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Biological activities and chemical characterization of *Lavandula angustifolia* essential oil from Seraïdi, Northeastern Algeria

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Abstract. *Hadj Moussa AH, Benaliouche F, Sbartai I, Sbartai H. 2023. Biological activities and chemical characterization of* Lavandula angustifolia *essential oil from Seraïdi, Northeastern Algeria. Biodiversitas 24: 4535-4542.* The objectives of this study are to examine the chemical composition of essential oil (EO) extracted by hydrodistillation from the flowering tops of dry lavender (*Lavandula angustifolia*) harvested in the town of Seraïdi in Northeastern Algeria and evaluate its antifungal, antibacterial, and antioxidant potential. The chemical analysis of this essential oil was carried out by gas chromatography coupled with mass spectrophotometry (GC-MS). The antimicrobial activity was evaluated by dilution method in solid and liquid medium, and the antioxidant activity was carried out using the DPPH° radical scavenging assay. It revealed the presence of 20 compounds representing the general component of this oil with a yield of 1.71%. This oil is composed mainly of Linalool (31.27%), followed by Camphor (16.21%), Linalool Oxide (11.98%), and Linalyl Acetate (11.93%). Other constituents were identified at relatively medium [2-Furarmethanol (7.49%), 1,8-Cineole/eucalyptol (6.76%), Borneol (5.34%)] and low contents [1-Hexyl butyrate (1.25%)]. The minimum inhibitory concentration (MIC) and the minimum fungicidal concentration (MFC) of lavender EO against *Fusarium roseum* were 3000 µg/mL and 4000 µg/mL, respectively. Lavender OE had moderate antibacterial activity against *Pseudomonas savastanoi*. The antioxidant activity of lavender EO was lower than that of vitamin C.

Keywords: Antibacterial activity, antifungal activity, antioxidant activity, chemical composition, essential oil

INTRODUCTION

Plants have been used as remedies for human diseases for centuries because they contain therapeutic components. These secondary metabolites, classified as phenols, alkaloids, terpenes, and polypeptides, play a role in the defense against pathogenic parasites. Essential oils (EOs) are natural substances with various biological effects on the cells, including infectious agents (Nazzaro et al. 2013) due to their diversity of compounds. The use of essential oils is increasing in various fields. EOs are "complex and variable mixtures of constituents that almost exclusively belong to two groups characterized by distinct biogenetic origins: the group of terpenoids on the one hand and, much less frequently, the group of aromatic compounds derived from phenylpropane on the other." Many studies have reported the benefits of essential oils, particularly lavender essential oil (Benny et al. 2019; De Oliveira et al. 2019). Terpenoids are the main constituents of lavender oil, which has long been known for its repairing, healing, antiseptic, and soothing properties. Lavender is widely used in anti-lice products, and its effectiveness has been well-established (Yang et al. 2010). It has also been used with other insecticides to control certain insect pests, such as *Myzus persicae*. In a previous study, Faraone et al. (2015) reported that *Lavandula angustifolia* EO could not be used alone as an insecticide. Its activity as an insecticide increases when it synergizes with industrial insecticides.

Most essential oils, including lavender essential oil, have antimicrobial properties. Several bacteria (*Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus cereus)* (Garzoli et al. 2021), and fungi (*Candida albicans* and *Aspergillus niger)* are inhibited by lavender essential oil (Blažekovića et al. 2018). It is synergistically effective with an antibiotic against the multi-resistant strain *Escherichia coli* (Yap et al. 2014) and replacement for the aqueous phase of body moisturizing gels to maintain microbiological stability in the cosmetic formulation (Kunicka-Styczyńska et al. 2015). According to Giovannini (2016), lavender EO exerts antibacterial and anti-inflammatory effects in macrophage-mediated immune Response against *Staphylococcus aureus*. Previous studies have discovered that lavender essential oil has cardioprotective properties on isoproterenol-induced myocardial infarction (Ziaee et al. 2015) by protecting myocardial, normalizing the ECG, decreasing lipid peroxidation, suppressing pro-inflammatory responses, and an improving antioxidant system. Blažekovića et al. (2018) study reported the antioxidant effects of lavender by inhibiting lipid peroxidation. The lavender EO showed anti-inflammatory activity by inhibiting the release of important inflammatory mediators and myeloperoxidase activity (Cardia et al. 2018).

Algeria's geographical situation and climatic diversity have allowed the development of a rich and diversified flora estimated at more than 3,000 species of plants belonging to several botanical families. However, the

Algerian medicinal flora remains unknown, and its use is limited to phytotherapy, which is integral to the local culture.

Moreover, essential oils from plants as antimicrobial agents and antioxidants have primarily proven their broad spectrum of action. Essential oils seem to be an excellent alternative to reduce the excessive use of pesticides, antibiotics, and chemical antioxidants to ensure food safety and reduce environmental damage. On the other hand, the variation in the components of intra-species and inter-species essential oils gives them a broad spectrum of action. It multiplies the possibilities of use from one region to another. The variability depends on pedoclimatic factors, but harvest periods, duration of sunshine, rainfall, altitude, and the nature of the soil influence the chromatographic profile of EOs (Boukhatem et al. 2017). In this context, this study aims to characterize the EO of *Lavandula officinale* (*Lavandula angustifolia*) harvested in the Seraïdi region (Northeastern Algeria) and to evaluate its antifungal, antibacterial and antioxidant activities to confirm its applications as a fungicide and bactericide, to reduce the harmful effects the traditional pesticide but also its use as an antioxidant agent to replace the chemical antioxidants used in the food industry.

MATERIALS AND METHODS

Plant material

The aerial parts of *L. angustifolia* plants were collected in June-July 2019 from various stations in the Seraïdi (Annaba), Northeastern Algeria. They were freshly collected and dried in the shade in a dry, ventilated place away from moisture in paper bags for a week before essential oil extraction.

Extraction of the essential oil of lavender

The essential oil was extracted using a Clevenger-type apparatus. 100 g of dried flowering tops were immersed in one liter of distilled water, followed by a two-hour extraction. The essential oil was decanted from the aqueous layer; the remaining water was disposed of with anhydrous sodium sulfate (Na_2SO_4) and stored in hermetically sealed bottles at 4°C following ISO 9235 standards. The yield was achieved in the dry state by recovering this oil over a 10-minute interval ranging from 0 to 90 minutes. The yield is expressed as a percentage and is calculated using the following formula:

$$HRE\ (\%) = M'/M \times 100$$

Where: HRE is the essential oil yield, M' is the mass of essential oil (g), and *M* is the dry plant mass (100 g).

Chemical characterization of *Lavandula angustifolia* EO by GC-MS

The chemical analysis of lavender EO was performed by a gas chromatograph coupled to mass spectrometry (GC/MS) equipped with an HP-5MS capillary column (30 m x 0.25 mm) with a film thickness of 0.25 µm, a detector set at 200°C and fed with an H2/Air-gas mixture and an injector set at 275°C. The injection mode is split (leakage ratio: 1/50). Pure helium is used as a carrier with a 0.5 mL/min flow rate. The column temperature is programmed from 50 to 250°C at 4°C/min. The injection volume was 2 mL, and MS was performed at 1 scan s^{-1} with an ionizing voltage of 70 eV and an ion source temp of 2508. The components were identified by comparing their retention indices with a homologous series of C9-C24 n-alkanes and those of authentic standards (Messaoud and Boussaid 2011).

Evaluation of the antifungal activity of the essential oil of *Lavandula angustifolia*

Fusarium roseum used in this study was a collection of the National Institute of Plant Protection of El-Tarf, Algeria. *F. roseum* is the pathogen responsible for the Fusarium head blight of wheat. It was isolated from lesions on wheat ears taken from a cereal field. The antifungal activity was assessed using the dilution method in a solid medium to determine inhibition rates.

Agar well diffusion method

Different concentrations of lavender EO (250, 500, 1000, 1500, 2000, 2500, 3000, 3500, and 4000 µg/mL) were added with 1 mL of 50% methanol. 0.5 mL of different methanolic solutions are mixed with 20 mL lukewarm PDA medium and poured into Petri dishes. The inoculation of the fungus is done using a Pasteur pipette or central puncture. Petri dishes are incubated for 7 days at 27°C. Mycelial growth is monitored daily. Finally, the diameters of various colonies are measured to calculate the inhibition rate (*I'%*) (Kordali et al. 2003).

$$I'(\%) = 100 \times (dC-dE) / dC$$

Where: I' (%) is the inhibition rate (%), dC is the diameter of colonies in the "positive control" plates, and dE is the diameter of colonies in the Petri dish containing the essential oil.

Dilution technique in liquid medium

The extract concentrations in solid medium tests with more than 50% inhibition percentages are further analyzed to determine their MIC values. 100 µL of these extract solutions is added to 900 µL of liquid Sabouraud medium containing the tested fungal strain and incubated at 27°C for 7 days. Following incubation, the tubes with no mold growth at the lowest concentrations are determined as the MIC value.

The minimum fungicidal concentration (MFC) was determined by adding 50 µL aliquots from the well with no growth into 950 µL of sterile liquid Sabouraud medium. After 7 days of incubation, the subcultures with no apparent growth are determined as the MFC value.

Evaluation of the antibacterial activity of *Lavandula angustifolia* EO

The agar diffusion method was used to test the antibacterial activity of lavender essential oil (Burt 2004)

against *Pseudomonas savastanoi*, a well-known contaminant bacteria in olive trees, particularly in Algeria. A pure culture of *P. savastanoi* was added to 10 mL of sterile physiological water. The bacterial population density was equal to 0.5 Mc Farland, corresponding to 10^8 CFU/mL, then diluted to obtain 10^6 CFU/mL and inoculated to agar media in a Petri dish. Sterile 0.6 mm diameter Whatman paper discs are soaked for a few seconds in various concentrations of lavender essential oil (2500, 3000, 3500, and 4000 g/mL) and put on the inoculated agar media. The plates are kept at 25-30°C for 30 minutes, then incubated at 37°C for 24 hours.

Evaluation of the antioxidant activity of the essential oil of *Lavandula angustifolia*

The antioxidant activity of lavender EO was assessed in vitro using the DPPH° radical scavenging assay described by Noumi et al. (2011). One mL of ethanol extract of the different sample concentrations was added with 250 µL of DPPH (0.2 mM) in ethanol and incubated for 30 minutes in the dark at room temperature. The absorbance of the mixture was measured at 517 nm. The antioxidant activity of this EO against the DPPH radical was assessed based on the reduction of the DPPH radical, as indicated by its change from purple to yellow.

$$\textit{Anti-free radical activity (\%)} = (A0 - A / A0) \times 100$$

where A0 is the absorbance of the DPPH solution without the sample (negative control), and A is the absorbance of the DPPH solution in the presence of the sample.

RESULTS AND DISCUSSION

Extraction kinetics and yield of essential oil of *Lavandula angustifolia*

Figure 1 shows the results obtained using the HRE (%) formula. The extraction kinetics of *Lavandula angustifolia* EO show that the yield increases with time and reaches a maximum of 1.71% after 80 minutes. In general, the amounts of EO produced by the plants are generally below 2% (Boukhatem et al. 2019), which is similar to the results in this study. Previous studies (Carrasco et al. 2015; Tardugno et al. 2018; and Adaszyńska-Skwirzyńska et al. 2023) reported that the yields of lavender EO were 1.5%, 1.67%, and 1.92%, respectively. Similarly, Elharas et al. (2013) reported that Moroccan lavender yields 1.5% lavender EO. However, Benyagoub et al. (2014) reported an extraction yield of *Lavandula angustifolia* EO of about 4.12% from plants harvested in the region of Tlemcen (Western Algeria) and 4.6% essential oil from plants in the region of Victoria (Australia) (Danh et al. 2013) which is significantly higher than the EO yield in this study. Several studies revealed varying extraction yields of *Lavandula angustifolia* EO from one region to another. A previous study by Boughendjioua (2017) showed that the yield of lavender EO from Skikda (East Algeria) was 1.5%, while the yield of lavender essential oil from Zagreb in central Croatia was 0.9% (Blažeković et al. (2018). Variation in EO yields could be attributed to various factors, including environment, agronomy, age, genotype, and climate (Bey-Ould Si Said et al. 2016; Boukhatem et al. 2017), as well as harvest period, extraction method and conditions, and recovery percentages (Bagheri et al. 2014), lavender flower maturity and interaction with the environment.

Identified compounds of *Lavandula angustifolia* EO by GC-MS

GC-MS analysis of *Lavandula angustifolia* EO revealed the presence of 20 compounds (Table 1, Figure 2). Linalool (31.27%), Camphor (16.21%), and Linalyl Acetate (11.93%) were the major compounds. The total content of these three compounds accounts for more than half of the total percentage, correlating with the findings of Lari et al. (2020) and Garzoli et al. (2021). Other significant secondary components include 2-Furanmethanol (7.49%), Eucalyptol =1,8-Cineole (6.76%), Borneol (5.34%), Linalool Oxide (5.93%), and Lavandulyl Acetate (4.63%). The second principal component differs significantly from other studies. Many factors influence the chemical composition of EO, including extraction and detection methods, geographical origin, cultivar type, adaptive metabolism of the plant, and harvesting period.

The chemical identification revealed that other constituents have low concentrations that do not exceed 2% of the total. Lavender varieties may have different components, but several compounds are the same, and these are frequently responsible for the therapeutic benefits of lavender. Linalool and Linalyl acetate are the main components in lavender EO. Linalool is a monoterpene alcohol abundant in plant essential oils, particularly lavender and coriander. It is a non-toxic compound with a wide range of bioactive properties in pharmaceutical and cosmetic applications (Pereira et al. 2018). Demasi et al. (2018) showed that plants growing at high altitudes and the distance from the sea affect their biochemical profile, i.e., lavender grown at high altitudes produced up to 10% more esters (linalyl acetate) than plants grown at medium altitudes.

Determination of the antifungal activity of *Lavandula angustifolia* EO

Figure 3 shows that the complete inhibition was obtained at 4000 µg/mL after seven days of incubation. The growth inhibition percentage was less than 50% up to 1500 µg/mL, confirmed by the mycelium density of Fusarium was half that of the control (Figure 4). The extract concentrations of 2000, 2500, and 3000 µg/mL have an average inhibition percentage of 70%, with a visible reduction in mycelium compared to the control. Lavender EO seems to effectively inhibit the growth of Fusarium starting from the concentration of 2000 µg/mL, where mycelium growth was inhibited up to 70%. The concentration is less than 2000 µg/mL, which inhibits less than 50% growth.

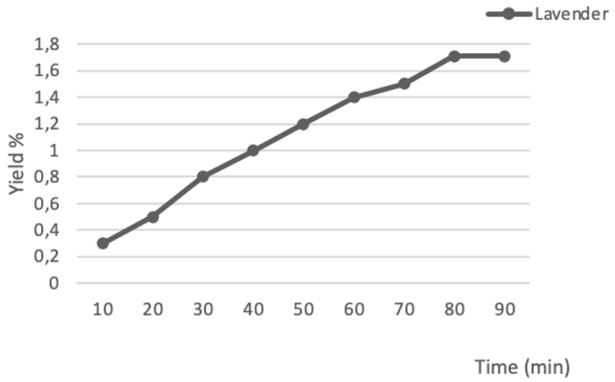

Figure 1. Extraction kinetics of *Lavandula angustifolia* EO

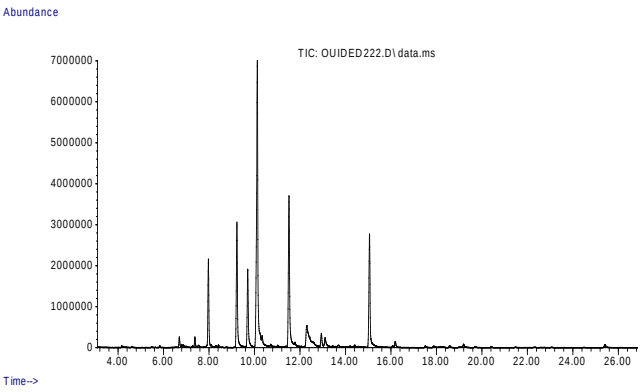

Figure 2. Chromatograms of *Lavandula angustifolia* EO by GC-MS

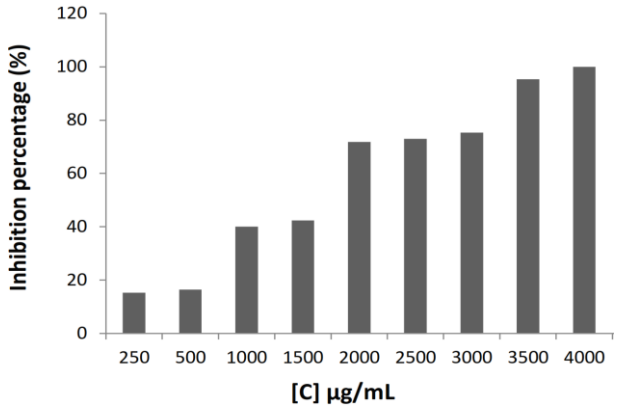

Figure 3. The effect of *Lavandula angustifolia* EO on the inhibition of mycelial growth of *Fusarium roseum*

The MIC and MFC were evaluated in liquid media using doses ranging from 2000 µg/mL to 4000 µg/mL (Table 2). The results showed that the MIC and MFC values against *F. roseum* were 3000 g/mL and 4000 g/mL, respectively. These findings are consistent with those obtained from the inoculated media, where doses of 3000 and 3500 g/mL were the most toxic to the plant pathogenic fungi.

Table 1. Identified chemical compounds of essential oil of *Lavandula angustifolia* by GC-MS

Retention time	Content (%)	Compound
6.697	0.79	3-Octanone
6.806	0.18	β-Myrcene
6.880	0.20	Tetrahydrofuran
7.384	0.73	Hexyl acetate
7.973	6.76	Eucalyptol; 1,8-cineole
8.420	0.21	β-Ocimene
9.227	11.98	Linalool oxide
9.707	7.49	2-Furanmethanol
10.125	31.27	Linalool
10.337	1.56	1-octen-3-yl acetate
11.521	16.21	Camphor
11.784	0.66	Cyclohexane
12.299	5.34	Borneol
12.562	0.85	Trimethylbicyclo[2.2.1]heptan-2-ol
12.940	1.25	1-Hexyl butyrate
13.106	1.21	1-Cyclohexene-1-methanol
15.063	11.93	Linalyl acetate
16.190	0.63	lavandulyl acetate
19.200	0.38	Lavandulol
25.414	0.39	Caryophyllene epoxide

Table 2. MIC and MFC of *Lavandula angustifolia* EO against *Fusarium roseum*

EO doses (µg/mL)	2000	2500	3000	3500	4000
MIC	+	+	-	-	-
MFC	NT	NT	+	+	-

Note: (+): the present of fungal growth, (-): no-fungal growth, NT: not tested

The antifungal activity of the essential oil of the Labiatae family, including lavender, has been the most widely studied. Previous research has shown that *Lavandula angustifolia* EO and its main components (linalool and linalyl acetate) effectively inhibit fungal growth (Danh et al. 2013; Elshafie et al. 2017; Puškárová et al. 2017). Zore et al. (2011) demonstrated that linalool has antifungal activity against clinical strains of *Candida albicans*. Lahkimi et al. (2020) showed that lavender essential oils have antifungal properties against *A. alternata*, *B. cinerea*, and *F. oxysporum*. The antifungal activity decreases with a group of chemical compounds in the following order: phenols, alcohols, aldehydes, ketones, ethers, and hydrocarbons (Urbanek et al. 2012).

Although the EO used in our study has a high content of monoterpene alcohols, ketones, and esters (linalool, camphor, linalyl acetate), it still demonstrated significant antifungal activity against the strain *Fusarium roseum*. Indeed, the antifungal activity of lavender EO relates to its chemical composition and the potential synergistic effects of its constituents. Likely, the minor compounds act synergistically to increase the activity of EO rather than solely their major compounds (Yap et al. 2014).

Figure 4. Effect of *Lavandula angustifolia* EO on the radial growth of *Fusarium roseum*

The MIC and MFC values (3000 g/mL; 4000 g/mL) of the EO in this study are very high compared to other studies, possibly due to the fungal strain's resistance to the oil. Pepeljnjak et al. (1999) identified differences in lavender EO sensitivity among several genera as follows: *Penicillium cyclopium*> *Penicillium puberurum*> *Penicillium urticae*> *Penicillium viridicatum*>*Aspergillus flavus*>*Penicillium camenberti*> *Aspergillus clavatus*> *Penicillium roqueforti*>*Rhisopus nigricans*> *Aspergillus niger*>*Aspergillus nidulans*> *Aspergillus versicolor*> *Fusarium exosporium* with MFCs ranging from 250 to 1000 g/mL, which was significantly lower than the values obtained in our study. Similarly, Blažeković et al. (2018) reported that the MICs of *Lavandula angustifolia* EO against 30 pathogens and microbial contaminants (bacteria and fungi) ranged from 0.25 to 3 mg/mL.

Determination of the antibacterial activity of *Lavandula angustifolia* EO

The antibacterial assay of lavender EO against *P. savastanoi* showed that inhibition diameter increases with increasing concentrations of lavender EO, as shown in Table 3. It has a diameter of 6 mm at the lowest concentration (2500 µg/mL) and a diameter of 14 mm at the highest concentration (4000 µg/mL).

De Billerbeck (2007) classified antibiotics based on the inhibition diameter as follows: resistant: D6 mm; intermediate: 13 mm>D >6 mm; sensitive: D >13 mm. It is used to determine the antibacterial activity of EOs. Based on this classification, the lavender EO at 3000 and 3500 µg/mL has an intermediate antibacterial activity and is effective at 4000 µg/mL. The results also showed that *Lavandula angustifolia* EO was ineffective against the Gram-negative bacterium *Pseudomonas savastanoi* at concentrations up to 2500 µg/mL). This resistance is most likely due to the loss of volatile compounds in the oil during storage and extraction and their evaporation during the incubation period, which reduces its concentration and, as a result, reduces its antibacterial activity.

Table 3. Diameter of growth inhibition of *Lavandula angustifolia* EO against *P. savastanoi*

Concentrations	2500 µg/mL	3000 µg/mL	3500 µg/mL	4000 µg/mL
Diameter	6 mm	10 mm	12 mm	14 mm

Linalool is known for its broad antimicrobial spectrum and has relatively strong activity against important pathogens, including *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* (Dias et al. 2017; Silva et al. 2017). It must be considered the possible synergistic effect of the various compounds of this oil because it could be at the origin of this antibacterial activity and not the major compounds like linalool or acetate linalyl. On the other hand, the presence of camphor (16.21%) could be the origin of antibacterial activity (Tardugno et al. 2018).

A previous study by Chebaibi et al. (2016) revealed inhibition diameters of lavender EO against several bacteria were less than 15 mm. Benyagoub et al. (2014) showed that the inhibition of 18% lavender EO from the region of Tlemcen (Western Algeria) against *S. aureus* was also less than 15 mm and the antibacterial activity was stronger against Gram-positive bacteria than Gram-negative bacteria. It might be because linalool and α-terpineol are active against Gram-positive and antibiotic-resistant bacteria (Smigielski et al. 2018). The differences in antibacterial activity between Gram-negative and Gram-positive bacteria could also be attributed to structural differences in their outer layers. The chemical components of EO exert antimicrobial activities on microorganisms by disrupting membrane integrity (Swamy et al. 2016), which disrupts ergosterol biosynthesis as they may also block the target strain's cell cycle (Zore et al. 2011). The outer membrane of Gram-negative bacteria serves as an effective permeability barrier because it is rich in lipopolysaccharide, whose negative surface charges prevent the diffusion of hydrophobic molecules. However, some low

molecular weight phenolic compounds can adhere to these bacteria by binding to proteins and membrane lipopolysaccharides with their functional groups. Therefore, this study showed that lavender EO had moderate antibacterial activity against the Gram-negative bacteria *Pseudomonas savastanoi*. The biological activity of EO was affected by its chemical compounds, in which many factors, such as temperature, relative humidity, insolation, and soil type, influenced the chemical compounds of EO.

Determination of the antioxidant activity of *Lavandula angustifolia* EO

Figure 5 shows the increasing inhibition percentages with increasing EO concentrations, reaching a maximum of 67.06% at 100 mg/mL. The IC_{50} value of lavender EO was 48.4 mg/mL. Ascorbic acid, as an antioxidant standard, had an IC_{50} of 8.33 mg/mL with a maximum inhibition of 78%. Lavender EO at 10-50 mg/mL concentrations exhibits low inhibition. However, at 60, 80, and 100 mg/mL, lavender EO inhibits at least 50% of DPPH free radicals. The inhibition percentages of lavender EO were lower than those of vitamin C at all concentrations.

The ability of the EO to scavenge DPPH was evaluated by the IC_{50} values, which express the number of antioxidants required to decrease the concentration of radicals by 50%. It indicated that *Lavandula angustifolia* EO from Seraïdi has lower anti-radical activity than lavender EO from different origins like EO from Croatia with an IC_{50} of 27.67 mg/mL (Blažeković et al. 2018) or of Italian origin (28.57 mg/mL) (Pistelli et al. 2017), which suggests that this oil has a moderate antioxidant power. Carrasco et al. (2015) obtained that the IC_{50} of lavender EO was 1.4 µg/mL and demonstrated better activity when the oils were extracted by distillation than hydrodistillation (27.5 mg/mL). Blažeković et al. (2018) stated that hydrodistillation promotes molecular rearrangements, differentiation in composition, and reduced antioxidant power. There is a close relationship between total phenolic content and antioxidant activity, in addition to the effect of the extraction method. Linalool/Linalyl acetate is synergistically required for the anxiolytic effect of inhaled lavender EOs (Buchbauer and Ilic 2013).

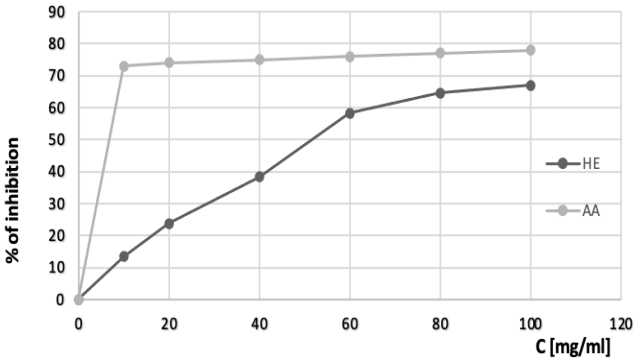

Figure. 5. DPPH free radical inhibition of *Lavandula angustifolia* EO and ascorbic acid (AA)

Our findings show a small amount of linalyl acetate, which may reduce the antioxidant activity in this study. On the other hand, Blažeković et al. (2018) showed that the antioxidant activity of Lavender EO is not entirely dependent on the presence of major compounds, i.e., linalool (IC50 218.6 mg/mL) and linalyl acetate (IC50 157.1 mg/mL), but is most likely the result of synergistic interactions between the EO's constituents (Ciesla et al. 2016).

The moderate anti-radical activity of Lavender EO in this study might be due to the low content of 1,8-Cineole (6.76%), which has been known to have good antioxidant activity, and the ratios of Camphor (16.21%) that decreases the quality of oil (Biswas et al. 2009) and consequently decreases antioxidant activity. This moderate activity could also be attributed to the fact that the EO was extracted from the plant's flowering tops, and it is well-known that extracts from lavender leaves are generally more active than extracts from flowers or stems.

In conclusion, the EO of *Lavandula angustifolia* extracted from the flowering tops of lavender harvested in the region of Séraidi (East Algerian) is primarily composed of Linalool, Acetate linalyl, and Camphor. These compounds have several biological activities, making them valuable oil in various fields. Despite being effective against the pathogens of fusariosis of wheat (*Fusarium roseum*) and tuberculosis of olive (*Pseudomonas savastanoi*), it has been found that lavender EO has a MIC value of 3000 ug/mL. As a result, it could be used as a bio-pesticide in conjunction with other fungicides and bactericides, reducing the environmental impact of phytosanitary products. The antioxidant activity of lavender EO appears lower than that of vitamin C.

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