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Phytochemical study and fumigant toxicity of *Mentha suaveolens* Ehrh essential oil from Morocco against adults of *S. oryzae* (L.)

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ABSTRACT

Background: Morocco provides a great botanical treasure that can be the source of many interesting products for the pharmaceutical industry, food industry and especially for the development of new insecticides. **Objective**: the aim of this work was to validate the therapeutic properties of *Mentha suaveolens* Ehrh. used strongly in Moroccan traditional medicine, to determine the chemical composition of its essential oils (EO) and evaluate its insecticidal activity. **Results**: the *M. suaveolens* leaves were collected from two regions in Middle-Atlas. Phytochemical tests, carried out by colored reactions, showed that this plant contains flavonoids, gallic tannins, alkaloids, saponins and sterols and triterpenes. The essential oils were analyzed by gas chromatography coupled with mass spectrometry. The EO from Azrou is dominated by piperitenone oxide (74.69%) while that from M'rirt is rich both in piperitenone oxide (81.67%) and piperitenone (10.14%) respectively. Fumigant toxicity of M. suaveolens EO, assessed in vitro against *Sitophilus oryzae* (L.) adults, has lasted five days; the LC_{50} and LC_{99} values revealed that *M. suaveolens* EO exhibits a strong insecticidal activity which influenced by the tested doses and exposure periods. **Conclusion**: the *M. suaveolens* leaves exhibit healing properties; the yields and chemical composition of studied essential oils vary according to the plant region as well this oil in fumigation can be very efficient for protection of stored grain from infestations caused by insect pests.

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INTRODUCTION

Plants have been in nature for millions of years without any adversative effects on the ecosystem (Khater, 2012). They have been used as insecticides to fight pests for centuries (Isman, 2006). The repellency of plant material has been exploited by man by hanging bruised plants in houses. Moreover, plants have also been used in the form of crude fumigants where plants were burnt to drive away nuisance mosquitoes and later as oil formulations applied to the skin or clothes (Khater, 2012). However, the onset of synthetic molecules with a large spectrum ruled out any application of biological control (Guèye *et al*., 2011). The adverse effect of chemical insecticides was realized with the problems like environmental contamination, residues in food and feed and pest resistance (Guèye *et al*. 2011; Kumar *et al*., 2011). Due to these negative effects, the growing interest in the use of either plant extracts or essential oils was revived. More than 1500 species have been reported to have insecticidal value (Kumar *et al*., 2011).

The Lamiacea is one of the large plant families used as a framework to evaluate the occurrence of some typical secondary metabolites (Wink, 2003). Most Lamiaceae accumulates terpenes and a range of other compounds in the epidermal glands of leaves, stems and reproductive structures (Hajlaoui *et al*., 2009). The genus *Mentha* has about 25 species growing in temperate regions of Eurasia, Australia and South Africa (Dorman *et al*., 2003). It exhibits a great importance in the medicinal and commercial fields (El Fadl and Chtaina, 2010). In Morocco, the *Mentha* genus is represented by five main species: *Mentha pulegium* L, *Mentha aquatiqua* L., *Mentha longifolia* L., *Mentha arvensis* L. and *Mentha suaveolens* Ehrh. (El Fadl and Chtaina, 2010).

Mentha suaveolens Ehrh is known by Moroccan name «Merssita" or "Timijja" (El Fadl and Chtaina, 2010), is a perennial herb that grows wildly in Morocco in the wet areas. *M. suaveolens* Ehrh or *Mentha* rotundifolia L. (Hendriks and Van Os, 1976) is used as a condiment and in traditional medicine for its properties: tonic, stimulating, digestive, carminative, and analgesic, choleric, antispasmodic, anti-inflammatory, sedative,

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hypotensive and insecticide (Moreno *et al*., 2002; Tripathi *et al*., 2004). The leaves of *M. suaveolens* Ehrh, in the Gharb region (Morocco), are used as an infusion in combination with other plants against stomach pain, fever and cough and as a decoction for personal hygiene in case of urogenital infection (Salhi *et al*., 2010); they also used in cosmetics, culinary preparations and perfumery (Brada *et al*., 2007; Sutour *et al.*, 2007; El Fadl and Chtaina, 2010). The *M. suaveolens* EO shown to be endowed with potent anticandidal activity; Pietrella *et al*., 2011 have proved that this oil was not only to be as an inhibitor of Candida growth but able to kill the yeasts.

The chemical composition of the *M. suaveolens* Ehrh essential oils and the determination of its different chemotypes were investigated by many studies (Lorenzo *et al*., 2002; El Arch *et al*., 2003; Brada *et al*., 2007; Abbaszadeh *et al*., 2009; Derwish *et al*., 2010; Sutour *et al*., 2010). The main components are piperitenone oxide, pulegone, carvone, dihydrovarvone, 1.2-epoxyneomenthyl acetate or cis-piperitol (Lawrence, 2007). Piperitenone oxide is considered as the major common constituent of *M. suaveolens* Ehrh. This oxygenated monoterpene exhibits interesting activities: cardiovascular, antibacterial, antifungal and insecticide (Tripathi *et al*, 2004; Sutour *et al*, 2010; Boughdad *et al*., 2011).

Main objectives of this study were to identify different chemical groups occurring in *M. suaveolens* leaves that are used tremendously by Middle-Atlas people for therapeutic purposes and to evaluate the efficiency of its essential oils against *Sitophilus oryzae* (L.) as well as the analysis and the comparison of their chemical composition.

MATERIALS AND METHODS

Plant material and extraction of essential oils:

The leaves of *M. suaveolens* Ehrh were collected in August from two regions in the Middle Atlas: Azrou (Latitude: 33° 25′ 59″; Longitude: 5° 13′ 01″; Altitude: 1278m) and M'rirt (Latitude: 33°10 00″; Longitude: 5° 34′ 00″; Altitude: 1113m). The climate is semi-humid with strong continental influence with an annual average temperature of 20°C.

100g of leaves were air-dried at room temperature and hydro-distilled using a Clevenger-type apparatus for 3 hours. The essential oils were dried with anhydrous sodium sulphate and stored in a refrigerator at 4°C until use. For calculations of essential oil yields, three replicates were performed for each plant material.

Chromatographic analysis of essential oils:

The chromatographic analyses were performed using a gas chromatograph Hewlett Packard (HP 6890 series) type equipped with a HP-5 capillary column (30m x 0.25 mm x 0.25 microns film thickness) , a FID detector set at 250 ° C and fed with a gas mixture H2/air. The mode of injection is split; the carrier gas used is nitrogen with a flow rate of 1.7 ml / min. The column temperature is programmed at a rate of 4 mounted ° C / min from 50 to 200 °C for 5 min. The unit is controlled by a computer system type "HP ChemStation" managing the operation of the device and to monitor chromatographic analyzes. GC-MS was carried out on chromatograph Hewlett Packard (HP 6890) coupled to a mass spectrometer (HP 5973 series). Fragmentation is performed by electron impact at 70 eV. The used column was a capillary-type HP 5SM (30 mx 0.25 mm x 0.25 mm). The column temperature is programmed at a rate of 4 mounted °C/ min from 50 to 200 °C for 5 min. The carrier gas is helium with a flow rate set at 1.7 ml / min. The injection mode is split type.

The EO compounds were identified by comparison of their Kovàts Index (Kovàts, 1965), calculated in relation to the retention time of a series of linear alkanes (C7 - C40), with those of the chemical constituents gathered by Adams (2007). Their mass spectra were then matched with those stored in the NIST library / EPA / NIH MASS SPECTRAL LIBRARY; Version 2.0, 2002.

Phytochemical Tests:

To perform the phytochemical screening, the *M. suaveolens* leaves were air-dried in the open air, milled in an electric grinder and used to prepare extracts, infusions and decoctions.

Selective extractions of homogenates were made specifically on each family of studied compounds. The extracts have been obtained by extraction with solvents as petroleum ether, methanol, ethanol, chloroform and distilled water.

The phytochemical screening was also focused on several reagents. Characterization of alkaloids was performed by Dragendorff reagent. Research of catechin tannins was carried out by isoamyl alcohol and hydrochloric acid and gallic tannins by Stiasny reagent, sodium acetate and ferric chloride. We used acetic anhydride and concentrated sulphuric acid to detect sterols and triterpenes. To seek the flavonoids, were used diluted alcohol hydrochloric acid, magnesium chips and isoamyl alcohol. Chloroform, dilute ammonia and hydrochloric acid have to look for quinonic substances.

Characterization tests of different chemical groups were conducted as described by Harborne, 1998; Amadou, 2005; Judith, 2005; Bruneton, 2009 and N'Ghessan *et al.*, 2009.

Animal material:

Sitophilus oryzae (L.) is a rice weevil belonging to the *Curculionidea* family; this species is the most widespread and destructive stored product pests throughout the world. The adults were brought from the grain market. Then, they were raised thereafter at the expense of wheat grains in glass jars at a temperature of 24 ± 1°C and a relative humidity of 76 ± 5% in the dark in order to obtain a homogeneous population.

Biological Tests:

Fumigation tests were carried out in plastic boxes of 1 liter volume. Thus, in each box was placed a Petri dish by airy chiffon gauze containing 10 adults of *S. oryzae* and filter paper soaked with *M. suaveolens* Ehrh essential oil. The concentrations of essential oil in the air were: 0.75; 0.25; 0.5; 1 and 2 µl /l air. For each concentration, five replicates were conducted. Control of mortality was performed daily by counting died individuals until the death of all insects.

Data Analysis:

To detect the toxic fumigant effect of tested essential oil, an analysis of variance performed using the function Arsin (square root (percentage mortality)) in the software Microsoft Excel 2007. The calculation of the survival probabilities and comparison of the effect of each concentration tested were taken respectively by the test of Kaplan-Mayer (1958) and the log-rank test (Lee and Wang, 2003). The lethal concentrations 50% (LC_{50}) and 99% (LC_{99}) fumigated insects were determined by the Probits method according to Finey (1971).

RESULTS AND DISCUSSION

Yield and chemical composition of the essential oil:

The yields of essential oils have been calculated from dry plant material. The yield of *M. suaveolens* EO from Azrou is higher (1.8%) than that from M'rirt (1.55%). However, these rates seem to be higher than those obtained from Meknes and Boulmane samples: 0.73% (Boughdad *et al*., 2011) and 0.53% (Derwich *et al*., 2010) respectively; but the highest one, from Oulmès region, reached 4.33% (Benayad, 2008).

Chromatographic analysis of two essential oils allowed identifying forty seven compounds which made up 99.61% of the total chemical composition for *M. suaveolens* EO from Azrou while that from M’rirt contains thirty four components representing 99.52% (Table 1). Both oils are rich of oxygenated monoterpenes but the larger contents were observed in M’rirt (94.5%) against Azrou (82.83%). However, the sesquiterpenes in Azrou oil reached 13.23% while they were about 3.11% in that from M'rirt. The monoterpenes and sesquiterpenes exert wide biological actions that are important in food chemistry, chemical ecology and pharmaceutical industry (Abdelgaleil *et al*., 2009; Buchbauer and Ilic, 2013).

Piperitenone oxide is the major compound of essential oil from Azrou (74.67%) followed at small levels by muurolene (5.53%), pulegone (2.34%), limonene (1.85%), <4a,7-β-α,α-7a> nepetalactone (1.81%), β-caryophyllene (1.68%) and piperitenone (1.17%).

Two chemotypes dominate the essential oil from M'rirt with larger rates than Azrou, mainly piperitenone oxide (81.69%) and piperitenone (10.14%). Other components were also relatively identified at low percentages: β-Caryophyllene (0.91%), limonene (0.56%), terpinen-4-ol (0.52%) and pulegone (0.47%).

α-pinene (0.36%), β-pinene (0.65%) and borneol (0.29%) exist approximately at equal amounts in both oils. Differences between both oils were pointed out. There are some compounds that are specific to Azrou oil such as trans-calamenene (0.77%), khusimene (0.68%) and longifolene (0.27%). In the contrast, ledol (0.23%), geranial (0.2%) and isobornyl acetate (0.1%) are present only in the EO from M’rirt.

The yields and chemical composition of essential oils varied from sample to sample; this variation depends on many factors a such as the method used, the used plant parts, the products and reagents used in the extraction, the environment, the plant genotype, geographical origin, the harvest period of the plant, the degree of drying, the drying conditions, temperature and drying time and the presence of parasites, viruses and weeds (Karousou *et al*., 2005; Kelen *et al*., 2008).

The chemical composition of the studied oils agrees with that reported by some researches previously conducted. *M. suaveolens* essential oil from Meknès is characterized by the dominance of piperitenone oxide 34% (Boughdad *et al*., 2011). Similarly, the samples originated from Uruguay and Greece have shown a preponderance of piperitenone oxide that reached 80.8% (Lorenzo *et al*., 2002) and 62.4% (Koulipoulos *et al*., 2010) respectively. However, the same species in northern Algeria (Brada *et al*., 2007) contain three variable chemical compositions; the first chemotype is characterized by the dominance of piperitenone oxide (29.36%) and piperitone oxide (19.72%). Conversely, the second one is predominated by piperitone oxide (31.4%) followed by piperitenone oxide (27.79%). The third Algerian chemotype contains piperitenone as major constituent (54.91%). The same component reached (33.03%) thus pulegone (17.61%) in Oulmès region (Benayad, 2008). The study performed by Sutour *et al*., 2010 on two Corsican *M. suaveolens* oils revealed two different main constituents: piperitenone (73.5%) and piperitenone oxide (72%). However, the chemical composition of the essential oil from Béni-Mellal (El Arch *et al*., 2003) and Boulmane (Derwich *et al*., 2010) is totally different than our samples, which pulegone (85.5%) and menthol (40.50%) are the major compounds respectively. Moreover, Eman and Abbas, 2010 reported that the species from Beheira (Egypt) is dominated by linalool (35.32%) and p-Menth-1-en-8-ol (11.08%).

Table 1: Chemical composition of *M. suaveolens* Ehrh essential oils from Middle-Atlas.

N°	Identified compound	Kovàts Index KI	Area %	
			Azrou	M'rirt
1	α-pinene	939	0.36	0,36
2	Camphene	954	--	0,03
3	β-pinene	979	0.65	0,65
4	Meta-mentha-1(7) ,8-diène	1000	0.18	0,02
5	α-Terpinene	1017	0.07	--
6	p-cimene	1024	0.13	--
7	Limonene	1029	1.85	0,56
8	γ -terpinene	1059	0.13	--
9	Cis-sabinene hydrate	1070	0.53	0,06
10	Trans-sabinene hydrate	1098	0.06	--
11	1-octen-3-yl-acetate	1112	0.13	0,16
12	Dehydro-sabina ketone	1120	0.05	--
13	4-acetyl-1-methyl cyclohexene	1137	0.08	--
14	Nopinone	1140	0.05	0,05
15	Borneol	1169	0.27	0,29
16	Terpinen-4-ol	1177	0.71	0.52
17	p-cymen-8-ol	1182	0.12	--
18	α-Terpineol	1188	0.25	0,34
19	Coahuilensol, methyl ether	1221	0.14	--
20	Pulegone	1237	2.34	0,47
21	Cis-carvone oxide	1263	0.44	0,19
22	Geranial	1267	--	0,2
23	Perilla aldehyde	1271	0.17	0,04
24	Isobornylacetate	1285	--	0,1
25	Acetophenonone<3'methoxy-	1298	--	0,14
26	Peperitenone	1343	1.17	10,14
27	Peperitenone oxide	1368	74.69	81.67
28	Daucene	1381	0.11	--
29	β-Elemene	1390	0.16	--
30	<4a-α,7-β,7a-α> nepetalactone	1392	1.81	0,42
31	Longifolene	1407	0.27	--
32	β-Caryophyllene	1419	1.68	0,91
33	Cis-muurola-3,5-diene	1450	0.09	--
34	Spirolepechinene	1451	0.16	0.09
35	Khusimene	1455	0.68	--
36	cis-cadina-1(6),4-diene	1463	0.81	0,29
37	γ -Muurolene	1479	5.53	0,5
38	γ -Amorphene	1495	0.30	0,04
39	Aciphyllene	1501	0.10	--
40	γ -cadinene	1513	0.11	0,1
41	Trans-calamenene	1522	0.77	--
42	α-cadinene	1538	0.09	0,05
43	Spathulenol	1578	0.60	0,25
44	Caryophellene oxide	1582	0.26	0,21
45	Globulol	1590	0.23	0,06
46	Ledol	1602	--	0,23
47	1,10-di-epi-Cubenol	1619	0.43	0,25
48	10-epi-α-cadinol	1640	0.28	0,04
49	Torreyol	1646	0.05	--
50	α-cadinol	1654	0.35	0,09
51	Germacra-4 (15), 5,10(14) trien-1-α-ol	1686	0.07	--
52	Shyobunol	1689	0.10	--
Oxygenated monoterpenes			82.83	94.5
Hydrocarbon monoterpenes			3.37	1.62
Oxygenated sesquiterpenes			2.37	1.13
Hydrocarbon sesquiterpenes			10.86	1.98
Others			0.18	0.29
Total			99.61	99.52

Phytochemical screening:

The results of screening tests, carried out on *M. suaveolens* leaves from two regions of Middle Atlas, are summarized in Table 2. The characterization tests by colored reactions led to identify the main chemical groups containing in the *M. suaveolens* leaves as gallic tannins, saponins, flavonoids, sterols and triterpenes, alkaloids and mucilages. However, the other families such as free and combined anthraquinones, reducing compounds, oses and holosides, Cyanogenic heterosides and catechin tannins have not been detected.

Table 2: Results of phytochemical screening of *M. suaveolens* leaves by colored reactions.

Chemical family	**Observations**
Gallic tannins	+
Catechin tannins	-
Flavonoids	+
Alkaloids	+
Saponins	+ (Foam index = 105.5)
Free anthraquinones	-
Combined Anthraquinones	-
Oses and holosides	-
Sterols and triterpenes	+
Reducing Compounds	-
Mucilages	+
Cyanogenic heterosides	-

Tannins show the properties of vitamin D, they could be used to strengthen blood vessels and contribute to the accumulation of vitamin C in the body (Lazurevskii *et al*., 1966 in Kabran *et al*., 2011). Flavonoids are powerful antioxidants offering particularly interesting biochemical functions battery for our health. They play an important role in immune function, gene expression, blood flow in the capillaries and the brain, liver function, enzyme activity and collagen metabolism, phospholipids, cholesterol and histamine (Hertog at al., 1993; D'Abrosca *et al*., 2007); they also exhibit antiulcer, antispasmodic, anti-secretory, anti-diarrheal, antiallergic, anti-inflammatory properties and protect against cancer and cataract (Di Carlo *et al*., 1999; Bruneton, 2009). Alkaloids have different pharmacological activities such as strengthening the heart activity, excitation of the central nervous system and nerves symptomatic, stimulating blood circulation (Lazurevskii *et al*., 1966 in Kabran *et al*., 2011). The presence of alkaloids may also justify the use of the plant in the treatment of certain diseases (N'Ghessan *et al*., 2009). The saponins have a healing effect and sterols and triterpenes have bactericidal properties (N'Ghessan *et al*., 2009).

These results proved the therapeutic virtues of *M. suaveolens* leaves and then justified its wide use in traditional medicine by people in Middle Atlas. Further studies will be conducted in order to isolate, identify and characterize the bioactive components occurring in this plant.

Insecticidal activity of M. suaveolens essential oil against S. oryzae adults:

The *M. suaveolens* oil from Azrou was investigated for its insecticidal activity against adults of *S. oryzae*. Considerable differences in insects mortality due to essential oil fumigation were observed using different concentrations and exposure times. The results showed that the *M. suaveolens* EO is very toxic against *S. oryzae*. The degree of this toxicity was influenced by the applied concentration ($F_{concentrations} = 53.82 > F_{(0.05;\ 4\text{-}120)} = 2.45$) and the exposure time ($F_{time} = 68.82 > F_{(0.05;\ 5\text{-}120)} = 2.29$). The survival of treated weevils decreased with rising concentrations and exposure time (Figure 1).

The *M. suaveolens* oil affected significantly the survival of *S. oryzae* weevils. In treated groups, the treated weevils were totally destroyed at 2µl /l air dose after an exposure time of 72 hours. At the low doses, the mortality within weevils was recorded on the first day and then reached the entire population on the fifth day. In the control group, one dead insect was observed during fumigation experiment.

The toxicity parameters of the *M. suaveolens* oil are summarized in Table 3. The calculated lethal concentrations LC_{50} and LC_{99} revealed that adults of *S. oryzae* are so susceptible to this oil. The extreme values of LC_{50} and LC_{99} vary according to the exposure time; they ranged from 1.742 to 0.070µl/ l air and 106.33 to 0.654µl/ l air respectively at the beginning of fumigation until the last day.

Many studies were carried out on the toxicity of *M. suaveolens* EO against *S. oryzae* and other pests. Benayad, 2008 found that this oil (12µl/l air) has decimated all *S. oryzae* weevils on the first day of treatment. Similarly, Eman and Abbas, 2010 and Boughdad *et al*., 2011 noticed that *M. suaveolens* EO was very effective against insects of *C. maculatus.* Moreover, *M. microphylla* oil which piperitenone oxide (46.70%) was the major component, showed also the strongest toxicity among tested oils against *S. oryzae* (LC_{50} = 0.21µl/ l) (Magdy and Abdelgaleil, 2008).

The insecticidal effect of essential oil depends closely to its chemical composition. Monoterpenes have been well documented as active fumigants and insecticides (Abdelgaleil *et al*., 2009). The *M. suaveolens* oil contains 86.2% of monoterpenes such as piperitenone oxide, pulegone, limonene, piperitenone, β-pinene, α-pinene and p-cimene which their toxicity was proved toward stored product pests (Prates *et al*, 1994; Franzios *et al*., 1997; El Arch *et al*., 2003; Tripathi *et al*., 2004; Benayad, 2008; Abdelgaleil *et al*., 2009; Bouchikhi *et al*., 2010; Koliopoulos *et al*., 2010; Boughdad *et al*., 2011). The fumigant toxicity of tested oil can be justified also by high rate of piperitenone oxide (74.69%). This oxygenated monoterpene displayed to possess a high toxicity against pests (Tripathi *et al*., 2004; Magdy and Abdelgaleil, 2008; Koliopoulos *et al*., 2010). Further, other components are present at low levels but they can exert a synergistic effect (N'domo *et al*., 2009).

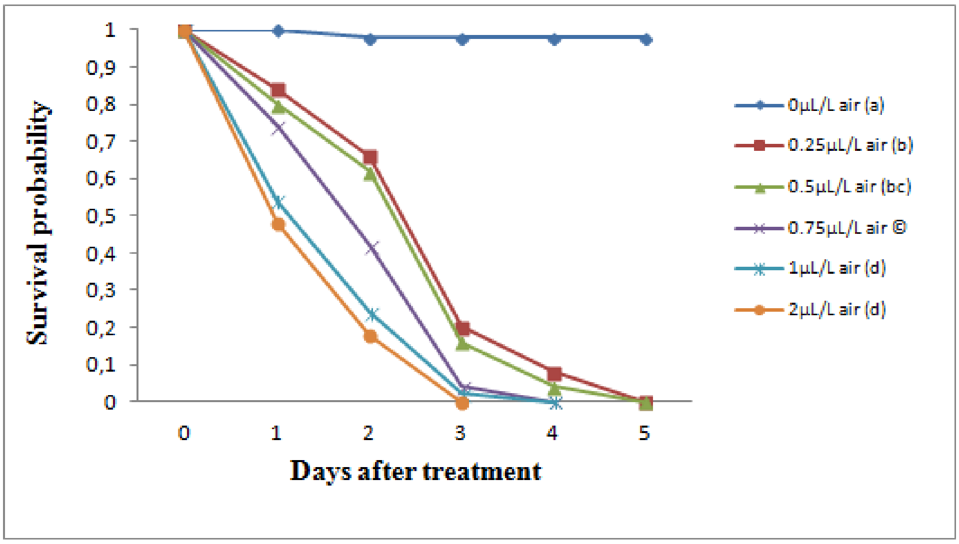

Fig. 1: Survival rate of *S. oryzae (*L.) adults fumigated by *M. suaveolens* oil (Concentrations affected with the same letter do not differ statistically between them (log-rank test)).

Table 3: Toxicity parameters of *M. suaveolens* EO against *S. oryzae* (L.) adults.

Days	Equation	$X^2_{observed} < X^2_{tabulated}$ = 7.815	LC_{50} (µl/ l air) [Confidence Interval]	LC_{99} (µl/ l air) [Confidence Interval]]
1	1.30x + 4.68	2.929	1.742 [1.224 ; 3.638]	106.336 [23.212 ; 5236.862]
2	1.66x + 5.46	4.357	0.531 [0.396 ; 0.665]	13.220 [6.054; 63.460]
3	2.22x+ 7.008	5.066	0.124 [0.039 ; 0.196]	1.391 [0.908 ; 3.977]
4	2.39x +7.76	1.582	0.070 [0.000 ; 0.150]	0.654 [0.438 ; 5.621]

The mode of action of essential oils and their constituents as insecticides has not been clearly known. Recent studies reported that essential oils affect insect physiology in diverse ways. Further, monoterpenes have been investigated for their neurotoxicity (Kumar *et al*., 2011); they are typically volatile and rather lipophilic compounds that can penetrate into insects rapidly and interfere with their physiologic functions (Lee *et al*., 2002) by inhibiting acetylcholinesterase activity (Abdelgaleil *et al*., 2009; López and Pascual-Villalobos, 2010) and acting on insects' octopaminergic sites (Price and Berry, 2006).

Conclusion:

The results of the present study indicate that the variation of yields and chemical composition of essential oils depend to the plant origin. In this respect, the both studied essential oils showed diverse chemical compositions. EO from Azrou is dominated mainly by piperitenone oxide (74.69%) while that from M'rirt is rich both of piperitenone oxide (81.67%) and piperitenone (10.14%).

M. suaveolens Ehrh leaves were found to contain flavonoids, gallic tannins, sterols and triterpenes, alkaloids and saponins which give them healing properties. Therefore, they can be seen as a potential source of useful drugs in food and pharmaceutical industries.

M. suaveolens Ehrh EO exhibits a strong fumigant effect toward *S. oryzae* weevils. This effect is mainly attributable to its constituents and to the synergistic role of minority compounds.

The use of essential oil of *M. suaveolens* in fumigation to control populations of *S. oryzae* can be very efficient since the fumigation can handle large masses of seeds without moving. In addition, the essential oils properties as high volatility and fast biodegradability cannot present any risk of residues on treated products or on the germination of processed grains. Consequently, the *M. suaveolens* oil has a huge potential as natural insecticide in stored cereals protection. Further studies should be carried out to increase the number of plants used for pest control in order to obtain cheaper pesticides and environmental pollution will gradually decrease.

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