

CHEMICAL COMPOSITION AND ANTIBACTERIAL ACTIVITY OF ESSENTIAL OILS FROM *Mentha pulegium* L. AND *Mentha suaveolens* Ehrh. GROWING IN NORTH-EAST OF ALGERIA

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Abstract. *Mentha pulegium* L. and *M. suaveolens* Ehrh. are spontaneous plants growing in the wetlands of the Souarekh region (north-eastern Algeria). They are very well known and used by the natives of this region for different virtues. Moreover, these subspecies have been chosen for their great morphological variations. Hence, in this study, we aim at determining the chemical composition of the essential oils of both plants and evaluating their antibacterial activities.

The aerial parts of the plants were hydrodistilled using a Clevenger type apparatus and the essential oils were analyzed and identified using gas chromatography-mass spectrometry. Antibacterial screening of essential oils was carried out on the basis of the diameter of the inhibition zone using the disc diffusion method against two bacterial strains. The chemical analysis of the essential oils of both mints resulted in main compounds pulegone (61.24%), isomenthone (11.32%) and menthone (5.6%) for *M. pulegium*, and piperityone oxide (47.52%) for *M. suaveolens*. Accordingly, the study of the biological activity of essential oils manifested the antibacterial effect against the strains studied. The obtained results are therefore promising and thus pave the way for manufacturers to use the essential oils of the two plants in the pharmaceutical and food industries.

Keywords: Essential oils; *Mentha pulegium* L.; *Mentha suaveolens* Ehrh.; Chemical composition; Antibacterial activity; Algeria.

INTRODUCTION

In the recent years, the use of medicinal and aromatic plants in phytotherapy has been developed through exploiting several herbs such as the mint species, (family Lamiaceae) which includes nearly 20 species [52]. Several species are known as aromatic and medicinal plants in Asia Minor, the Middle East, Europe and North Africa (including Algeria) [7, 9, 22].

The study of the chemical composition of the essential oils showed variability of its constituents across the region [31, 48]. This variety is probably related to various vegetative phases of the plant, to the environmental conditions as well as to seasonal and geographical variations and to soil composition [35].

In Algeria, the use of spontaneous mints for food and phytotherapeutic is known in coastal regions such as the region of Souarekh (El Tarf, northeast - Algeria). This region is, also, famous for its richness in medicinal and aromatic plants, favored by its sub-humid climate and the important of the recovery of its meadows floodable with mints mainly pennyroyal (*M. pulegium*) and mint with round leaves (*M. suaveolens*).

In continuation of our research program on the valorisation of natural resources of Algeria, the objective of this work is to study the antibacterial activity of two medicinal plants: *M. pulegium* and *M. suaveolens* from the Souarekh region which is frequently used for the treatment of various infectious diseases [15]. In addition, the chemical composition of the essential oils was investigated, to establish a potential link between antibacterial activity and specific compounds.

MATERIAL AND METHODS

Plant material

M. pulegium and *M. suaveolens* that are used in the study were identified at the Laboratory of Agriculture and Ecosystem Functioning following the procedure described by Dobignard and Chatelin (2010-2013) [25]. Aerial parts of these plants were collected from Souarekh region - northeast Algeria (Figure 1) in May 2018. Afterwards, leaves were separated and dried in open air for two weeks in darkness.

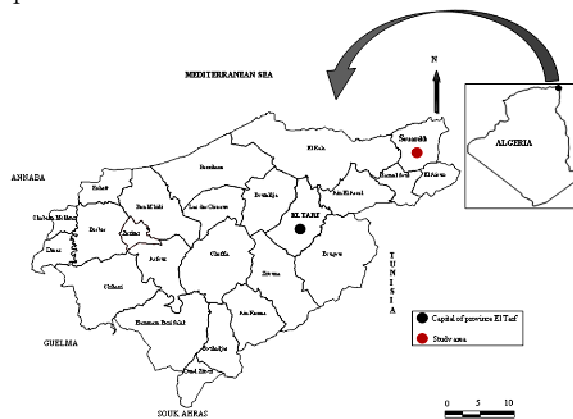


Figure 1. Geographic location of Study area (Souarekh)

Extraction of essential oils

After two weeks of drying, the essential oils were extracted from the dried plants (100 g) by hydrodistillation, at a temperature of 100 °C using a Clevenger-type apparatus and the recovery time was optimized to two hours. After extraction, the obtained essential oils were dried over anhydrous sodium

sulphate and, kept in an amber color polyethylene vials and stored at 4 °C until tested.

Analysis of essential oils

The essential oils were analyzed using a Perkin Elmer Clarus 600 GC System, fitted with a Rtx-5 MS capillary column (30 m x 0.25 mm i.d. x 0.25 µm film thickness; maximum temperature, 350 °C), coupled to a Perkin Elmer Clarus 600C MS. The carrier gas was helium at a flow rate of 1.5 mL/min. The injector, transfer line and ion source temperatures were 280, 270 and 260°C, respectively. The ionizing energy of MS was 70 eV. The injected sample volume was 0.3 mL with a split ratio of 200:1. The oven temperature program was 60 °C at a rate of 3 °C/mine 280 °C hold for 10 min. Components identification was achieved in comparing respective retention indices relative to C₈ C₂₈ (n-alkanes); and respective mass spectra to those reported in the literature [1] and in (NIST 2011 v.2.3 and Wiley, 9th edition) mass spectral libraries.

Method for evaluating antibacterial activity

Choice of strains

The choice of strains is tested according to the use of traditional medicine of pennyroyal and round leaf mint; 4 strains were chosen: 2 of gram negative (*Escherichia coli* and *Klebsiella pneumoniae*) and 2 of gram positive (*Staphylococcus aureus* and *Pseudomonas aeruginosa*).

Aromatogram method

The antibacterial activity is evaluated by the aromatogram method which makes it possible to determine the sensitivity of the various bacterial species with respect to the given essential oil. The aromatogram method consists of using Petri dishes containing a suitable agar medium, already solidified and inoculated with the microbial strain tested. Blotting paper discs 6 mm in diameter, previously impregnated with known quantities of essential oil (07µl), are then placed on the agar surface. Generally, microorganisms are classified as susceptible, intermediate or resistant, depending on the diameter of the inhibition zone [54].

Measurement of antimicrobial activity of essential oils

The aromatogram technique was applied to assess the antimicrobial activity of essential oils. This test is carried out by depositing a sterile disc 6 mm in diameter impregnated with an amount of essential oil on an agar medium previously seeded with a microbial culture. After incubation, the results are read by measuring the diameters of the zones of inhibition in millimeters [4, 20].

RESULTS

Yield of essential oils

The yields of essential oils of *M. pulegium* and *M. suaveolens* that are harvested from the Souarekh region are expressed in milliliters compared to 30 g of dry vegetable matter. These rates are 1.82% for *M. pulegium* and 1.03% for *M. suaveolens*.

Organoleptic characteristics

The organoleptic characteristics of the essential oils of *M. pulegium* and *M. suaveolens* obtained by hydrodistillation are presented in Table 1.

Organoleptic properties are a means of checking and controlling the quality of the essential oil. To this end, the results obtained are compatible those reported by AFNOR (1986) [2] having analyzed the essential oils of the two mints studied.

Chemical composition of essential oils from *M. pulegium* and *M. suaveolens* from the Souarekh region

The compositions of the extracted essential oils were identified on the basis of GC retention time (t_R) on fused silica capillary column and are shown in Table 2.

The GC/MS analyses showed the presence of twenty two chemical compounds for the *M. pulegium*, which represents about 97.9% of the total composition. Only Nineteen compounds were obtained for the *M. suaveolens*, representing over 75.2% of the total oil compositions.

The *M. pulegium* and *M. suaveolens* essential oils were composed of to 90.73% and 62.85% respectively of oxygenated monoterpenes. The high percentage component found in the *M. pulegium* essential oil was as pulegone (61.24%), isomenthone (11.32%), menthone (5.6%), neo-menthol (3.33%) and sabinene (2.09%). In the case of *M. suaveolens*, was as piperitenone oxide (47.52%), pulegone (8.44%) and limonene (2.81%). Other minor chemical components with different percentage obtained from the *M. pulegium* and *M. suaveolens* oils are also listed in Table 2.

Antibacterial activity of essential oils from *M. pulegium* and *M. suaveolens* from the Souarekh region

The aromatogram test of the essential oil of *M. pulegium* and *M. suaveolens* from the Souarekh region is shown in Table 3.

So, the results indicate that the essential oils of the mints studied have antimicrobial activity on all the bacteria tested. This sensitivity is different according to the strains and to the two species studied.

The *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* strains are very sensitive to the essential oils of both *M. pulegium* and *M. suaveolens*. While the *Escherichia coli* strain showed less sensitivity to essential oils of the same species.

The results obtained from Table 3, manifest that the bacteria examined are very sensitive to pure oil. On the other hand, these germs have a relative sensitivity towards ½ and / or ¼ dilutions of the previously stated mints essential oils of the two mints studied.

Table 1. Organoleptic characteristics of the essential oils from *M. pulegium* and *M. suaveolens*

Parametres	<i>M. pulegium</i>	<i>M. suaveolens</i>
Aspect	Clear, mobile liquid	Clear liquid
Odour	Very aromatic	Spicy, Penetrating
Color	Pale yellow	Yellow

Table 2. Chemical composition of the essential oils obtained from *M. pulegium* and *M. suaveolens* collected in the Souarekh region

N°	Compound name and class	t _R [min]	RI ^a	Content [%] ^b	
				<i>M. pulegium</i>	<i>M. suaveolens</i>
1	α-pinene	3.00	934	0.73	0.45
2	camphene	4.31	945	0.02	-
3	sabinene	4.59	973	0.57	0.52
4	β-pinene	5.65	985	2.09	-
5	myrcene	6.40	993	0.28	0.67
6	limonene	6.52	1023	1.94	2.81
7	1,8-cineole	7.23	1036	0.62	0.19
8	linalool	8.43	1105	0.21	0.83
9	borneol	9.76	1146	-	0.92
10	menthone	10.03	1151	5.6	-
11	isomenthone	10.52	1159	11.32	1.64
12	menthofuran	11.47	1164	0.91	0.86
13	menthol	12.33	1168	0.99	-
14	neo-menthol	13.01	1172	3.33	-
15	cis-isopulegone	13.47	1174	1.83	-
16	α-terpineol	14.88	1193	0.45	0.22
17	bornyl acetate	15.77	1283	-	0.75
18	pulegone	16.45	1249	61.24	8.44
19	piperitone	17.20	1254	1.42	-
20	piperitenone	18.63	1332	0.89	1.28
21	piperitenone oxide	19.12	1343	1.92	47.52
22	(E)-β-caryophyllene	20.18	1409	0.64	1.39
23	δ-cadinene	21.30	1429	-	1.11
24	α-humulene	21.69	1445	0.38	-
25	α-gurjunene	22.38	1459	-	3.25
26	β-bourbonene	23.77	1469	-	0.14
27	germacrene D	29.45	1481	0.52	2.01
Total identified				97.9	75.2
Monoterpene hydrocarbons				5.63	4.45
Oxygenated monoterpenes				90.73	62.85
Sesquiterpene hydrocarbons				1.54	7.9

^aRI : Retention index; ^bContent : expressed as percentage of the total oil composition in the *M. pulegium* and *M. suaveolens*; -: Not detected.

Table 3. Inhibition diameters (mm) of the different strains tested in the aromatogram in solid medium

Species	<i>M. pulegium</i>					<i>M. suaveolens</i>				
Dilution	Single disc	DMSO disk	Pure oil	Dilution 1/2	Dilution 1/4	Single disc	DMSO disk	Pure oil	Dilution 1/2	Dilution 1/4
Strains										
<i>Staphylococcus aureus</i> ATCC 25923	6	6	17	10	8	6	6	18	11	9
<i>Pseudomonas aeruginosa</i> ATCC 27853	6	6	14	9	8	6	6	15	8	7
<i>Escherichia coli</i> ATCC 25922	6	6	9	7	6	6	6	10	8	8
<i>Klebsiella pneumoniae</i> ATCC 70603	6	6	15	8	6	6	6	16	10	8

DISCUSSION

As a matter of a fact, the study carried out in the commune of Souarekh of the wilaya of El Tarf (extreme northeast of Algeria) on the chemical composition of the essential oils of two known mints of the region was very interesting.

The results obtained indicate that the yield is higher in the species *M. pulegium* with 1.82% than in the species *M. suaveolens* with 1.03%. The same observation was recorded in Algeria: by Benabdallah (2017) [10] in other regions from the wilaya of El Tarf, by Brahmi *et al.* (2016) [19] in the Smaoun region from the wilaya of Bejaia and by Benazzouz & Hamdane (2012) [13] in the Ouagnoun region from the wilaya of Tizi-Ouzou; Besides in Tunisia by Soilhi *et*

al. (2019) [48] in the Sedjnane region from the wilaya of Bizerte and Tabarka from the wilaya of Jandouba.

Additionally, for *M. pulegium*, the yield is lower than that of the species studied in Morocco by Cherrat *et al.* (2014) [21], Ait-Ouazzou *et al.* (2012) [3] and Hmiri *et al.* (2011) [33] with 1.9%, 2.7% and 3.30% respectively. However, it is higher than that obtained by: Mata *et al.* (2007) [43] in Portugal (0.7%); Sutour (2010) [49] in Corsica (0.62 to 0.84%); Kamkar *et al.* (2010) [36] in Iran (0.65%); Başer *et al.* (2012) [8] in Turkey (1.2%); Benabed *et al.* (2017) [11] at Djelfa in Algeria (1.47%) and Attou (2017) [5] at Ain Temouchent in Algeria (1.37%).

By the way, Brada *et al.* (2007) [18] having studied the phytochemistry of *M. suaveolens* in the regions of Chlef and Ain Defla (Algeria), indicate the recording

of a yield in essential oils of between 0.7% and 0.9% during the end of flowering period. This yield corresponds to that obtained in this study and this for the early flowering phase. Still in the Ain Defla region but this time in the pre-flowering phase, a yield of 0.73% was noted by Sahnoune & Zebboudj (2019) [46].

Other studies carried out on this species in the Maghreb indicate that the yield is higher than that obtained in this work. It is 1.26% in Tunisia [44], 1.17%, 2.33% and 4.33% in Morocco [12, 24, 37]. The opposite would be for the yield recorded in Corsica since it is between 0.08% and 0.10% [49]. Variations in essential oil yield can be attributed to genetic, environmental and ontogenic factors, as well as to analytical methods [32, 40].

In the second part of our study, we are interested in studying the chemical composition of the essential oils of *M. pulegium* and *M. suaveolens*. We have found that the chemical composition of the essential oils of *M. pulegium* is, therefore, characterized by pulegone; the main constituent, as in many oils described in the literature [5, 6, 10, 19] in Algeria, [29, 47, 48] in Tunisia, [3, 14, 17, 21, 23] in Morocco, [27] in Egypt, [28] in Italy, [38] in Greece and [41] and in Uruguay.

Furthermore, it is important to mention that the association of pulegone (61.24%) with both isomenthone (11.32%) and menthone (5.6%) are no longer original from the essential oils of *M. pulegium* from Corsica in France as mentioned by Sutour (2010) [49] in his thesis because the present study indicates the existence of the aforementioned association. The same observation was made in Tunisia by Hadjlaoui *et al.* (2010) [29] and by Soilhi *et al.* (2019) [48]. The geographical location of the Souarekh region, on the one hand on the Tunisian border and on the other hand on the extreme eastern coast of Algeria (approximation compared to the island of Corsica), suggests that the unique outcome probably due to an ecotype of *M. pulegium*. The variations in the chemical composition of essential oils from one species, from one region to another and from one country to another are attributed to edaphoclimatic factors that can influence the regulation of the biosynthesis of essential oils [28, 35, 55].

In addition, the antibacterial activity of the essential oil was tested by the disc diffusion assay. Gram positive bacteria are known to be more susceptible to essential oils than Gram negative bacteria [45]. Gram-negative organisms are less susceptible because they possess an outer membrane surrounding the cell wall which restricts diffusion of hydrophobic compounds through its lipopolysaccharide covering [53]. Gram positive bacteria with a simple membrane structure are less protected against the diffusion of fine essential oils particles [34]. However, the weak antibacterial activity of Gram negative bacteria observed in this investigation is in accord with other studies [5, 21, 50].

The essential oils of *M. pulegium* have shown a strong inhibitory effect against most of the bacteria

tested and the results obtained are in agreement with those of pennyroyal from Tunisia [30, 42] and that from Portugal [51]. However, in Algeria, weak antibacterial activities against the same strains tested in this study were found for *M. pulegium* from the Sétif region [16] and that from the Béjaia region [19].

Also, it should be noted that the best bacteriostatic and bactericidal effects are found among the Moroccan medicinal and aromatic plants tested [3, 21].

The bactericidal effect of the essential oil of *M. pulegium* could be attributed to the presence of the pulegone in high quantity (61.24%) especially for the strain *Pseudomonas aeruginosa* known for its resistance to essential oils of Lamiaceae. This result consolidates that obtained by Taalbi (2016) [50] and Benabed *et al.* (2017) [11].

The essential oil of *M. suaveolens* has been shown to be more active than that of *M. pulegium* (Table 3). It has shown strong antimicrobial activities against certain microorganisms tested, particularly Gram-positive bacteria: *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

The inhibition of growth was obtained by undiluted and diluted essential oils. The same result was obtained by Brahimi *et al.* (2016) [19]. In addition, a weak antibacterial activity against Gram negative bacteria has been noted mainly for *Escherichia coli*, this could be explained by the fact that it has an external lipopolysaccharide wall surrounding the cell wall of peptidoglycans, which limits the access of these compounds [44]. On the contrary, the essential oil of *M. suaveolens* collected in the south-east of Algeria, Tunisia and Morocco has shown an activity in particular against *Escherichia coli* [26, 39, 44]. The possible explanation for the differences in activity could be associated with the chemical compositions of the oil [19, 26]. Characterized by a high abundance of piperitenone oxide, the essential oil of *M. suaveolens* has good bactericidal activity for the strains tested. This result agrees with that of Ait-Ouazzou *et al.* (2012) [3] and Taalbi (2016) [50].

Due to their antimicrobial activity, the essential oils of *M. pulegium* and *M. suaveolens* can be used in the pharmaceutical industry for the production of new synthetic agents in the treatment of infectious diseases caused by the bacteria studied or can be suggested as natural agents food preservation as reported by some authors [3, 5, 50].

In conclusion we can say that both mint species studied are promising plants for further research in order to obtain a biopesticide allowing the fight against insect pests of stored products.

The essential oil of *M. pulegium* with a high abundance of isomenthone and menthone constitutes a good commercial alternative to that rich in pulegone. Like the essential oil of *M. suaveolens* rich in piperitenone oxide constitutes a strong economic potential because of the interest carried to this molecule by the pharmaceutical industry.

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REFERENCES

- [1] Adams, R.P., (2007): Identification of essential oil components by gas chromatography/mass spectrometry. 4th ed., Allured Publishing Corporation. Carol Stream; Illinois, USA, 804 p.
- [2] AFNOR, (1986): Recueil des Normes Françaises « huiles essentielles », AFNOR. Paris, 57 p.
- [3] Ait-Ouazzou, A., Lorán, S., Arakrak, A., Laglaoui, A., Rota, C., Herrera, A., Pagán, R., Conchello, P., (2012): Evaluation of the chemical composition and antimicrobial activity of *Mentha pulegium*, *Juniperus phoenicea* and *Cyperus longus* essential oils from Morocco. Food Research International, 45: 313-319.
- [4] Andrews, J.M., (2001): The development of the BSAC standardized method of disc diffusion testing. Journal of Antimicrobial Chemotherapy, 48(1): 29-42.
- [5] Attou, A., (2017): Détermination de la composition chimique des huiles essentielles de quatre plantes aromatiques de l'Ouest algérien (région d'Ain Témouchent): étude de leurs activités antioxydante et antimicrobienne. Thèse de doctorat, Université de Tlemcen, Algérie, 101 p.
- [6] Baali, F., Boumerfeg, S., Napoli, E., Boudjelal, A., Righi, N., Deghima, A., Baghiani, A., Ruberto, G., (2019): Chemical composition and biological activities of essential oils from two wild algerian medicinal plants: *Mentha pulegium* L. and *Lavandula stoechas* L. Journal of Essential Oil Bearing Plants, 22(3): 821-837.
- [7] Baba-Aissa, F., (1999): Encyclopédie des plantes utiles: Flore d'Algérie et du Maghreb, substances végétales d'Afrique d'Orient et d'Occident. Ed. EDAS, librairie moderne, Rouiba, 368 p.
- [8] Başer, K.H.C., Kürkçüoğlu, M., Demirci, B., Özek, T., Tarımcılar, G., (2012): Essential oils of *Mentha* species from Marmara region of Turkey. Journal of Essential Oil Research, 24(3): 265-272.
- [9] Bellakhdar, J., (2006): Plantes médicinales au Maghreb et soins de base – Précis de phytothérapie moderne. Ed. Le Fennec, Casablanca, 385 p.
- [10] Benabdallah, A., (2017): Etude écophysiologique, développement et importance des plantes médicinales du genre *Mentha* dans le Parc National d'El-Kala (Nord-Est Algérie). Thèse de doctorat, Université de Constantine, Algérie, 151 p.
- [11] Benabed, K.H., Gourine, N., Ouinten, M., Bombarda, I., Yousfi, M., (2017): Chemical composition, antioxidant and antimicrobial activities of the essential oils of Three algerian *Lamiaceae* species. Current Nutrition and Food Science, Bentham Science Publishers, 13(2): 97-109.
- [12] Benayad, N., Ebrahim, W., Hakiki, A., Mosaddak, M., (2012): Chemical characterization and insecticidal evaluation of the essential oil of *Mentha suaveolens* L. and *Mentha pulegium* L. growing in Morocco. Scientific Study and Research. Chemistry and Chemical Engineering, Biotechnology, Food Industry, 13(1): 27-32.
- [13] Benazzouz, A., Hamdane, A., (2012): Etude et analyse des plantes médicinales Algérienne: *Mentha pulegium*, *Mentha rotundifolia* et *Mentha spicata* L. Mémoire Master en Chimie pharmaceutique, Université de Tizi Ouzou, Algérie, 66 p.
- [14] Bouchra, C., Achouri, M., Idrissi Hassani, L.M., Hmamouchi, M., (2003): Chemical composition and antifungal activity of essential oils of seven Moroccan Labiatae against *Botrytis cinerea* Pers: Fr. Journal of Ethnopharmacology, 89(1): 165-169.
- [15] Boutabia, L., Telailia, S., Djouamaa, S., (2019): La flore médicinale de la région de Souarekh (wilaya d'El Tarf): inventaire et étude ethnobotanique. 1^{er} Séminaire National des Molécules Bioactives "Valorisation des Plantes Médicinales pour lutter contre les dommages cellulaires" (SNMB 2019). Université Oum El Bouaghi, Algérie: 18-19 nov. 2019, pp. 5.
- [16] Boukhebt, H., Chaker, A.N., Belhadj, H., Sahli, F., Ramdhani, M., Laouer, H., Harzallah, D., (2011): Chemical composition and antibacterial activity of *Mentha pulegium* L. and *Mentha spicata* L. essential oils. Der Pharmacia Lettre, 3(4): 267-275.
- [17] Bouyahya, A., Et-Touys, A., Bakri, Y., Talbaui, A., Fellah, H., Abrini, J., Dakka, N., (2017): Chemical composition of *Mentha pulegium* and *Rosmarinus officinalis* essential oils and their antileishmanial, antibacterial and antioxidant activities. Microbial Pathogenesis, 111: 41-49.
- [18] Brada, M., Bezzina, M., Marlier, M., Carlier, A., Lognay, G., (2007): Variabilité de la composition chimique des huiles essentielles de *Mentha rotundifolia* du Nord de l'Algérie. Biotechnologie, Agronomie, Société et Environnement, 11(1): 3-7.
- [19] Brahmi, F., Adjouad, A., Marongiu, B., Porcedda, S., Piras, A., Falconieri, D., Yalaoui-Guellal, D., Elsebai, M-F., Madani, K., Chibane, M., (2016): Chemical composition and in vitro antimicrobial, insecticidal and antioxidant activities of the essential oils of *Mentha pulegium* L. and *Mentha rotundifolia* (L.) Huds growing in Algeria. Industrial Crops and Products, 88: 96-105.
- [20] Chao, S.C., Young, D.G., Oberg, G.J., (2000): Screening for inhibitory activity of essential oils on selected bacteria, fungi and viruses. Journal of Essential Oil Research, 12(5): 639-649.
- [21] Cherrat, L., Espina, L., Bakkali, M., Pagán, R., Laglaoui, A., (2014): Chemical composition, antioxidant and antimicrobial properties of *Mentha pulegium*, *Lavandula stoechas* and *Satureja calamintha* Scheele essential oils and an evaluation of their bactericidal effect in combined processes. Innovative Food Science and Emerging Technologies, 22: 221-229.
- [22] Chevallier, A., (2001): Encyclopédie des plantes médicinales: identification, préparation, soin. Ed. Larousse, London, 335 p.
- [23] Chraïbi, M., Farah, A., Lebrazi, S., El Amine, O., Iraqui Houssaini, M., Fikri-Benbrahim K., (2016): Antimycobacterial natural products from Moroccan medicinal plants: Chemical composition, bacteriostatic and bactericidal profile of *Thymus satureioides* and *Mentha pulegium* essential oils. Asian Pacific Journal of Tropical Biomedicine, 6(10): 836-840.
- [24] Derwich, E., Benziane, Z., Taouil, R., Senhaji, O., Touzani, M., (2010): Comparative essential oil composition of leaves of *Mentha rotundifolia* and *Mentha pulegium* a traditional herbal medicine in Morocco. American-Eurasian Journal of Sustainable Agriculture, 4(1): 47-54.
- [25] Dobignard, A., Chatelain, C., (2010-2013): Index synonymique de la flore d'Afrique du Nord (4 vol.), Genève, C.J.B.G., pp. 283-286.
- [26] El Arch, M., Satrani, B., Farah, A., Bennani, L., Boriky, D., Fechtal, M., Blaghen, M., Talbi, M., (2003): Composition chimique et activités antimicrobienne et insecticide de l'huile essentielle de *Mentha rotundifolia* du Maroc. Acta Botanica Gallica, 150(3): 267-274.
- [27] El-Ghorab, A.H., (2006): The chemical composition of *Mentha pulegium* L. essential oil from Egypt and its antioxidant activity. Journal of Essential oil Bearing Plants, 9(2): 183-195.
- [28] Fancello, F., Zara, S., Petretto, G.L., Chessa, M., Addis, R., Rourke, J.P., Pintore, G., (2017): Essential oils from three species of *Mentha* harvested in Sardinia: chemical

- characterization and evaluation of their biological activity. International Journal of Food Properties, 20(S2): 1751-1761.
- [29] Hajlaoui, H., Snoussi, M., Noumi, E., Zanetti, S., Ksouri, R., Bakhrouf, A., (2010): Chemical composition, antioxidant and antibacterial activities of the essential oils of five Tunisian aromatic plants. Italian Journal of Food Science, 22(3): 323-332.
- [30] Hajlaoui, H., Trabelsi, N., Noumi, E., Snoussi, M., Fallah, H., Ksouri, R., Bakhrouf, A., (2009): Biological activities of the essential oils and methanol extract of two cultivated mint species (*Mentha longifolia* and *Mentha pulegium*) used in the Tunisian folkloric medicine. World Journal of Microbiology and Biotechnology, 25: 2227-2238.
- [31] Hamdani, I., Chikri, M., Fethi, F., Salhi, A., Bouyanzer, A., Zarrouk, A., Hammouti, B., Costa, J., Desjobert, J.M., (2017): Essential oil *Mentha suaveolens* L.: Chemical composition, anticorrosive properties on mild steel in 0.5 M H₂SO₄ and chemometric approach. Journal of Materials and Environmental Sciences, 8(2): 526-538.
- [32] Heywood, V.H., (2002): The conservation of genetic and chemical diversity in medicinal and aromatic plants. pp. 13-22. In Sener, B. (Ed.), Biodiversity: Biomolecular Aspects of Biodiversity and Innovative Utilization. Kluwer Academic/Plenum Publishers, New York.
- [33] Hmiri, S., Rahouti, M., Habibi, Z., Satrani, B., Ghanmi, M., El Ajjouri, M., (2011): Evaluation du potentiel antifongique des huiles essentielles de *Mentha pulegium* et d'*Eucalyptus camaldulensis* dans la lutte biologique contre les champignons responsables de la détérioration des pommes en conservation. Bulletin de la Société Royale des Sciences de Liège, 80: 824-836.
- [34] Hogan, D., Kolter, L., (2002): Why are bacteria refractory to antimicrobials? Current Opinion in Microbiology, 5(5): 472-477.
- [35] Hussain, A., Anwar, F., Nigam, P.S., Ashraf, M., Gilani, A.H., (2010): Seasonal variation in content, chemical composition and antimicrobial and cytotoxic activities of essential oils from four *Mentha* species. Journal of the Science of Food and Agriculture, 90(11): 1827-1836.
- [36] Kamkar, A., Javan, A.J., Asadi, F., Kamalinejad, M., (2010): The antioxidative effect of Iranian *Mentha pulegium* extracts and essential oil in sunflower oil. Food and Chemical Toxicology, 48(7): 1796-1800.
- [37] Kasrati, A., Alaoui Jamali, C., Bekkouche, K., Spooner-Hart, R., Leach, D., Abbad, A., (2015): Chemical characterization and insecticidal properties of essential oils from different wild populations of *Mentha suaveolens* subsp. *timija* (Briq.) Harley from Morocco. Chemistry and Biodiversity, 12: 823-831.
- [38] Kokkini, S., Handilou, E., Karouscou, R., (2004): Clinal variation of *Mentha pulegium* essential oils along the climatic gradient of Greece. Journal of Essential Oil Research, 16: 588-593.
- [39] Ladjel, S., Gherraf, N., Hamada, D., (2011): Antimicrobial effect of essential oils from the Algerian medicinal plant *Mentha rotundifolia* L. Journal of Applied Sciences Research, 7(11): 1665-1667.
- [40] Lawrence, M.B., (2007): Mint: The genus *Mentha*. Medicinal and aromatic plants-Industrial profiles. 1st Ed. New York, London, CRC Press Taylor and Francis group, 598 p.
- [41] Lorenzo, D., Paz, D., Dellacassa, E., Davies, P., Vila, R., Cañigueral, S., (2002): Essential Oils of *Mentha pulegium* and *Mentha rotundifolia* from Uruguay. Brazilian Archives of Biology and Technology, 45(2): 519-524.
- [42] Marzouk, B., Ben Hadj Fredj, M., Chraïef, I., Mastouri, M., Boukef, K., Marzouk, Z., (2008): Chemical composition and antimicrobial activity of essential oils from Tunisian *Mentha pulegium* L. Journal of Food, Agriculture and Environment, 6(1): 78-82.
- [43] Mata, A.T., Proenc, C., Ferreira, A.R., Serralheiro, M.L.M., Nogueira, J.M.F., Araújo, M.E.M., (2007): Antioxidant and antiacetylcholinesterase activities of five plants used as Portuguese food spices. Food Chemistry, 103: 778-786.
- [44] Riahi, L., Elferchichi, M., Ghazghazi, H., Jebali, J., Ziadi, S., Aouadhi, C., Chograni, H., Zaouali, Y., Zoghalmi, N., Mliki, A., (2013): Phytochemistry: antioxidant and antimicrobial activities of the essential oils of *Mentha rotundifolia* L. in Tunisia. Industrial Crops and Products, 49: 883-889.
- [45] Russell, A.D., (1991): Mechanisms of bacterial resistance to non-antibiotics: food additives and pharmaceutical preservatives. Journal of Applied Bacteriology, 71(3): 191-201.
- [46] Sahnoune, H., Zebboudj, S., (2019): Etude des extractions d'huile essentielle à partir d'une plante *Mentha rotundifolia* L. de la région de Ain Defla. Mémoire de Master, Université de Khemis Miliana, Algérie, 45 p.
- [47] Snoussi, M., Hajlaoui, H., Noumi, E., Usai, D., Sechi, L.A., Zanetti, S., Bakhrouf, A., (2008): *In vitro* anti-*Vibrio* spp. activity and chemical composition of some Tunisian aromatic plants. World Journal of Microbiology and Biotechnology, 24: 3071-3076.
- [48] Soihia, Z., Rhimib, A., Heuskinc, S., Fauconnier, M.L., Mekkia, M., (2019): Essential oil chemical diversity of Tunisian *Mentha* spp. collection. Industrial Crops and Products, 131: 330-340.
- [49] Sutour, S., (2010): Etude de la composition chimique d'huiles essentielles et d'extraits de Menthes de Corse et de Kumquats. Thèse de doctorat, Université de Corse, France, 213 p.
- [50] Taalbi, A., (2016): Variabilité chimique et intérêt économique des huiles essentielles de deux menthes sauvages: *Mentha pulegium* (Fliou) et *Mentha rotundifolia* (Domrane) de l'ouest algérien. Mémoire de Master, Université de Tlemcen, Algérie, 50 p.
- [51] Teixeira, B., Marques, A., Ramos, C., Batista, I., Serrano, C., Matos, O., Neng, N.R., Nogueira, J.M.F., Saraiva, J.A., Nunes, M.L., (2012): European pennyroyal (*Mentha pulegium*) from Portugal: chemical composition of essential oil and antioxidant and antimicrobial properties of extracts and essential oil. Industrial Crops and Products, 36: 81-87.
- [52] Tison, J-M., De Foucault, B., (2014): Flora Gallica, Flore de France. Biotope Éditions, Société Botanique de France, Metz, pp. 802-803.
- [53] Vaara, M., (1992): Agents that increase the permeability of the outer membrane. Microbiology Reviews, 56(3): 395-411.
- [54] Wilkinson, J.M., (2006): Methods for testing the antimicrobial activity of extracts. Chapitre VIII. pp.157-165. In Ahmad, I., Aqil, F., Owais, M. (eds.): Modern Phytomedicine: Turning Medicinal Plants into Drugs. Ed. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 405 p.
- [55] Zouari-Bouassida, K., Trigui, M., Makni, S., Jlaïel, L., Tounsi, S., (2018): Seasonal variation in essential oils composition and the biological and pharmaceutical protective effects of *Mentha longifolia* Leaves Grown in Tunisia. BioMed Research International, article ID 7856517, 12 p.

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