Original Article

Asian Pacific Journal of Tropical Biomedicine

journal homepage: www.apjtb.org

doi: 10.4103/2221-1691.294089

Impact Factor: 1.90

Phytochemical profile, antioxidant activity and wound healing properties of *Artemisia absinthium* essential oil

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ABSTRACT

Objective: To evaluate chemical compositions, antioxidant and wound healing properties of Algerian *Artemisia absinthium* essential oil.

Methods: The chemical composition of the essential oil from *Artemisia absinthium* was analyzed by a combination of GC-FID and GC/MS. The antioxidant capacities including the total antioxidant capacity, $DPPH^{\bullet}$ and $ABTS^{+\bullet}$ scavenging capacities were measured. The wound healing potential was assessed by the excision wound model of rats. The wounds were treated daily with an ointment prepared with two concentrations (5% and 10%) of *Artemisia absinthium* essential oil. The percentage of wound contraction was determined and wound healing was also evaluated by histological examination of the healed skin.

Results: The main component of *Artemisia absinthium* essential oil was camphor (48%) followed by chamazulene (10%) that was responsible for the dark blue color of the oil. *Artemisia absinthium* essential oil exhibited moderate antioxidant activity compared with BHT and Trolox. All preparations showed significant effects on wound contraction and the ointment prepared with 10% of essential oil was effective as the reference drug Cicatryl.

Conclusions: The essential oil of *Artemisia absinthium* shows moderate antioxidant activity. The 10% ointment enhances skin wound re-epithelialization and speeds up the healing process. The essential oil of *Artemisia absinthium* may be used as an alternative drug for wound healing.

KEYWORDS: *Artemisia absinthium*; Essential oil; Antioxidant; Wound healing

1. Introduction

Artemisia absinthium (*A. absinthium*) popularly known as common wormwood belongs to the family Asteraceae (Compositae). The genus *Artemisia* consists of over 500 different species and is distributed in almost all temperate zones. Many *Artemisia* species have been studied for their phytochemical profiles and pharmacological properties. *A. absinthium* has a long history as a medicinal plant[1,2] and is native to temperate regions of Eurasia and Northern Africa but is rather rare in Algeria[3]. *A. absinthium* contains an essential oil that is characterized by a particular color ranging from green to dark blue. One of the most peculiar features of this oil is the presence of large amounts of thujone, an oxygenated monoterpene, which can account for 40%-90% of the oil. This compound is normally present in two isomeric forms named α- and β-thujone and the latter is more abundant. Other important constituents of *A. absinthium* are the non-volatile sesquiterpene lactones, particularly absinthin, which are responsible for the bitter taste of its extracts.

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How to cite this article: Benkhaled A, Boudjelal A, Napoli E, Baali F, Ruberto G. Phytochemical profile, antioxidant activity and wound healing properties of *Artemisia absinthium* essential oil. Asian Pac J Trop Biomed 2020; 10(11): 496-504.

Article history: Received 2 January 2020; Revision 11 February 2020; Accepted 7 May 2020; Available online 9 September 2020

Besides the use as a medicinal plant, *A. absinthium* was used between the end of the 19th and the beginning of the 20th century for the production of the spirit absinthe, whose production and consumption grew very largely during the aforesaid periods[4–6]. However, this alcoholic beverage was successively banned since the presence of thujone was considered as the cause of the so-called 'absinthism' syndrome, including convulsions, hallucinations and mental disorders. However, no correlation was found between thujone and health. Then the limit of thujone content has been set as 35 mg/L in alcoholic beverages[2,7].

As a medicinal plant, *A. absinthium* has been used as an antipyretic, antispasmodic anti-inflammatory and memory-improving agent and was used to treat abscesses, wounds and other skin diseases[1,8]. In a recent study, the petroleum ether extract of *A. absinthium* collected in Turkey, which was particularly rich in volatile components, showed positive effects on *in vivo* induced pseudopregnancy[9].

A recent ethnopharmacological survey performed in Algeria reports that various phytotherapeutic preparations from *Artemisia* spp. (including *A. absinthium*) possess antidiabetic, antihypertensive, and analgesic properties[10]. Furthermore, *A. absinthium* essential oil also showed pesticide, insecticidal, and antimicrobial activities[8,11–13].

The main aim of the present study was to evaluate the antioxidant efficacy and the *in vivo* wound healing properties of *A. absinthium* essential oil and to provide a reference for sustainable exploitation of Algerian flora.

2. Materials and methods

2.1. Reagents and standards

All solvents used were high-purity American Chemical Society solvents from VWR (Milan, Italy); reagents and reference standards were purchased from Sigma-Aldrich Products (Merck KGaA, Darmstadt, Germany), Extrasynthese (Lyon, France) and Fluka (Milan, Italy).

2.2. Plant material

The flowering aerial parts of *A. absinthium* L. were collected in May 2018, in M'sila (situated in the central part of Algeria) at 35 °12' 36.97" N latitude and 4°10' 46.08" E longitude. The plant was authenticated by Dr. Sarri DJ, Department SNV/ M'sila University, and a specimen (AB-13) was deposited at the herbarium of the Department.

2.3. Essential oil extraction

The essential oil was extracted by hydrodistillation using a Clevenger-type apparatus (Clevenger D04000201, Somiver, Algeria) according to the European Pharmacopoeia[14]. The oil was dried with anhydrous sodium sulfate, weighed, and stored at 4℃ until use.

2.4. Essential oil analysis

Gas chromatographic (GC) analyses were performed on a Shimadzu gas chromatograph, Model 17-A (Shimadzu, Japan) equipped with a flame ionization detector (FID) and with an operating software Class VP Chromatography Data System version 4.3 (Shimadzu). Analytical conditions: SPB-5 capillary column (15 m×0.10 mm× 0.15 μm), helium as carrier gas (1 mL/min). Injection in split mode (1:200), injected volume 1 μL (4% essential oil/CH_2Cl_2 v/v), injector and detector temperature 250 and 280℃, respectively. Linear velocity in column 19 cm/s. The oven temperature was held at 60℃ for 1 min, then, programmed as reported previously[15]. Percentages of compounds were determined from their peak areas in the GC-FID profiles.

Gas-chromatography-mass spectrometry (GC-MS) was carried out in the fast mode on a Shimadzu GC-MS mod. GCMS-QP5050A, with the same column and the same operative conditions used for analytical GC-FID and GCMS solution version 1.02 operating software (Shimadzu). Ionization voltage 70 eV, electron multiplier 900 V, ion source temperature 180℃. Mass spectra data were acquired in the scan mode in the *m/z* range 40-400. The same oil solutions (1 μL) were injected with the split mode (1:96).

2.5. Identification of components of essential oil

The identity of components was based on their GC retention index (relative to C_9-C_{22} *n*-alkanes on the SPB-5 column), computer matching of spectral MS data with those from NIST MS libraries[16], the comparison of the fragmentation patterns with those reported in the literature[17] and, whenever possible, co-injections with authentic samples.

2.6. Total antioxidant capacity (TAC)

The TAC of *A. absinthium* essential oil was evaluated by the phosphomolybdenum method[18]. An aliquot of 0.3 mL of the essential oil was mixed with 3 mL of the reagent solution (0.6 mol/L of sulfuric acid, 28 mmol/L of sodium phosphate and 4 mmol/L of ammonium molybdate). The reaction mixture was incubated at 95℃ for 90 min and the absorbance measured at 695 nm. Butylated hydroxytoluene (BHT) was used as standard antioxidant. The antioxidant activity was expressed in μg equivalent of BHT per mg of essential oil (μg EBHT/mg essential oil).

2.7. DPPH radical scavenging activity

The 1,1-diphenyl-2-picryl-hydrazyl (DPPH) radical scavenging

capacity was measured according to Li *et al*[19]. A total of 1 mL of the freshly prepared 0.1 mM DPPH in methanol was added to the 3 mL of EO solution at different concentrations (0.05-1.5 mg/mL). The reaction mixture was left to stand at room temperature in the dark for 30 min and the absorbance was recorded at 517 nm. The ability to scavenge the DPPH radical was calculated using the following equation:

DPPH scavenging effect (%) = $[(A_c-A_s) / A_c] \times 100$

where A_c and A_s are the absorbances of the control and the sample, respectively. BHT was used as the reference compound. The assay was done in triplicate.

2.8. Scavenging activity of ABTS radical

The scavenging activity of ABTS radical ($ABTS^+$) has been evaluated following the method of Re *et al*[20]. An aliquot of 1 mL of essential oil was mixed with 2 mL of diluted $ABTS^+$, after 30 min of incubation; the absorbance was measured at 734 nm. The percentage of $ABTS^+$ inhibition was calculated using the following formula:

ABTS scavenging effect (%) = $[(A_c-A_s) / A_c] \times 100$

where A_c and A_s are the absorbances of the control and the sample, respectively. Trolox was used as the reference antioxidant. All measurements were performed in triplicate.

2.9. Wound healing activity

2.9.1. Preparation of the ointment

The *A. absinthium* essential oil (AEO) was mixed with petroleum jelly (PJ) (Unilever, France) in two concentrations of 5% and 10% to obtain the essential oil ointments OAEO 5% and 10%, respectively[21]. Cicatryl-Bio (CIC) (Pierre Fabre, France) was used as a reference drug.

2.9.2. Animals

Healthy adult male Wistar albino rats, weighing between 200-220 g, were obtained from Pasteur Institute of Algeria. Animals were fed with commercially pelleted rat diet and water *ad libitum*.

2.9.3. Experimental protocol

The rats were weighed, marked and divided into 5 groups of 5 rats each: Untreated group (UT group), Cicatryl-treated group (CIC group), ointment artemisia essential oil 5%-treated group (OAEO 5% group), ointment artemisia essential oil 10%-treated group (OAEO 10% group), and petroleum jelly-treated group (PJ group). An area of 250 mm^2 on the back of the rat was shaved. The animals were left in their cages 24 hours to verify the absence of irritation of the shaved zone[22].

2.9.4. Skin irritation test

The OAEO 5% and 10% were applied separately on the back of the rats. After 4 h, the skin of the animals was evaluated to detect the presence of inflammation signs[23].

2.9.5. Healing activity

Animals were anaesthetized using intraperitoneal injection of ketamine (90 mg/kg)-xylazine (10 mg/kg)[24]. A circle approximately 2.5 cm in diameter was drawn on the skin of the lumbar region and was then excised. The animals were placed in individual cages with clean litters.

Preparations (CIC, OAEO 5%, OAEO 10%, and PJ) were applied locally at an amount of 0.5 g per rat of the different groups once per day until complete re-epithelialization[25]. The dimensions of excision wounds were measured every 3 days during the trial period by tracing the wounds on transparent paper and measuring through the graph paper. The percentage of the evolution of wound contraction was calculated using the following formula[26]:

% Wound contraction =[(Initial wound size − Specific day wound size) / Initial wound size]$\times$100

2.9.6. Histological sections

At the end of the experimentation, the rats were sacrificed, the skin healed and 0.5 cm of healthy skin were removed for histological study[25]. The tissue slices were fixed in formalin (10%) for 72 h. These samples were dehydrated by passing it through three successive baths of ethanol. Then they were thinned in two baths of xylene and embedded in paraffin by two successive baths at 60℃ each one. The obtained paraffin blocks were then cut by microtome, rehydrated, stained with haematoxylin-eosin[27] and analyzed by Optika B-500 microscope (Optika s.r.l., Italy) at$\times$10 and $\times$40 magnifications.

2.10. Statistical analysis

All statistical analyses were performed using GraphPad Prism 7.0. Data were expressed as mean ± SD. Statistical significance between groups was analyzed by one-way ANOVA followed by Dunnett's test. Values for $P<0.05$ were considered statistically significant.

2.11. Ethical statement

All experimental protocols were approved by the National Committee for Evaluation and Programming of University Research of Algerian Ministry of Higher Education and Scientific Research (Registration N : DO1N01UN280120150001), according to International Council for Laboratory Animal Science[28].

3. Results

3.1. Yield and chemical composition

The extraction yield of essential oil from the flowering aerial parts

of *A. absinthium* collected in Algeria was (0.29 ± 0.08)% as v/w. The oil showed an intense dark blue color.

A total of 75 components were identified in the oil (Table 1). Oxygenated monoterpenes were quantitatively the main constituents accounting for 59.64% of the total oil and including 19 components. Camphor with ca. 47.59% was the main compound of this class and also of the total oil, followed by terpinen-4-ol (ca. 6.36%). While linalool and *cis*-sabinene hydrate also exceeded 1%, the content of all other components was below this value. The second class of components was represented by sesquiterpenes accounting for 16.67% of the oil. It included more classes with 24 components. Chamazulene, which is responsible for the blue color of the oil reached a higher concentration (10.35%). Among the other components, only caryophyllene oxide and a dihydrochamazulene isomer slightly exceeded 1%. Monoterpene hydrocarbons accounted for 14.93% of the oil and included 13 components. The main compounds were γ-terpinene, camphene, *p*-cymene, α-pinene, and α-terpinene. The last group was represented by the so-called ‘other compounds’, with a total content of 3.73% and 18 components. The composition was rather variegated and the main component was geranyl *p*-cymene. A typical GC profile of *A. absinthium* essential oil with some of the main components is shown in Figure 1.

Table 1. Chemical composition of the essential oil of *Artemisia absinthium* from Algeria.

No[a]	RI[b]	Class/Compound	%[c]
Monoterpene hydrocarbons (*n*=13)			
2	927	Tricyclene	0.084±0.002
3	930	α-Thujene	0.180±0.002
4	938	α-Pinene	2.157±0.018
5	954	Camphene	2.677±0.022
7	977	Sabinene	0.137±0.001
8	981	β-Pinene	0.137±0.001
10	990	Myrcene	0.844±0.005
11	1006	α-Phellandrene	0.202±0.001
12	1019	α-Terpinene	1.576±0.012
13	1028	*p*-Cymene	2.644±0.021
14	1032	Limonene	0.643±0.003
17	1063	γ-Terpinene	2.878±0.016
20	1091	Terpinolene	0.768±0.003
Oxygenated monoterpenes (*n*=19)			
15	1037	1,8-Cineole	0.236±0.002
18	1073	*cis*-Sabinene hydrate	1.311±0.010
19	1078	Camphenilone	0.018±0.002
21	1100	Linalool	1.418±0.015
23	1110	*trans*-Sabinene hydrate	0.090±0.001
24	1132	*cis*-*p*-Menth-2-en-1-ol	0.479±0.007
25	1159	Camphor	47.592±0.208
26	1161	Camphene hydrate	0.280±0.265
28	1175	Borneol	0.350±0.000
29	1186	Terpinen-4-ol	6.359±0.042
31	1197	α-Terpineol	0.414±0.003
34	1108	*trans*-Piperitol	0.067±0.002
35	1205	Verbenone	0.033±0.001
39	1248	Carvone	0.076±0.001
40	1273	Perillaldehyde	0.177±0.004
44	1305	Carvacrol	0.411±0.003
52	1459	Neryl acetone	0.022±0.002
62	1584	Geranyl butanoate	0.090±0.001
65	1623	Geranyl isovalerate	0.221±0.001
Sesquiterpenes (*n*=24)			
46	1386	α-Copaene	0.184±0.001
47	1391	β-*E*-Damascenone	0.030±0.001
48	1396	β-Bourbonene	0.194±0.002
50	1434	β-Caryophyllene	0.622±0.014
51	1442	β-Copaene	0.029±0.002
53	1455	α-Humulene	0.089±0.005
54	1474	7-*epi*-1,2-dehydro-Sesquicineole	0.042±0.001
55	1478	γ-Gurjunene	0.040±0.001
56	1480	γ-Muurolene	0.042±0.003
57	1494	Germacrene D	0.504±0.003
58	1525	Dihydrochamazulene 1[d]	0.853±0.010
59	1530	Dihydrochamazulene 2[e]	0.141±0.002
60	1562	Elemol	0.434±0.003
61	1578	*E*-Nerolidol	0.024±0.003
63	1595	Spathulenol	0.133±0.001
64	1601	Caryophyllene oxide	1.475±0.112
66	1631	Humulene epoxide II	0.113±0.004
67	1634	Dihydrochamazulene 3[f]	1.014±0.036
68	1649	β-Eudesmol	0.099±0.004
69	1706	γ-*E*-Atlantone	0.033±0.002
70	1758	Chamazulene	10.346±0.152
71	1800	Dehydrochamazulene 4[g]	0.228±0.005
73	1884	Hexahydrofarnesyl acetone	0.037±0.006
74	1911	*Z*-Nuciferol acetate	0.055±0.001
Diterpenes (*n*=1)			
72	1841	Neophytadiene	0.049±0.002
Others (*n*=18)			
1	854	2-*E*-Hexenal	0.052±0.002
6	966	Benzaldehyde	0.031±0.001
9	987	6-methyl-5-Hepten-2-one	0.078±0.002
16	1049	4,6-dimethyl-5-Hepten-2-one	0.125±0.001
22	1103	3-methyl-butyl 2-mehyl Butanoate	1.080±0.045
27	1162	2-ethyl Hexyl acetate	0.040±0.000
30	1191	*p*-methyl-Acetophenone	0.185±0.003
32	1200	Methyl salicylate	0.344±0.004
33	1202	Methyl chavicol	0.085±0.003
36	1233	2-methyl-3-*Z*-Hexenyl butanoate	0.058±0.001
37	1235	3-methyl-3-*Z*-Hexenyl butanoate	0.058±0.003
38	1237	Cumin aldehyde	0.061±0.001
41	1290	*E*-Anethole	0.084±0.001
42	1293	2-Undecanone	0.967±0.009
43	1295	Tridecane	0.180±0.010
45	1364	Eugenol	0.194±0.001
49	1407	γ-4-dimethyl-Benzenebutanal	0.111±0.006
75	1946	Geranyl *p*-cymene	2.430±0.015

[a]The numbering refers to elution order; [b]Retention index (RI) relative to standard mixture of *n*-alkanes on SPB-5 column; [c]Values (relative peak area percent) represent averages of three determinations with ±SD; [d]Isomer not determined, electron impact mass spectrometry (EIMS): 186 (86%), 171 (36%), 157 (100%), 142 (56%), 128 (28%), 115 (25%), 91 (7.5%); [e]Isomer not determined, EIMS: 186 (100%), 171 (75%), 157 (65%), 143 (65%), 129 (45%), 115 (28%), 91 (15%); [f]Isomer not determined, EIMS: 186 (100%), 171 (85%), 157 (55%), 142 (65%), 128 (45%), 115 (25%), 91 (20%); [g]Isomer not determined, EIMS: 182 (100%), 167 (66%), 152 (55%), 141 (10%), 128 (6%), 115 (15%), 91 (10%).

3.2. In vitro antioxidant activity

The antioxidant activity of *A. absinthium* essential oil was evaluated by total antioxidant capacity, and DPPH and ABTS radical scavenging assays, using BHT and Trolox as standards.

The results showed that the total antioxidant capacity of the essential oil was significantly ($P<0.001$) lower than that of the reference compound BHT [(228.99±6.06) μg EBHT/mg and (417.99 ± 1.31) μg EBHT/mg, respectively].

A. absinthium essential oil was able to reduce the stable free radical DPPH with an IC_{50} of (139.93±7.81) μg/mL, but was significantly less active ($P<0.001$) than the synthetic antioxidant BHT [IC_{50} (14.60±0.71) μg/mL].

In the ABTS assay, the anti-radical activity of the essential oil of *A. absinthium* showed higher IC_{50} in comparison with the IC_{50} of Trolox [(32.96±0.71) and (3.15±0.02) μg/mL, respectively] ($P<0.001$).

3.3. Skin irritation test

No edema, erythema or signs of inflammation were observed after topical application of *A. absinthium* essential oil formulations on rats.

3.4. Evolution of healing process of wounds

During the healing period, and according to a specific interval of time of three days, the wounds were regularly measured. The evolution of the surface of each wound excision was assessed and the results are represented in Figure 2, which showed that the OAEO 10% treatment had the best results.

All treated animals showed a significant reduction in wound area when compared to the untreated group ($P<0.05$). There was no significant difference between groups treated with the *A. absinthium* essential oil ointment and the reference drug Cicatryl. An improved healing pattern with wound closure was observed in treated groups within 9-12 days (Table 2).

Daily visual observations indicated the presence of signs of inflammation around the wound in rats of different groups on the first day after the excision of the skin. These signs disappeared rapidly in the treated groups (CIC, OAEO 5% and 10%) and persisted for a few days for the rest of the groups (UT and PJ). There was a complete closure of wounds in the treated groups with OAEO and Cicatryl in comparison with the untreated group and the group treated with petroleum jelly.

3.5. Histological sections

Histology of the skin area of the excised wound on day 21 post wounding showed incomplete epithelization with more inflammatory cells, poorly formed granulation tissue and sparse distribution of collagen fibers for the UT and PJ groups. A wound gap was observed in the epidermis layers in the two groups. These observations explain the delay in the wound healing process (Figure 3A&B).

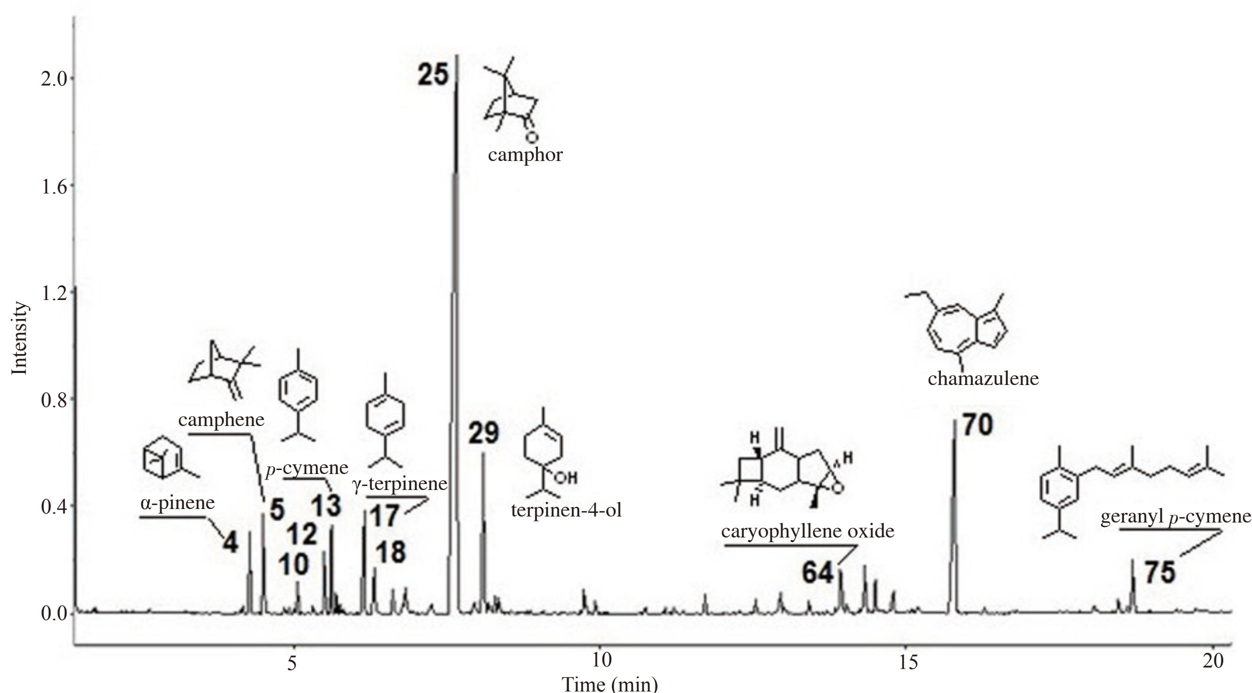

Figure 1. GC profile of the essential oil of *Artemisia absithium* from Algeria and some of the main components (for numbering see Table 1).

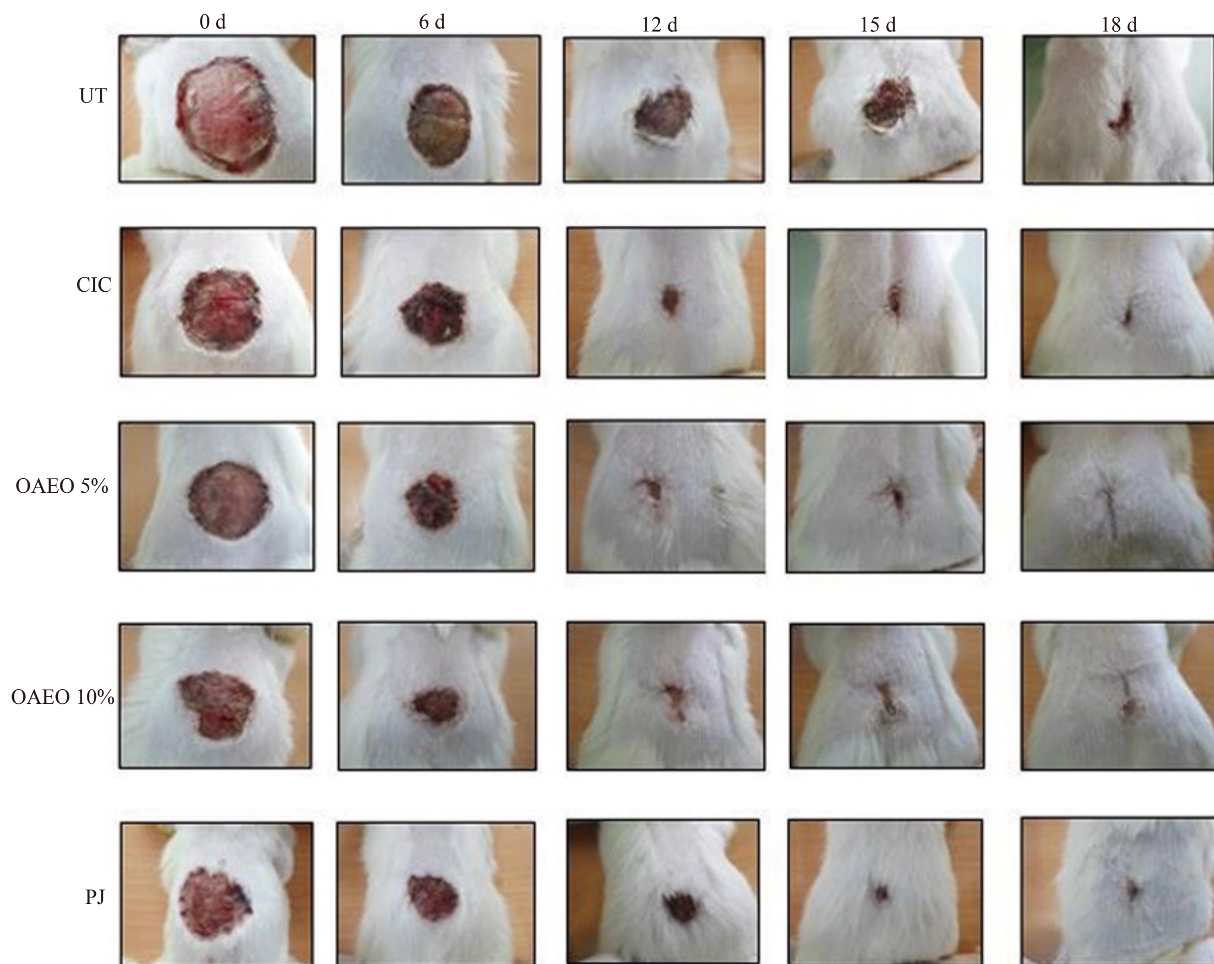

Figure 2. Chronology of excision wound healing in different groups. UT: Untreated group, CIC: Cicatryl-treated group, OAEO 5%: ointment artemisia essential oil 5%-treated group, OAEO 10%: ointment artemisia essential oil 10%-treated group, and PJ: petroleum jelly-treated group.

Table 2. Effect of different treatments on the evolution of the healing process of excision wounds in Wistar albino rats.

Groups	Days						
	3	6	9	12	15	18	21
UT	9.58±1.67	17.82±1.20	19.77±2.83	20.54±2.39	22.32±1.10	27.54±1.20	36.58±2.00
CIC	9.18±1.83	29.81±3.29*	49.91±1.55***	60.53±1.19***	75.87±1.10***	84.52±2.80***	96.00±1.36***
OAEO 5%	8.13±1.31	34.64±2.76***	52.77±2.32***	60.09±1.93***	68.75±1.34***	80.45±2.80***	91.81±2.01***
OAEO 10%	9.54±2.05	29.34±4.57*	44.74±3.57**	56.65±4.01***	72.00±4.64***	83.33±1.97***	97.23±3.25***
PJ	8.99±2.27	24.79±1.60	34.85±1.61**	39.51±1.37***	44.75±1.85***	50.56±1.52***	60.55±2.46***

Values are expressed as mean ± SD (n=5); $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.001$ (when treated groups are compared to the UT group); UT: Untreated group, CIC: Cicatryl-treated group, OAEO 5%: ointment artemisia essential oil 5%-treated group, OAEO 10%: ointment artemisia essential oil 10%-treated group, and PJ: petroleum jelly-treated group.

The histological sections of all treated groups (CIC, OAEO 5% and OAEO 10%) showed better healing resulting in more regular cell layers and more epidermal ridges. There was a complete re-epithelialization with a visible thick neo-formative epidermis, abundant granulation tissue and higher collagen deposition. These histopathological observations provide additional evidence for the contraction value of wound areas in treated groups (Figure 3C, D, E).

4. Discussion

The essential oil yield in our study was slightly higher than literature data which report a yield range between 0.2% and 1.5%[4,29–31]. The chemical composition of *A. absinthium* oil can explain the biological activity of this oil and justify the use of this plant in folk medicine. *A. absinthium* from Algeria can be defined as a camphor chemotype, and in comparison with literature data, this sample appears partially similar to plants collected in Brazil and Tunisia, which show

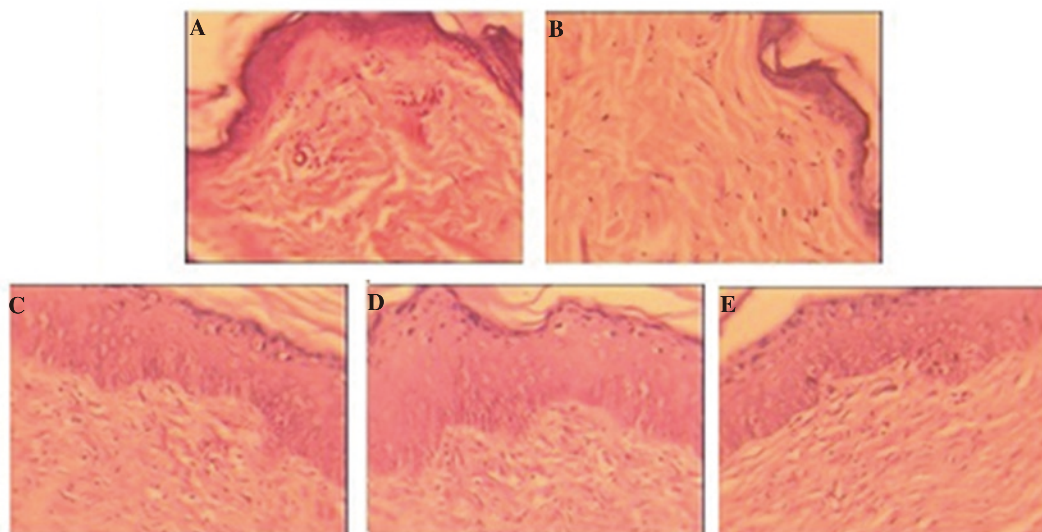

Figure 3. Histological evaluation of wound skin sections stained with hematoxylin and eosin (40×magnification). A and B: UT and PJ treatments, respectively, showing fewer collagen fibers and more inflammatory cells. C, D, and E: animals treated with OAEO 5%, OAEO 10%, and CIC drug reference, respectively, showing better healing and complete re-epithelialization.

the following main components: camphor>caryophyllene>1,8-cineole>germacrene-D>α-cadinol in the Brazilian sample, and chamazulene>camphor>bornyl acetate>chrysanthenyl acetate>γ-terpinene in the Tunisinian sample[11,32].

Oxygenated monoterpenes such as camphor and terpinen-4-ol, which are representative components in the investigated oil, were reported to exhibit many biological activities, comprising anti-leishmania, insecticidal and repellency activity, as well as antimicrobial, anti-infammatory and anti-respiratory tract infections[32–34]. Among the minor components, γ-terpinene, camphene, *p*-cymene, gernanyl *p*-cymene and α-pinene are of an amount over 2%.

On the basis of a literature survey, many other important compounds have also been identified in *A. absinthium* oil from different origins, including epoxyocimene, 1,8-cineole, myrcene, *trans*-sabinyl acetate, sabinene, viridiflorol, and thuja-2,4(10)-diene[2,30,32,35]. The predominance of one or two of the aforesaid components defines pure or mixed chemotypes[2,36].

The antioxidant/anti-radicals activity of *A. absinthium* essential oil was rather modest and probably ascribable to the presence of chamazulene.

Camphor is endowed with various pharmacological properties such as anti-bacterial, anti-fungal, and wound-healing activities[37]. A recent study has shown the effect of camphor on skin health by inducing fibroblast proliferation, maintaining or recovering collagen and elastin production in UV exposed skin, and preventing thickening of the epidermis and subcutaneous fat layer[38]. Camphor also showed a significant effect on epithelization and neovascularization on second-degree burn wounds in rats[39]. Therefore, the presence of camphor in *A. absinthium* essential oil may explain the wound healing activity of the OAEO 10% ointment group.

The wound healing property of *A. absinthium* essential oil was also remarkable in comparison with the standard drug Cicatryl. This suggests that *A. absinthium* essential oil could be developed as a potential effective wound healing ingredient for topical medicaments.

Conflict of interest statement

We declare that there is no conflict of interest.

Funding

This work was supported by Algerian Ministry of Higher Education and Scientific Research/ Algeria (CNEPRU: DO1N01UN280120150001) and Consiglio Nazionale delle Ricerche, Rome, Italy.

Acknowledgments

The authors are grateful to Mr. Antonio Greco (ICB-CNR, Catania) for his skilful technical support.

Authors' contributions

Amel B. and GR conceived and designed the experiments, supervising all steps of research; EN conducted the essential oil analyses, organized and wrote the relative experimental section; Amel B., AB and FB performed the essential oil extrcation, the antioxidant activity evaluation, the *in vivo* experiments and wrote the pertinent portion; GR and Amel B. wrote the article with the contribution from all co-authors. All authors approved the final version of the manuscript.

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