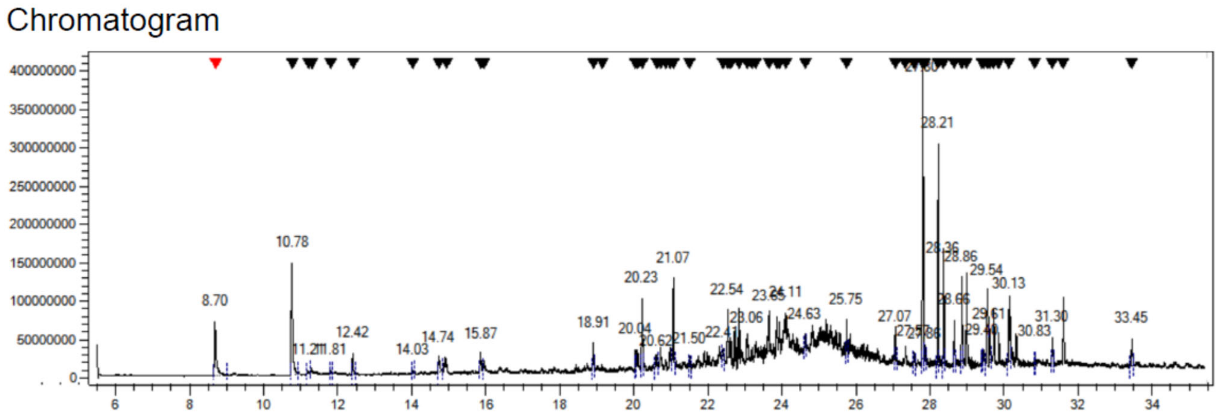

Fig. 3. GC-MS chromatogram of the chloroform extract (Ah_2) of the leaves of *Artemisia herba-alba*

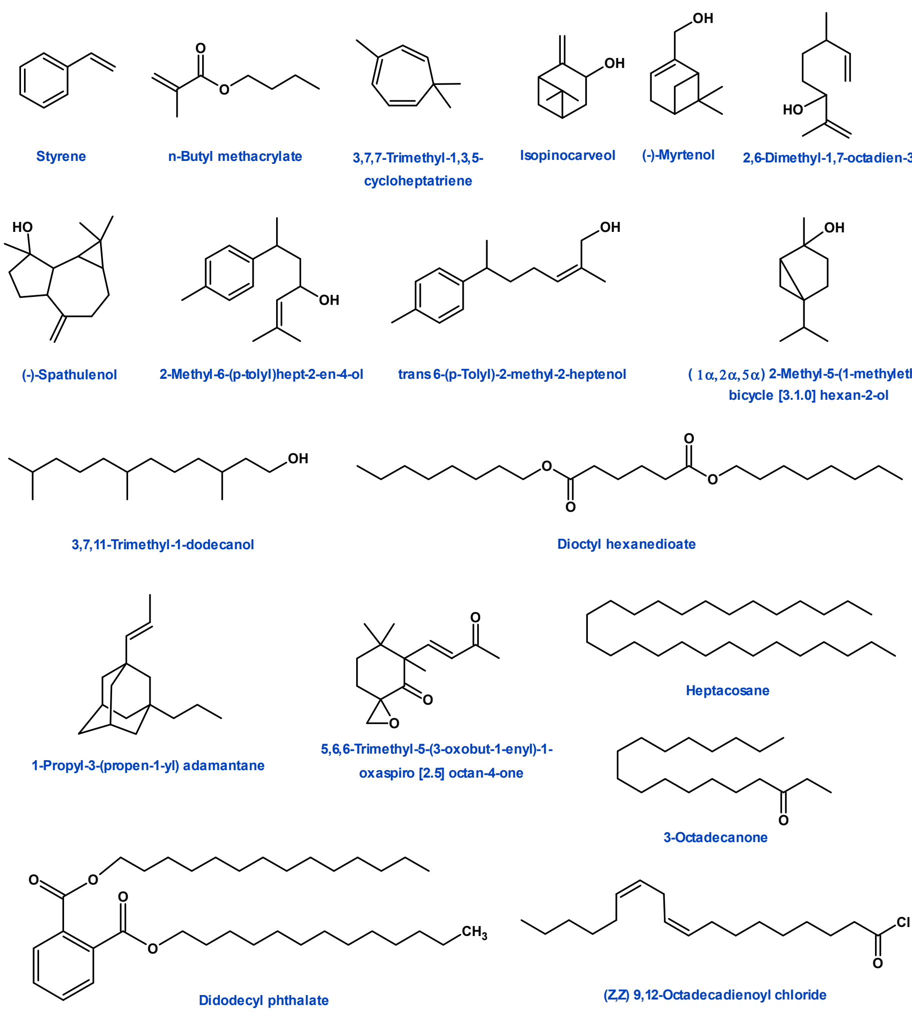

Fig. 4. The main chemical formula of the chloroform extract (Ah_2)

Table. 2. Chemical components of the chloroform extract (Ah_2) of the leaves of *Artemisia herba-alba* determined by GC-MS

No.	Compound name	Molecular formula	Class	Mw (g/mol)	R_t	area %
1	Styrene	C_8H_8	ArH	104.14	8.7	5.0
2	n-Butyl methacrylate	$C_8H_{14}O_2$	OE	142.19	10.78	7.0
3	1-Propenyl benzene	C_9H_{10}	AH	118.17	11.21	0.3
4	1,2,3,5-Tetrahydro-1,3-methanopentalene	C_9H_{10}	AH	118.18	11.31	0.3
5	3,7,7-Trimethyl-1,3,5-cycloheptatriene	$C_{10}H_{14}$	HM	134.21	11.81	2.2
6	Isopinocarveol	$C_{10}H_{16}O$	OM	152.23	14.03	5.2
7	5-(1-Methylethyl) bicycle [3.1.0] hexan-2-one	$C_9H_{14}O$	OC	138.20	14.74	1.1
8	(-)-Myrtenol	$C_{10}H_{16}O$	OM	152.23	14.94	4.3
9	2,6-Dimethyl-1,7-octadien-3-ol	$C_{10}H_{18}O$	OM	154.24	15.87	1.1
10	(1α,2α,5α) 2-Methyl-5-(1-methylethyl) bicycle [3.1.0] hexan-2-ol	$C_{10}H_{18}O$	OM	154.24	15.95	0.3
11	1-Tetradecene	$C_{14}H_{28}$	AH	196.37	18.91	1.1
12	2-Methyl-6-(p-tolyl)hept-2-en-4-ol	$C_{15}H_{22}O$	OS	218.33	20.04	0.7
13	Diethyl Phthalate	$C_{12}H_{14}O_4$	OA	222.23	20.11	0.7
14	(-)-Spathulenol	$C_{15}H_{24}O$	OS	220.35	20.23	7.1
15	Methyl 2,5-octadecadiynoate	$C_{19}H_{30}O_2$	OE	290.44	20.62	0.7
16	γ,4-Dimethyl benzenebutanal	$C_{12}H_{16}O$	OC	176.25	20.73	0.7
17	cis-5,8,11,14,17-Eicosapentaenoic acid	$C_{20}H_{30}O_2$	OF	302.45	20.86	0.3
18	trans 6-(p-Tolyl)-2-methyl-2-heptenol	$C_{15}H_{22}O$	OS	218.33	20.98	0.7
19	2-(Acetyloxy)-1-[(acetyloxy)methyl]ethyl (Z,Z,Z)-9,12,15-octadecatrienoate	$C_{25}H_{40}O_6$	OE	436.6	21.50	0.5
20	2-Butyloxycarbonyloxy-1,1,10-trimethyl-6,9-epidioxydecalin	$C_{18}H_{30}O_5$	OE	326.4	22.41	0.4
21	1-Propyl-3-(propen-1-yl) adamantane	$C_{16}H_{26}$	AH	218.38	22.54	4.2
22	2-Myristynoyl pantetheine	$C_{25}H_{44}N_2O_5S$	OF	484.7	22.62	1.0
23	(3β,5α) 2-Methylene cholestan-3-ol	$C_{28}H_{48}O$	OF	400.7	22.84	2.4
24	2,2,6-Trimethyl-1-(3-methylbuta-1,3-dienyl)-7-oxabicyclo [4.1.0] heptan-3-ol	$C_{14}H_{22}O_2$	OB	222.32	23.06	1.7
25	3,7,11-Trimethyl-1-dodecanol	$C_{15}H_{32}O$	OS	228.41	23.65	2.8
26	5,6,6-Trimethyl-5-(3-oxobut-1-enyl)-1-oxaspiro [2.5] octan-4-one	$C_{14}H_{20}O_3$	OC	236.31	23.86	2.5
27	2,3-bis (acetyloxy)propyl (Z,Z,Z)-9,12,15-Octadecatrienoate	$C_{25}H_{40}O_6$	OE	436.6	23.93	0.9
28	Retinal	$C_{20}H_{28}O$	D	284.43	24.11	0.8
29	Z-(13,14-Epoxy)tetradec-11-en-1-ol Acetate	$C_{16}H_{28}O_3$	OF	268.39	25.75	1.1
30	2,6,10-Trimethyl tetradecane	$C_{17}H_{36}$	HS	240.46	27.07	1.1
31	Tetrahydro-2-(12-pentadecynyloxy)-*2H*-Pyran	$C_{20}H_{36}O_2$	OF	308.5	27.33	0.6
32	Dioctyl hexanedioate	$C_{22}H_{42}O_4$	OE	370.56	27.80	13.2
	2-Butoxyethyl dodecanoate	$C_{18}H_{36}O_3$	OE	300.5	28.21	6.1
33	Heptacosane	$C_{27}H_{56}$	AH	380.73	28.36	5.8
34	3-Octadecanone	$C_{18}H_{36}O$	OC	268.47	28.86	3.2
35	Didodecyl phthalate	$C_{32}H_{54}O_4$	OA	502.76	28.98	2.5
36	2-Hexadecanol	$C_{16}H_{34}O$	OB	242.44	29.45	0.3
37	(Z,Z) 9,12-Octadecadienoyl chloride	$C_{18}H_{31}OCl$	OD	298.9	29.54	7.3
38	5-Heptyldihydro-2(3H)-furanone	$C_{11}H_{20}O_2$	OF	184.27	29.71	1.9
39	1-(Ethenyloxy) octadecane	$C_{20}H_{40}O$	OF	296.53	30.83	0.6
Total identified compounds						**99.7**

	No. of compounds	Compound symbol	
Monoterpenes			**13.1**
Hydrocarbon	1	HM	2.2
Oxygenated	4	OM	10.9
Sesquiterpenes			**12.4**
Hydrocarbon	1	HS	1.1
Oxygenated	4	OS	11.3
Diterpenes		D	**0.8**
Hydrocarbons			**16.7**
Aliphatic	5	AH	11.7
Aromatic	1	ArH	5
Oxygenated compounds			**56.7**
Phthalic acid esters	2	OA	3.2
Alcohols	2	OB	2
Carbonyl (aldehyde, ketone)	4	OC	7.5
Acyl chloride	1	OD	7.3
Ester compounds	7	OE	28.8
Other	7	OF	7.9

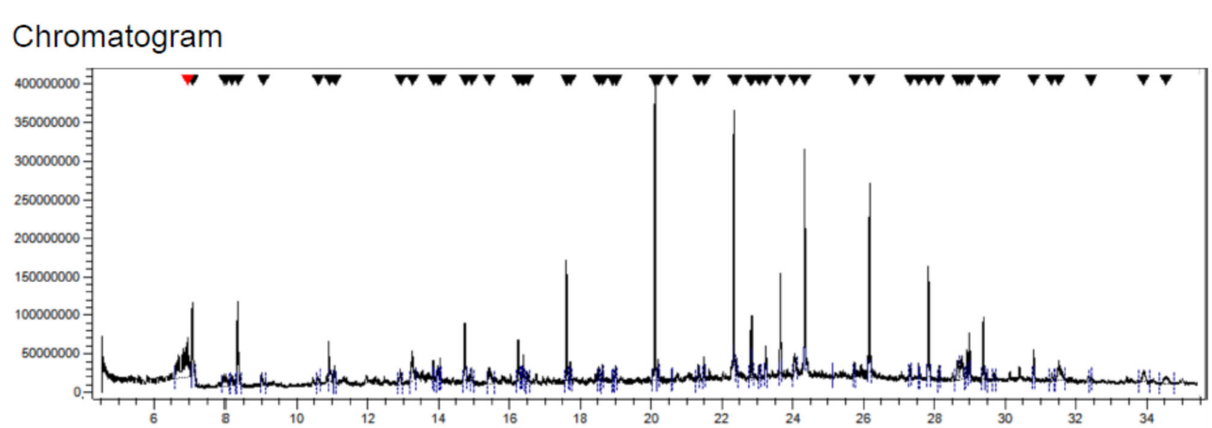

Fig. 5. GC-MS chromatogram of the ethyl acetate extract (Ah_3) of the leaves of *Artemisia herba-alba*

The ethyl acetate extract was obtained in a dark yellow color with a yield of 2.7% of the dry weight of the plant. The GC/MS chromatogram of the ethyl acetate extract (Ah_3) of the *Artemisia herba-alba* plant **(Fig. 5)** showed the presence of 45 different compounds, representing 97.2 % of the total composition of the extract. The ethyl acetate extract (Ah_3) consists mainly of seven alcohol compounds (14.7%), four aliphatic hydrocarbon compounds (14.2%), two oxygenated monoterpenes (13.5%), seven silicon compounds (10.4%), as well as two fatty acid compounds (9.7%) and six ester compounds (7.5%). The most abundant compound obtained was pentanoic acid (9.5%), followed by the monoterpene compound geranyl isovalerate (9.3%), the alcoholic compound 2-butyl-1-octanol (7.5%), and 1-heptadecene. (6.4%). Other compounds present include tetradecyloxirane (4.5%), anethole (4.2%), and hexadecamethylheptasiloxane (4.2%), among others at percentages less than 4%. **Table 3.** shows the chemical composition of the ethyl acetate extract (Ah_3) of the leaves of *Artemisia herba-alba* using GC/MS. **Fig. 5** shows the GC-MS chromatogram of the ethyl acetate extract (Ah_3) of the leaves of *Artemisia herba-alba*, and **Fig. 6** shows the main chemical formulas of the ethyl acetate extract (Ah_3).

Table. 3. Chemical components of the ethyl acetate extract (Ah_3) of the leaves of *Artemisia herba-alba* by GC-MS

No.	Compound name	Molecular formula	Class	Mw (g/mol)	R_t	area %
1	Pentanoic acid	$C_5H_{10}O_2$	OE	102.13	6.95	9.5
2	Hexamethyl cyclotrisiloxane	$C_6H_{18}O_3Si_3$	OG	222.46	7.09	3.4
3	Isosorbide dinitrate	$C_6H_8N_2O_8$	OI	236.13	8.00	1.9
4	1-Methoxy-2-propyl acetate	$C_6H_{12}O_3$	OC	132.15	8.34	3.4
5	2-Phenylethyl 3-methyl- 2-butenoate	$C_{13}H_{16}O_2$	OC	204.26	9.05	0.9
6	Butyl 2-butenoate	$C_8H_{14}O_2$	OC	142.19	10.92	1.9
7	Octamethyl cyclotetrasiloxane	$C_8H_{24}O_4Si_4$	OG	296.61	11.08	0.7
8	O-decyl hydroxylamine	$C_{10}H_{23}NO$	OI	173.29	13.26	2.3
9	Decamethyl cyclopentasiloxane	$C_{10}H_{30}O5Si_5$	OG	370.77	13.86	0.5
10	1-(Methoxymethoxy)-3-methyl-3- hydroxybutane	$C_7H_{16}O_3$	OD	148.2	13.99	0.5
11	2-hydroxy-2-methyl propanoate methyl	$C_5H_{10}O_3$	OC	118.13	14.05	0.4
12	4-(1-Methylethyl)-2-cyclohexen-1-one	$C_9H_{14}O$	OB	138.20	14.76	2.4
13	Cyclodecanol	$C_{10}H_{20}O$	OD	156.26	14.94	0.4
14	1-acetate 1,2,3-Propanetriol	$C_5H_{10}O_4$	OD	134.13	15.43	1.6
15	Anethole	$C_{10}H_{12}O$	OM	148.20	16.24	4.2
16	1-Octadecanesulphonyl chloride	$C_{18}H_{37}C_lO_2S$	OI	353.0	16.36	0.2
17	Dodecamethyl cyclohexasiloxane	$C_{12}H_{36}O_6Si_6$	OG	444.92	16.40	0.5
18	Bicyclo[4.4.1]undeca-1,3,5,7,9-pentaene	$C_{11}H_{10}$	AH	142.20	16.52	0.5
19	Allyl 2-ethyl butyrate	$C_9H_{16}O_2$	OC	156.22	18.52	0.4
20	Tetradecamethyl cycloheptasiloxane	$C_{14}H_{42}O_7Si_7$	OG	519.07	18.63	0.3
21	Cetene	$C_{16}H_{32}$	AH	224.43	19.02	1.3
22	Geranyl isovalerate	$C_{15}H_{26}O_2$	OM	238.36	20.11	9.3
23	Hexadecamethyl cyclooctasiloxane	$C_{16}H_{48}O_8Si_8$	OG	593.23	20.59	0.3
24	7-Methyl-Z-tetradecen-1-ol acetate	$C_{17}H_{32}O_2$	OC	268.4	21.32	0.5
25	1,2-15,16-Diepoxyhexadecane	$C_{16}H_{30}O_2$	OH	254.41	21.51	0.6
26	2-Butyl 1-octanol	$C_{12}H_{26}O$	OD	186.33	22.33	7.5
27	6,10,14-Trimethyl-2-pentadecanone	$C_{18}H_{36}O$	OB	268.47	22.84	2.0
28	Phytol	$C_{20}H_{40}O$	D	296.5	23.25	3.0
29	(Z) 14-Methyl- 8-hexadecenal	$C_{17}H_{32}O$	OA	252.4	23.64	3.2
30	Butyl octyl 1,2-benzenedicarboxylate	$C_{20}H_{30}O_4$	OF	334.44	24.03	1.2
31	1-Docosene	$C_{22}H_{44}$	AH	308.58	24.34	6.5
32	Amyl cyclopentenone	$C_{13}H_{22}O_2$	OB	210.31	25.75	0.5
33	1-Heptadecene	$C_{17}H_{34}$	AH	238.45	26.16	6.4
34	Tetrahydro-6-nonyl-2H-pyran-2-one	$C_{14}H_{26}O_2$	OI	226.35	27.56	0.4
35	1-Hexadecanol	$C_{16}H_{34}O$	OD	242.44	27.83	4.0
36	n-Nonadecanol-1	$C_{19}H_{40}O$	OD	284.52	28.13	0.4
37	Glycine, N-[(3α,5β)-24-oxo-3-[(trimethylsilyl)oxy]cholan-24-yl]-, methyl Ester	$C_{30}H_{53}O_4SiN$	OI	519.8	28.65	0.5
38	Hexadecamethyl heptasiloxane	$C_{16}H_{48}O_6Si_7$	OG	533.14	28.76	4.2
39	Tetradecanal	$C_{14}H_{28}O$	OA	212.37	28.92	0.8
40	Mono(2-ethylhexyl) phthalate	$C_{16}H_{21}O_4$	OF	277.33	28.98	0.9
41	Tetradecyl oxirane	$C_{16}H_{32}O$	OH	240.42	29.37	4.5
42	Behenic alcohol	$C_{22}H_{46}O$	OD	326.60	29.68	0.3
43	Oleic Acid	$C_{18}H_{34}O_2$	OE	282.46	32.42	0.2
44	Tris(2,4-di-tert-butylphenyl) phosphate	$C_{42}H_{63}O_4P$	OI	662.92	33.90	1.3
45	Digitoxin	$C_{41}H_{64}O_{13}$	OI	764.95	34.53	1.5
Total identified compounds						**97.2**

	No. of compounds	Compound symbol	
Oxygenated monoterpenes	2	OM	**13.5**
Diterpenes	1	D	**3.0**
Hydrocarbon compounds (Alkenes)	4	AH	**14.2**
Oxygenated compounds			**66.5**
Aldehyde	2	OA	4
Ketone compounds	3	OB	4.9
Ester compounds	6	OC	7.5
Alcohol compounds	7	OD	14.7
Acides	2	OE	9.7
Phthalic acid esters	2	OF	2.1
Silicon compounds	7	OG	10.4
Epoxy compounds	2	OH	5.1
Other	7	OI	8.1

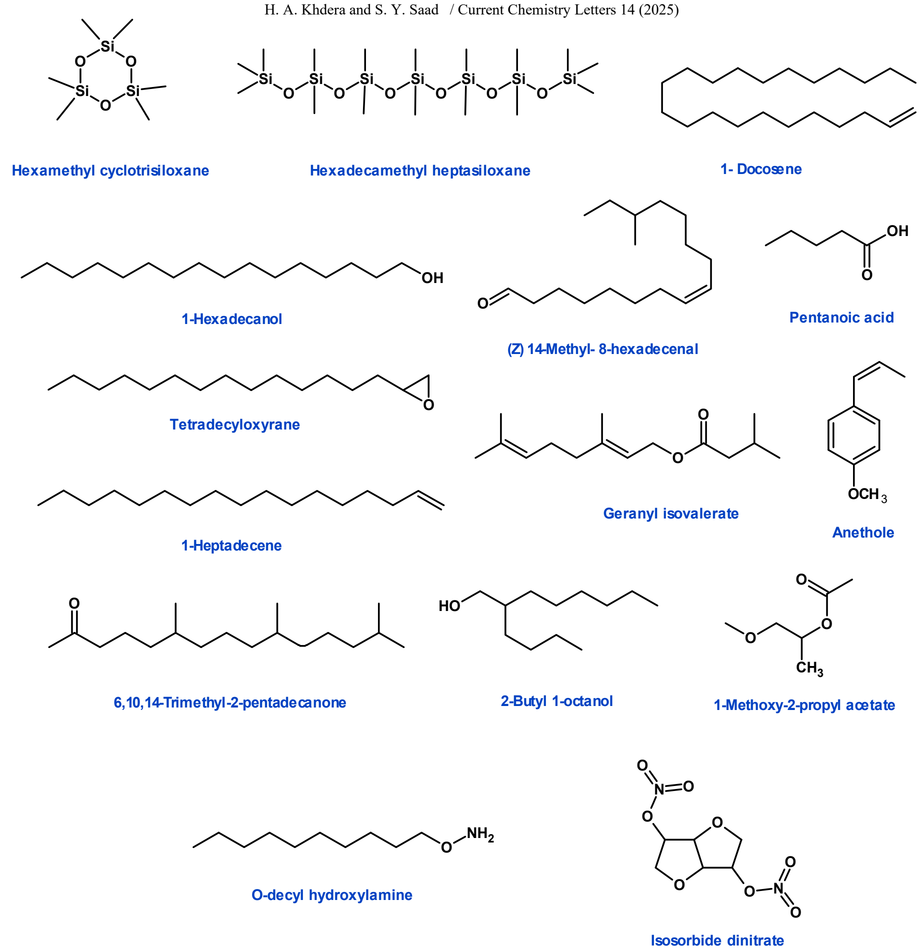

Fig. 6. The main chemical formulas of the ethyl acetate extract (Ah_3)

The aim of the extraction procedure (serial exhaustive extraction method) with different polar solvents (starting with the nonpolar solvent petroleum ether up to the most polar solvent ethyl acetate) on the same plant sample was first to extract the nonpolar compounds (in the petroleum ether and chloroform extracts) and then extract the medium polar compounds (in the ethyl acetate extract). The predominant compounds in the petroleum ether and chloroform extracts were saturated and unsaturated hydrocarbons, monoterpenes, and sesquiterpenes, while the predominant compounds in the ethyl acetate extract were oxygenated. It was not observed in the reference studies that the serial exhaustive extraction method was used on the *Artemisia herba-alba* plant using the Soxhlet continuous extraction device, and the solvents chloroform and ethyl acetate were not previously used in the extraction process on the plant above.

The chemical composition of the extracts obtained shows that the plant is rich in monoterpenes and sesquiterpenes since the chemical composition of the petroleum ether extract (Ah_1) was found to contain a high percentage (23.9%) of the sesquiterpene compound longiverbenone, a compound that has not previously been found in the plant *Artemisia herba-alba*, either in essential oils obtained by the Clevenger method (water distillation) or by extraction with organic solvents. In addition, the monoterpene 3,3,6-trimethyl-1,5-heptadien-4-one was detected in the petroleum ether extract (Ah_1) at a level of (16.5 %), a new compound not found in the plant in previous studies. The percentage of the monoterpene camphor in the petroleum ether extract was (2.1%), while its percentage in the essential oils extracted from the plant in reference studies was high and ranged between (15-50 %). [18-27]

The percentage of the monoterpene endo-borneol in the petroleum ether extract was (1.5), while its percentage in the essential oils extracted from the plant in previous studies was (1.61%). [28] The percentage of the monoterpene isopinocarveol was (5.2%) in the petroleum ether extract, while its percentage in the essential oils extracted from the plant grown in Tunisia and Algeria was (0.3 - 2.6%) according to previous studies, where isopinocarveol is considered as a geometric isomer of the compound trans-pinocarveol. [24, 29] The percentage of monoterpene (-)-myrtenol in the chloroform extract was (4.3%), while its percentage in the essential oils obtained from the plant cultivated in Morocco was (1.74-4.19%). [30] The percentage of caryophyllene oxide in the petroleum ether extract was (5.8%), while its percentage in the essential oil of the plant grown in Morocco was (1.49-1.76). [30] The percentage of sesquiterpene (-)-spathulenol in the chloroform extract was (7.1%), while its percentage in the essential oil of the plant in reference studies was (0.4 - 3.3%). [24, 31] The percentage of the monoterpene geranyl isovalerate in the ethyl acetate extract was (9.3%), while its percentage in the extract of the plant grown in Iraq was very low (0.01 %). [32] The percentage of the monoterpene anethole was (4.2%), while its percentage in the essential oil extracted from the plant grown in Saudi Arabia was (0.2%). [31] The percentage of the terpene cis-thujopsene was found to be 1.1%, and this compound had not previously been found in the plant *Artemisia herba-alba*. A high percentage of the hydrocarbon compound heneicosan was also found in the petroleum ether extract (18.2%), and this compound had not been found in previous studies of the plant.

The percentage of the monoterpene β-element in the petroleum ether extract was 1.4%, while its percentage in the essential oil obtained from the Moroccan plant was about 0.16%. [33] The percentage of the terpene trans-Z-α-bisabolene epoxide in the petroleum ether extract was 0.7%, while the percentage in the essential oil obtained from the plant grown in Morocco was about 2.86%. [34] The terpene cis-Z-α-bisabolene epoxide was not found in previous studies, as its percentage in the petroleum ether extract was 4.4% The percentage of the terpene 4-methylene-1-(1-methylethyl) bicyclo[3.1.0]hexane in the petroleum ether extract was 1.4%, while its percentage in the methanol extract of the plant grown in Syria was 4.6%. [17] The percentage of the compound (3β,5α) 2-methylenecholestan-3-ol in the chloroform extract was 2.4%, while the percentage in the methanol extract of the plant grown in Syria was about 0.7%. [17] The percentage of the compounds hexamethyl cyclotrisiloxane, octamethyl cyclotetrasiloxane, and hexadecamethyl cyclooctasiloxane in the ethyl acetate extract was 3.4%, 0.7%, 0.3%, while the percentage in the essential oil extracted from the Iraqi plant was 0.66%, 0.38%, 0.73% respectively. [35]

Monoterpenes and sesquiterpenes make up a high percentage in the petroleum ether extract (25.3%) and (39.3%) and in the chloroform extract (13.1%) and (12.4%), respectively. The ethyl acetate extract contains (13.5%) monoterpenes and (3%) diterpenes. According to the literature, monoterpenes have high biological activity as they are antimicrobial, antifungal and have repellent properties on insect pests. [36, 37] The terpene compound camphor, for example, has antiviral, antimicrobial, antitussive and analgesic effects. [38] Endo-borneol has insect repellent properties, [39] while (-)-myrtenol has analgesic and anti-inflammatory properties. [40]

The Asteraceae family contains a large number of sesquiterpene compounds that are associated with plant defense mechanisms due to their antifungal, antibacterial and antiviral activities. [41] Many studies have shown that sesquiterpenes promote health against many diseases such as cardiovascular complications, neurological disorders and diabetes. [42, 43] For example, the compound cis-thujopsene has biological antifungal properties, [44] the compound leden oxide (II) has antibacterial and antioxidant properties, [45] the compound acorenone β has inhibitory properties of AChE and BChE, [46] and the compound longiverbenone has antibacterial activity. It is cytotoxic, [47] caryophyllene oxide has anticancer and analgesic activity [48] and (-)-spathulenol has anti-inflammatory, antioxidant, and antimicrobial activity. [49] A high percentage of the ester compound dioctyl hexanedioate (13.2%) was found in the chloroform extract (Ah_2). This compound has biological activity as an inhibitor of alkyl acetylglycerophosphatase, as an inhibitor of sugar phosphatase, and as an inhibitor of acylcarnitine hydrolase. [50]

The differences in the percentages of the chemical components of the organic extracts studied are due to the different cultivation methods of the plants and the different geographical regions, which affect the accumulation of the chemical compounds. [51-53] In addition, there are some external factors such as sunlight, quality and components of the soil and its pH that can increase the amount of terpenes in the plant. [54] Differences in isolation methods for essential oils or organic extracts also lead to differences in the chemical composition of the plant. [55] The previous tables show a qualitative and quantitative difference in the chemical composition of organic extracts compared to essential oils and organic extracts from previous studies. For example, we note that the main component in the petroleum ether extract of the *Artemisia herba alba* plant is Longiverbenone at a rate of 23.9%, which is a compound that is not found in reference studies, whether in essential oils or organic extracts. For the same plant. This specific composition is likely the result of plant adaptation to the bioclimatic conditions of the region or to intrinsic factors related to plant genetics. [56]

3. Conclusions

The study of the chemical composition of the leaves of the *Artemisia herba-alba* plant using three solvents with different degrees of polarity (petroleum ether, chloroform and ethyl acetate) is a new study in Syria, as there are no previous chemical studies on organic extracts (chloroform, ethyl acetate) from the leaves. For the plant. The main compounds that make up the extracts were identified using GC/MS technology, and these compounds were found to be monoterpenes, sesquiterpenes, saturated and unsaturated aliphatic hydrocarbons, alcohols and silicon compounds. According to the literature, the leaves of the *Artemisia herba-alba* plant contain chemical compounds with biological antimicrobial, antioxidant, anticancer and antimalarial activity.

4. Experimental

4.1. Materials and Methods

Soxhlet-type apparatus (BÜCHI), GC-MS (**Shimadzu** - 17A/QP5050), laboratory heating (Heraeus), rotary evaporator (BÜCHI), sensitive scale (Sartorius), laboratory glassware (Isolab), ethyl acetate (P.R.S Panreac), chloroform (Merck), petroleum ether (S.C.P), sodium sulphate, filter paper (ZELPA).

4.2. General procedure

4.2.1. Preparation of organic extracts

The leaves of the plant *Artemisia herba-alba* were collected in May and June 2023 in the Latakia region. They were freed from dust and suspended matter. The plant was dried for 30 days at room temperature in a shaded, well-ventilated place. The plant was ground to the appropriate fineness and stored in tightly closed containers until use.

Three chemical extracts of the plant were prepared with different solvents (petroleum ether (Ah_1), chloroform (Ah_2), ethyl acetate (Ah_3)) using a continuous Soxhlet extractor by placing 50 g of the plant in a cartridge and adding 300 ml of petroleum ether to a 500 ml round bottom flask. The extraction process took 15 hours. The extraction process was repeated with the other solvents on the same plant sample (the plant sample was dried in an oven at 35 °C before each extraction with a different solvent). The solvents were evaporated with a rotary evaporator at a temperature of 45 °C and then dried in a desiccator. Shows **Fig. 7** General scheme for the extraction of leaves of *Artemisia herba-alba* using polar gradient solvents. The dried extracts were weighed, and the percentage yield was calculated using the following relationship:

Yield % = (weight of dry extract / weight of plant material used) × 100.

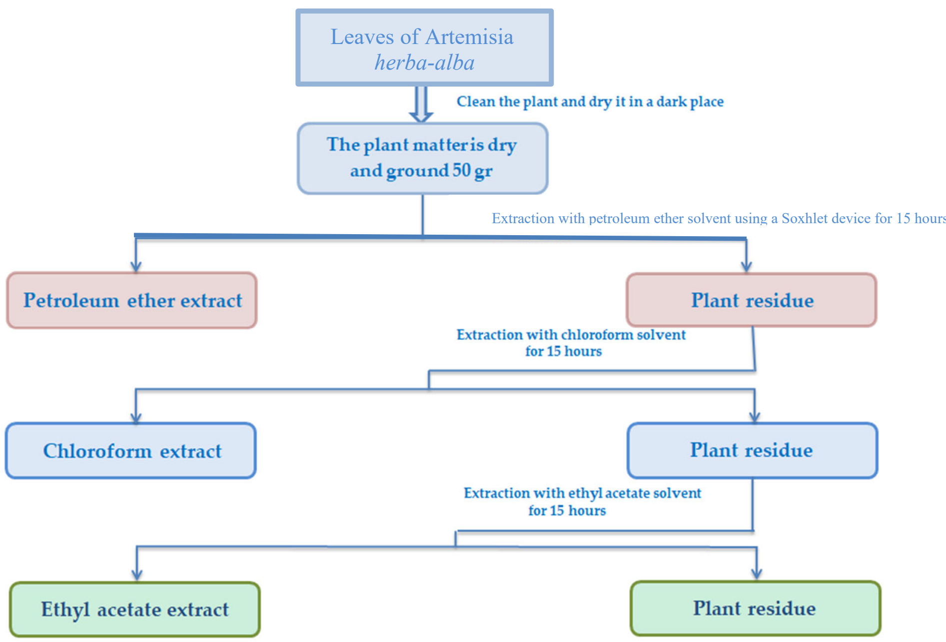

Fig. 7. General scheme for the extraction of leaves of *Artemisia herba-alba* using polar gradient solvents

4.2.2. GC-MS analysis

The analysis was performed by injecting 2 µl of each sample into a SHIMADZU GC-MS instrument, model GCMS-17A/QP5050, using a nonpolar capillary column (BP5MS, 5% phenylpolysilphenylene siloxane) with the dimensions of 30 m X 0.25 mm, i.d. 0.25 µm, and the carrier gas was helium with a purity of 99.9999% at a flow rate of 1 ml/min. Chloroform was used as the solvent for injecting the samples.

The thermal programme started at 80 °C for 4 minutes and then increased by 10 °C per minute until 200 °C was reached. This temperature was maintained for 5 minutes, after which the temperature was increased from 200 °C by 7 °C per minute to 300 °C, after which the temperature was maintained for 15 minutes. The total run time was 50.3 minutes. Mass spectra were recorded from 42 m/z to 600 m/z in 70 eV ionization energy mode, and the ionization source temperature was set to 280 °C.

The chemical compounds present in each extract were identified based on the interpretation of the GC-MS mass spectrum using the NIST and WILEY databases by comparing the mass spectrum of the analysed compound with the spectrum of known compounds stored in the libraries available on the instrument's computer (Nist 05a. L, Nist 02. L, Wiley 7.1).

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