Trop J Nat Prod Res, February 2024; 8(2):6108-6114 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

GC-MS Characterization, Antioxidant, Antimicrobial and Insecticidal Potential of Moroccan *Cuminum Cyminum L.* Essential Oil

Imane Ouryemchi[1,*], Asmaa Oubihi[1], Mohamed Taibi[2], Amine Elbouzidi[2], Hassna Jaber[1], Sara Haida[3], Kelthoum Tarfaoui[1], Khadija Atfaoui[1], Khalid Chaabane[2], Bouchra El Guerrouj[1], Reda Bellaouchi[4], Abdeslam Asehraou[4], Mohamed Addi[2,*], Abderrahim Benzakour[1], Mohammed Ouhssine[1]

[1]*Laboratory of Natural Resources and Sustainable Development, Department of Biology, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco;*
[2]*Laboratory of Improvement of Agricultural Productions, Biotechnology, and Environment (LAPABE), Faculty of Sciences, Mohammed Premier University, Oujda 60000, Morocco;*
[3]*Laboratory of Separation Processes, Team of Environment and Applied Chemistry, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco;*
[4]*Laboratory of Bioresources, Biotechnology, Ethnopharmacology and Health, Faculty of Sciences, Mo-hammed First University, Boulevard Mohamed VI, B.P. 717, Oujda 60000, Morocco*

ARTICLE INFO

Article history:
Received 12 October 2023
Revised 21 February 2024
Accepted 22 February 2024
Published online 01 March 2024

ABSTRACT

Human health has constantly been improved using medicinal plants. Notwithstanding synthetic chemistry advancements, medicinal plants remain widely used due to their effectiveness, reduced toxicity, and therapeutic use. This investigation examines the antioxidant, antimicrobial, and insecticidal properties of essential oil extracted from Moroccan cumin seeds (*Cuminum cyminum* L.). The essential oil was obtained through hydrodistillation from cumin seeds with a 3% yield. The EO was subjected to antioxidant, antimicrobial, and insecticidal activity screening using standard methods. The EO was investigated against a panel of pathogenic microorganisms using the disc diffusion method. The GC-MS analysis of the EO revealed the presence of 41 constituents. The major compounds identified were cuminaldehyde (21.94%), γ-terpene (18.20%), mentha-1,3-diene-7-al (14.93%), and α-pinene (13.789%). The EO showed moderate antioxidant activity against DDPH free radicals with anIC_{50} values of 273.409 mg/mL. The antibacterial screening results revealed that the EO of *Cuminum cyminum* possesses potent antibacterial activity against all tested bacterial strains, with MIC of 0.5 µL/mL against *Acinetobacter baumannii* and 1 µL/mL against *Proteus mirabilis*. The EO exhibited potent insecticidal activity against black bean aphids (*Aphis fabae* Scop.), with an 80% mortality rate. In conclusion, this study shows that *Cuminum cyminum L.* has interesting pharmacological effects and could be used to develop insecticidal and antimicrobial drug leads.

Keywords: *Cuminum cyminum L.*, essential oil, antioxidant activity, antibacterial effect, insecticidal activity, black bean aphid.

Introduction

The misuse of antibiotics in an attempt to control bacterial infections has yielded several detrimental consequences. These include the emergence of bacterial resistance and adverse effects on human health, as highlighted by Jaber *et al*.[1] Additionally, the indiscriminate use of antibiotics has been associated with oxidative stress, a phenomenon that inflicts substantial cellular damage, accelerates the aging process, and contributes to the development of severe pathologies like cancer. Consequently, the current utilization of synthetic antioxidant compounds has come under scrutiny due to potential health risks.[2] In response to these concerns, scientific research endeavors have focused on identifying novel biomolecules possessing both antioxidant properties and antibacterial activity.

*Corresponding author. E mail: m.addi@ump.ac.ma;
imane.ouryemchi@gmail.com
Tel: +212 536500601/2; 0651585897

Citation: Ouryemchi I, Oubihi A, Taibi M, Elbouzidi A, Jaber H, Haida S, Tarfaoui K, Atfaoui K, Chaabane K, El Guerrouj B, Bellaouchi R, Asehraou A, Addi M, Benzakour A, Ouhssine M. GC-MS Characterization, Antioxidant, Antimicrobial and Insecticidal Potential of Moroccan *Cuminum Cyminum L.* Essential Oil Trop J Nat Prod Res. 2024; 8(2):6108-6114. http://www.doi.org/10.26538/tjnpr/v8i2.8

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

Derivatives of these biomolecules, often found in extracts of medicinal and aromatic plants, are emerging as promising alternatives to synthetic antioxidants and antibiotics, as reported by Islam *et al.*[3] It is worth noting that the antimicrobial attributes of these plants have been recognized since ancient times. However, a comprehensive scientific investigation of their potential benefits did not commence until the early 20th century.[4] In the field of pest control, the use of pesticides, while intended to eliminate harmful organisms, presents a grave threat to human health. These chemicals have been classified as carcinogenic by the National Cancer Institute and are known to harm the nervous and endocrine systems.[5] Natural products of plant origin tend to degrade more rapidly in the environment, thereby reducing their harm to humans and animals and mitigating their adverse impact on the ecosystem. [6] Plants serve as a protective defense against the adverse effects of oxidative stress, which contribute to the development of severe medical conditions such as cancer, cardiovascular disease, diabetes, inflammation, and digestive disorders.[7–11] Furthermore, plants have been harnessed for centuries as natural remedies, providing a valuable source of bioactive compounds.[12] Among this diverse array of plants, *Cuminum cyminum L.* stands out. It is a small annual herbaceous plant belonging to the Apiaceae family (Umbelliferae). It is found in various ethno-medical systems across Northern Europe, the Mediterranean regions, Russia, Iran, Indonesia, and North America.[13] Moreover, the seeds of *Cuminum cyminum* have a rich history of use in traditional medicine, where they have been employed to alleviate conditions such

as flatulence, diarrhea, and various digestive ailments. Additionally, the species has demonstrated antimicrobial and insecticidal properties.[14–16] Research has shown that cumin seeds are used as a spice because of their unique aroma. They are widely used in traditional medicine to treat various health problems such as toothache, indigestion, diarrhea, and jaundice [17,18]. It is generally believed that these medicinal properties are due to the richness and powerful effects of active ingredients such as terpenes and polyphenols. There is a need to investigate the relationship between the chemical profile of cumin seed and its application in traditional medical practice and determine its antioxidant, antibacterial, and insecticidal potential to identify its bioactive principles.

Materials and Methods

Plant Collection and Identification

Cumin grains (*Cuminum cyminum L*) were harvested in May 2021 from the Alnif Region, a rural community situated in the province of Tinghir, Morocco (31° 06' 50.9" N 5° 09' 57.7" W). The plant was by Mr. *Zidane Lahcen* at Plant, Animal Productions and Agro-Industry Laboratory, Ibn Tofail University, Kenitra, Morocco.

Preparation of plant material

All extraneous materials, including dust, straws, and stones, were manually removed from the harvested grains.

Extraction of Essential Oils

The essential oil (EO) of cumin was obtained by hydrodistillation in a Clevenger apparatus as described by [19]. Distillation was done by boiling 250 g of ground grains with 1L water in a 2L flask for 4 hours. The resulting essential oil was carefully stored in an opaque glass container, maintained at a temperature of + 4 °C. The calculation of the essential oil yield percentage was conducted as follows:

Yield % = (Weight of EO in grams / Weight of dry matter in grams) x 100 ……..1

Chromatographic Analysis

The chromatographic analyses were conducted using CG/MS CLARUS 580SQ8S system from PERKIN ELMER. This system was equipped with a column measuring 40 meters long and 180 micrometers in diameter, utilizing Helium gas as the carrier. The injector was configured as a split-split injector and maintained at a temperature of 250 degrees Celsius. The temperature program for the chromatographic column commenced at 60 degrees Celsius and was gradually increased to 250 degrees Celsius over 10 minutes, with a heating rate of 4 degrees Celsius per minute. The identification of the chemical constituents present in the samples was accomplished by referencing the retention indices of the oil constituents and utilizing gas-phase chromatography coupled with mass spectrometry. The instrument was integrated with a computer system that managed a NIST mass spectrum library for precise compound identification. [20]

Antioxidant Activity procedure

The assessment of the antioxidant activity in the EO was conducted via a methodology rooted in the reduction of 2,2-diphenyl-1-picrylhydrazyl (DPPH), as described by Haida and Kribii[21] and Zrouri[22], with some modifications. Briefly, a solution of DPPH at a concentration of 76 µM (0.03 mg/mL) was prepared using ethanol. Subsequently, 0.1 mL of cumin essential oil (EO) of concentrations from 0-3 mg/mL, was mixed with 2 mL of DPPH solution. A solution of DPPH and methanol serves as blank control. These preparations were incubated in the dark for 30 minutes. The absorbance of the solutions was measured at 517 nm utilizing a conventional spectrophotometer (UV-2005, Selecta), with ascorbic acid serving as a reference standard for comparative purposes. The evaluation of antioxidant activity was derived from calculating the percentage inhibition of DPPH radicals, as shown in Equation 2.

$$Inhibition\ (\%) = \left(\frac{Ab - Ae}{Ab}\right) \times 100 \qquad (2)$$

Ab: Absorbance of blank, Ae: Absorbance of the sample.

This assay was conducted in triplicate. The extract's half-maximal (IC_{50}) concentration, i.e., the percentage of the antioxidant necessary to inhibit 50% of the DPPH free radicals, was computed from the linear regression curve (y = ax + b) plot shown in Equation 3.

$$IC_{50} = \left(\frac{50 - b}{a}\right) \times 100 \qquad (3)$$

Where **a** is the slope of the regression line, and **b** signifies the y-intercept.

Antibacterial Activity

The antimicrobial efficacy of cumin essential oil (EO) was determined by the disk diffusion method, as described.[23–26] This investigation utilized ten clinical isolates of pathogenic bacterial, namely Gram-positive (*Staphylococcus aureus*, *Staphylococcus epidermidis*) and Gram-negative (*Escherichia coli*, *Proteus mirabilis*, *Acinetobacter baumannii*, *Salmonella sp*, *Klebsiella pneumonia*, *Citrobacter freundii*, *Enterobacter cloacae* and *Pseudomonas aeruginosa*). In this assay, microbial suspensions of the bacteria strains were inoculated onto the Mueller Hinton (MH) agar medium surface in Petri dishes. Sterile discs, measuring 6 mm in diameter, were then impregnated with 10 µL of cumin EO and gently placed onto the surface of the MH agar medium. The Petri dishes were subsequently incubated at 37 degrees Celsius for 24 hours. This entire process was performed in triplicate. The EO antimicrobial activity was assessed by measuring the diameters of the inhibition zones (in millimeters) surrounding the impregnated discs. Cefazolin and penicillin were employed as standard control agents.

The Minimal Inhibitory Concentration (MIC) is the lowest concentration of essential oil (EO) at which no observable growth occurs compared to a control.[1,27,28] The MIC of the EO was determined by incorporating different concentrations (100 µL/mL, 40 µL/mL, 20 µL/mL, 10 µL/mL, 5 µL/mL, 3.3 µL/mL, and 2 µL/mL) of the oil in a 0.2% agar solution to ensure a uniform dispersion. Each dilution was introduced into test tubes containing 13.5 mL of Muller Hinton medium, which had been sterilized by autoclaving at 121°C for 20 minutes and cooled to 45°C. Following this, 1.5 mL of each dilution was added to achieve final concentrations of 10 µL/mL, 4 µL/mL, 2 µL/mL, 1 µL/mL, 0.5 µL/mL, 0.33 µL/mL, and 0.2 µL/mL, according to an established.[29] The medium was thoroughly mixed to ensure uniform dispersion of the EO in the growth medium, and each tube's contents were transferred separately to a sterile Petri dish. With a platinum handle, the test organisms were streaked on the plates and incubated at 37°C for 24 hours. Control samples were concurrently prepared, consisting of the culture medium and 0.2% agar solution. A triplicate determination was carried out.

Insecticidal Activity

The protocol described by Rashedi *et al*. was adopted for this assay. [30] In this assay, Black aphids (*Aphis fabae*) were grown in a controlled laboratory environment with a temperature of 25.2°C, relative humidity of 75%, and a photoperiod of 14 hours of light and 10 hours of darkness in entomological cages. An emulsion of the EO was prepared by mixing a dispersion of the oil in water with 0.01% Triton X-100. Five concentrations (0.01%, 0.02%, 0.03%, 0.05%, and 0.10%) of the emulsified cumin essential oil were administered by direct contact using a 30 mL sprayer. For each concentration, five adult aphids were introduced into a glass petri dish equipped with Whatman No.1 filter paper and a fresh bean leaf for subsistence. Mortality assessments were performed at 1, 2, 3, 24, and 48 hours after contact by observation with a binocular microscope (Motic, Germany). Aphid's mortality was determined by gently probing each adult insect with a brush; those displaying immobility of their legs were classified as dead.[31] The observed mortality rate was adjusted using the Abbot formula, using a corrected method by Khandekar and Yadu[32], as shown in Equation 4.

$$M(\%) = \left(\frac{Mi - Mt}{100 - Mt}\right) \times 100 \qquad (4)$$

Where:

M % represents the percentage of mortality.
Mi signifies the observed mortality in the insect population.
Mt represents the observed mortality in the control group.

Statistical Analysis

Statistical analysis of the data was done by the analysis of variance (ANOVA) with Excel (Microsoft Suite, USA). In some cases, results were presented as mean±SD.

Results and Discussion

The yield of *C. cyminum* essential oil (EO) was 3.5% based on the dry material weight. This result closely aligns with Petretto's findings[33]. Still, it is slightly lower than the yield reported for Indian cumin grains at 4.5%[34] and higher than that observed for Algerian EO (1.08%) reported by Ben Miri and Djenane.[35] These variations in yield underscore the influence of the cumin grain's origin and the prevailing climatic conditions. The analysis of *C. cyminum* EO using Gas Chromatography-Mass Spectrometry (GC-MS) revealed the presence of 41 constituents, representing approximately 98.04% of the plant's composition (Table 1, Figure 1). The major constituents in the EO from Alnif cumin include cuminaldehyde (21.94%), γ-terpinene (18.20%), mentha-1,3-dien-7-al (14.93%), α-pinene (13.789%), and cymene (7.80%). These findings are consistent with some prior studies[43], which identified cuminaldehyde (29.1%), γ-terpinene (10.0%), α-pinene (7.1%), and p-cymene (6.1%) as primary components.[40] Variations in EO composition were observed in cumin from different sources, including Chinese cumin, where cuminaldehyde was the major constituent (36.6%), accompanied by γ-terpinene (11.14%), *p*-cymene (9.85%), and α-pinene (7.75%), as reported.[36,37] Cuminaldehyde was also the predominant constituent in Algerian *C. cyminum* EO, constituting 65.98% of its composition.[35] These disparities underscore the impact of factors such as sample variation, geographical origin, soil conditions, climate, and extraction methodologies on the nature and content of essential oil compounds.[26] Figure 2 illustrates the variation in percentage inhibition as determined through the DPPH reduction assay. The figure shows that the inhibition is dose-dependent, indicating that the tested essential oil (EO) can counteract the aggressive DPPH radical as the concentration of the antioxidant increases. This activity is quantified by the IC_{50} values, as presented in Table 2, where ascorbic acid exhibits robust antioxidant potency with an IC_{50} of 0.090 mg/mL. In contrast, the EO derived from cumin records a moderate IC_{50} value of 273.409 mg/mL. It is essential to note that a higher IC_{50} value correlates with reduced antioxidant activity, while a lower value signifies potent antioxidant efficacy.[38] Notably, the EO of cumin demonstrates lower antioxidant activity than ascorbic acid and falls below the levels reported in other studies.[39,40] The disparity in antioxidant activity could be attributed to various factors, including genetic variances, harvest stage, geographical origin, and environmental conditions.[41] Furthermore, the chemical composition of cumin EO predominantly comprises monoterpenes, namely γ-terpinene and α-pinene. Several research endeavors have suggested that higher monoterpenes content may be less effective in generating the desired antioxidant effects.[34,42]

The outcomes of the antibacterial assessment and antibiotic susceptibility determined through the disc diffusion method are presented in Table 3. The result showed that cumin essential oil exhibits antibacterial activity against all tested bacterial strains except *Pseudomonas aeruginosa*, which displayed resistance with an inhibition zone of up to 11 mm. Conversely, a significant portion of the bacterial strains in our study exhibited resistance to Cefazolin and penicillin. These results agree with the findings of Hajib *et al*.[43], who also assessed the susceptibility of these strains. In contrast, the research conducted by Athamena et *al*.[44] indicated that *C. cyminum* EO exclusively inhibited *Staphylococcus aureus*. The results align with numerous studies demonstrating the antibacterial activity of *C. cyminum* EO against both Gram-positive and Gram-negative bacteria.[34] Table 4 illustrates the minimum inhibitory concentrations (MIC) ranging from 0.5 µL/mL to 4 µL/mL. Notably, a concentration as low as 0.5 µL/mL is sufficient to impede the growth of *A. baumannii*. *Salmonella sp* exhibits the highest level of resistance, necessitating a concentration of 4 µL/mL for inhibition.

Table 1: The Chemical Composition of *Cuminum cyminum* L Essential Oil

number	Compound	Retention time	%
1	α-Thujene	11.242	0.340
2	1-isopropylcyclohexene	11.38	0.058
3	D- α -Pinene	11.58	0.829
4	Sabinene	12.980	0.651
5	α-Pinene	13.234	13.789
6	α-Myrcene	13.370	0.675
7	α-Phellandrene	14.114	0.388
8	Carene	14.364	0.050
9	α - Terpinolen	14.551	0.129
10	Cymene	14.851	7.801
11	4-ethenyl-1.4-dimethylcyclohexene	15.025	0.284
12	α-Sabine	15.112	0.192
13	Eucalyptol	15.208	0.161
14	γ - Terpinene	16.139	18.205
15	2-Carene	17.286	0.059
16	2-Pentadecen-4-yne, (Z)-	19.261	0.046
17	*Trans*-Pinocarveol	19.424	0.042
18	Cyclohexene, 1-butyl-	19.681	0,150
19	2-Isopropylidene-3-methylhexa-3.5-dienal	20.312	0,155
20	Terpinenol-4	20.749	0,289
21	Terpineol	21.182	0,146
22	3- Mentha-7-al	21.322	1.075
23	Cuminaldehyde	23.133	21,947
24	Menth - 2-in-7- ol,trans	23.874	0,051
25	Phellandral	24.431	0,201
26	Mentha-1,3-dien-7-al	24.768	14.931
28	Mentha-1.4-dien-7-al	24.915	14.149
29	1.4cyclohexanediol	25.452	0.043
30	4-(2-Methyl-3oxocyclohexyl)butanal	25.858	0.123
31	1.4 -Menthandien-7-ol	26.055	0.247
32	2 -Caren-10-al	26.636	0.067
33	Daucene	28.017	0.115
34	Caryophyllene	29.547	0.069
35	*Trans*-α- Bergamotene	29.697	0.042
36	Farnesene	30.044	0.145
37	*Cis*- β-Copaene	31.209	0.052
38	3.11-Acoradian	31.285	0.172
39	Acorenol	32.142	0.059
40	Caryophyllene oxide	34.834	0.042
41	Caratol	35.184	0.217

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Table 2; Comparative antioxidant activity results of cumin essential oil and ascorbic acid, quantified by IC_{50} values derived from the DPPH radical scavenging assay

Assays	Cumin Essential oil	Ascorbic acid
DPPH (IC_{50} mg/mL)	273.409 ± 10.735	0.090 ± 0.008

These findings underscore the pronounced antibacterial efficacy of cumin oil. Research on Cumin Essential Oil in Morocco has previously demonstrated its ability to inhibit the growth of *Salmonella sp* at low concentrations while failing to exhibit significant effects against the bacterium *Proteus mirabilis*, even at high concentrations, as reported by Hajib *et al*.[43] The essential oil derived from *C. cyminum* demonstrates a bactericidal effect, as evidenced by the minimal inhibitory concentration (MIC) being equivalent to the minimum bactericidal concentration (CMB), against a panel of bacterial strains including *S. aureus, S. epidermidis, E. cloacae, E. coli,* and *Salmonella sp* (Table 4). Conversely, with regards to *C. freundii, K. pneumonia, P. mirabilis,* and *A. baumannii*, the EO of *C. cyminum* exerts a bacteriostatic influence. The observed potency of cumin EO can be attributed to its chemical compounds, notably γ-Terpinene, which acts synergistically with sabinene against pathogens, as reported in some studies.[45,46] Additionally, α-pinene has been shown to induce inhibition of pathogenic bacteria by exerting toxic effects on cell membrane structure and function, thereby compromising cellular integrity and hindering both respiration and ion transport processes, ultimately leading to alterations in cellular permeability.[47] Furthermore, the antibacterial activity of *β*-pinene and cymene, recognized for their antibacterial efficacy, further contributes to the overall antimicrobial potency of cumin EO.[34]

In the insecticidal activity screening, the adjusted mortality rates observed following the treatment of *Aphis fabae* populations with varying concentrations of *C. cyminum* essential oil over time and dosage are presented in Figure 3. The EO of *C. cyminum* exhibited a potent toxic effect on black aphids infesting bean plants. It induced mortality rates as high as 13% after just 2 hours of contact at a concentration of 0.1%, rising to an impressive 80% mortality within 48 hours of contact. The results indicate that Cumin Essential Oil achieves a 50% mortality rate against black aphids within 24 hours of contact, suggesting a positive correlation between repulsion percentage and time and dosage. Our findings align with the research conducted by Aouina in 2017, who reported an 84.17% repulsion rate, demonstrating the high toxicity of *C. cyminum* essential oil against pests. [44] It showed better insecticidal activity when compared to *Rosmarinus officinalis*, which exhibits relatively lower activity against *Aphis fabae*, with a mortality rate of 30% after 48 hours of initial treatment.[48] This elevated mortality rate can be attributed to the constituents of cumin essential oil, particularly γ-Terpinene and α-Pinene, which significantly impact insects, as corroborated by some studies.[49,50] The substantial variations in repulsive activities can be attributed to multiple factors, encompassing the chemical composition of these essential oils, the part of our aromatic plant tested, oil extraction methods, the insect's sensitivity levels, application conditions, treatment procedures, as well as time, dosage, and the sampling season.[51]

Conclusion

The EO of *C. cyminum* was characterised by GC-MS, which revealed the presence of some terpenes and other potent plant secondary metabolites with significant insecticidal, antibacterial, and antioxidant activities. This plant can be used to develop alternative drugs to treat infectious diseases caused by pathogenic organisms, as well as a bioagent for use as an insecticide against the black aphid and the food grains insects. There is, however, room for further studies to highlight the exact phytoconstituents in the plant implicated in the observed biological activity and its mechanism of action. This study highlights cumin essential oil's multiple applications in various fields, from food preservation to pest management and pharmaceuticals.

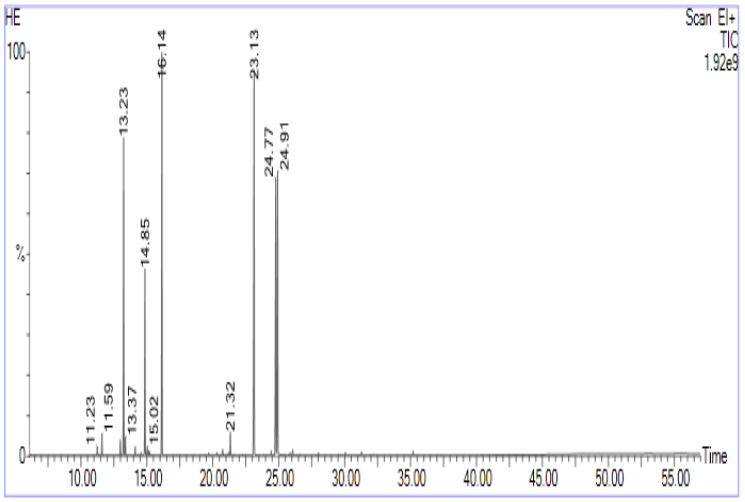

Figure 1: Chromatographic chromatogram of *Cuminum cyminum. L* essential oil, analyzed by GC-MS

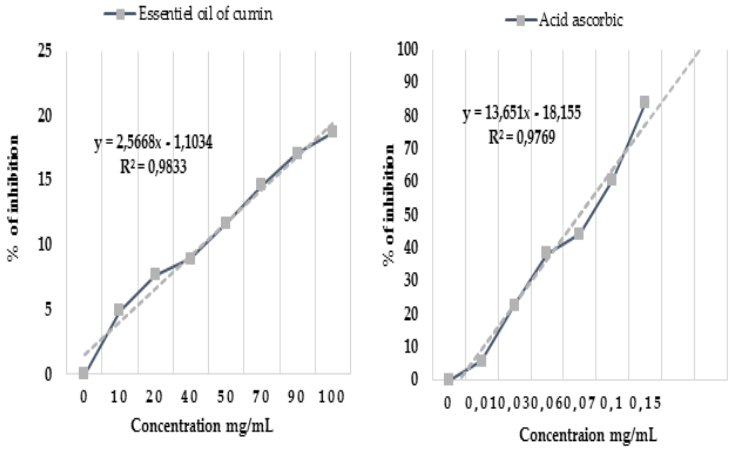

Figure 2: Linear representation of percent inhibition variation of essential oil relative to ascorbic acid in the DPPH radical scavenging assay.

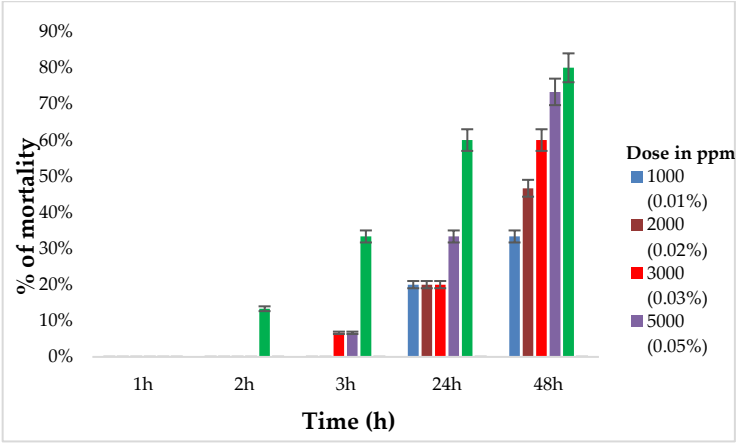

Figure 3: Mortality rate following the essential oil treatment of *C. cyminum* depending on time and dose.

Table 3: The antibacterial activity of *Cuminum cyminum* L. essential oil by the diffusion method on disc.

Microorganisms	Inhibition diameter (mm)		
	Essential oil	Antibiotic	
	Cuminum cyminum L	Cefazolin	Penicillin
Gram +			
Staphylococcus aureus	08 ± 1.15	12 ± 0.00	00 ± 0.00
Staphylococcus epidermidis	08 ± 1.00	00 ± 0.00	00 ± 0.00
Gram -			
Escherichia coli	10 ± 1.05	00 ± 0.00	00 ± 0.00
Acinetobacter baumannii	11 ± 1.52	00 ± 0.00	00 ± 0.00
Proteus mirabilis	08 ± 0.57	00 ± 0.00	00 ± 0.00
Salmonella sp	10 ± 1.02	00 ± 0.00	00 ± 0.00
Klebsiella pneumoniae	08 ± 0.57	00 ± 0.00	00 ± 0.00
Citrobacter freundii	08 ±1.15	00 ± 0.00	00 ± 0.00
Enterobacter cloacae	06 ± 1.00	00 ± 0.00	00 ± 0.00
Pseudomonas aeruginosa	00 ± 0.00	00 ± 0.00	00 ± 0.00

Diameter of the inhibition zone, including the disc diameter of 6 mm, by the agar disc diffusion method at a concentration of 15 µl of oil/disc and a concentration of 30 et 5 µg / disc of Cefazolin, respectively.

Table 4: *Cuminum cyminum* L. minimal inhibition concentration (MIC) and bactericidal concentration (MIB)

Microorganisms	Essential Oil	
	MIC	MIB
Gram +		
Staphylococcus aureus	4 µL/mL	4 µL/mL
Staphylococcus epidermidis	1 µL/mL	1 µL/mL
Gram -		
Acinetobacter baumannii	0.5 µL/mL	1 µL/mL
Escherichia coli	4 µL/mL	4 µL/mL
Enterobacter cloacae	4 µL/mL	4 µL/mL
Proteus mirabilis	1 µL/mL	10 µL/mL
Klebsiella pneumoniae	2 µL/mL	4 µL/mL
Citrobacter freundii	4 µL/mL	10 µL/mL
Salmonella sp	10 µL/mL	10 µL/mL

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

References

1. Jaber H, Oubihi A, Ouryemchi I, Boulamtat R, Oubayoucef A, Bourkhiss B, Ouhssine M. Chemical composition and antibacterial activities of eight plant essential oils from Morocco against *Escherichia coli* strains isolated from different Turkey organs. Biochem Res Int. 2021;2021:1-9.
2. Tarfaoui K, Brhadda N, Ziri R, Oubihi A, Imtara H, Haida S, Al Kamaly OM, Saleh A, Parvez MK, Fettach S, Ouhssine M. Chemical Profile, Antibacterial and Antioxidant Potential of Zingiber officinale Roscoe and *Elettaria cardamomum* (L.) Maton Essential Oils and Extracts. Plants (Basel). 2022;11(11):1487
3. Islam ME, Islam KMD, Billah MM, Biswas R, Sohrab MH, Rahman SMM. Antioxidant and anti-inflammatory activity of *Heritiera fomes* (Buch.-Ham), a mangrove plant of the Sundarbans. Adv Tradit Med. 2020;20:189-97.
4. Yahiaoui F, Zekkour N, Boukhalfoun L. Evaluation of the antimicrobial activity of methanolic and aqueous extracts of *Eucalyptus sp* [Internet] [PhD Thesis]. 2018 [cité 11 déc 2023]. Disponible sur: http://dspace.univ-medea.dz/handle/123456789/9161
5. Özkara A, Akyıl D, Konuk M. Pesticides, environmental pollution, and health. In: Environmental health risk-hazardous factors to living species. IntechOpen; 2016.
6. Smith P, Calvin K, Nkem J, Campbell D, Cherubini F, Grassi G, Korotkov V, Le Hoang A, Lwasa S, McElwee P, Nkonya E. Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification?. GlobChange Biol. 2020;26(3):1532-75.
7. Oubihi A, Hosni H, Nounah I, Ettouil A, Harhar H, Alaoui K, Ouhssine M, Guessous Z. Phenolic content, antioxidant activity, anti-inflammatory potential, and acute toxicity study of Thymus leptobotrys Murb. extracts. Biochem Res Int. 2020; DOI: 10.1155/2020/8823209
8. Hayani M, Bencheikh N, Ailli A, Bouhrim M, Elbouzidi A, Ouassou H, Kharchoufa L, Baraich A, Atbir A, Ayyad F, Drioiche A, Addi A, Hano C and Zair T. Quality Control, Phytochemical Profile, and Antibacterial Effect of Origanum compactum Benth. Essential Oil from Morocco. Int J Plant Biol. 2022;13:546-60.
9. Bencheikh N, Elachouri M, Subhash C. M, Noureddine B, Mostafa E, Mandal SC. Ethnobotanical, pharmacological, phytochemical, and clinical investigations on Moroccan medicinal plants traditionally used for the management of renal dysfunctions. J Ethnopharmacol. 2022;292:115178.
10. Ouassou H, Bouhrim M, Kharchoufa L, Imtara H, Elhouda Daoudi N, Benoutman A, Bencheikh N, Ouahhoud S, Elbouzidi A, Bnouham M. *Caralluma europaea* (Guss) NE Br.: A review on ethnomedicinal uses, phytochemistry, pharmacological activities, and toxicology. J Ethnopharmacol. 2021;273:113769.
11. Elbouzidi A, Ouassou H, Aherkou M, Kharchoufa L, Meskali N, Baraich A, Mechchate H, Bouhrim M, Idir A, Hano C, Zair T and Addi M LC–MS/MS Phytochemical Profiling, Antioxidant Activity, and Cytotoxicity of the Ethanolic Extract of *Atriplex halimus* L. against Breast Cancer Cell

Lines: Computational Studies and Experimental Validation. Pharmaceuticals. 2022;15:1-25.
12. El Amri J, Elbadaoui K, Zair T, Bouharb H, Chakir S, Alaoui TI. Study of the antibacterial activity of the essential oils of Teucrium capitatium L and the extract of *Silene vulgaris* on different strains tested. J Appl Biosci. 2014;82:7481-92.
13. Yaacoube R, Tlidjane I. Physicochemical characterization and biological analyses of the essential oil of *Cuminum cyminum* L. and *Foeniculum vulgare* Mill grains. Extracted by hydrodistillation and Supercritical CO_2: Comparative study. 2018. Thesis of Master's Degree in Chemical Engineering, Larbi ben M'Hidi University, Oum el Bouaghi, pp: 98.
14. El-Sayed HS, El-Sayed SM. A modern trend to preserve white soft cheese using nano-emulsified solutions containing cumin essential oil. Environ Nanotechnol Monit 2021;16:100499.
15. Mandal M, Mandal S. Cumin (*Cuminum cyminum* L.) oils. In: essential oils in food preservation, flavor, and safety. Elsevier; 2016; 377-83.
16. Bencheikh N, Elbouzidi A, Kharchoufa L, Ouassou H, Alami Merrouni I, Mechchate H, Es-safi I, Hano C, Addi M, Bouhrim M, Eto B, Elachouri M Inventory of medicinal plants used traditionally to manage kidney diseases in north-eastern Morocco: Ethnobotanical fieldwork and pharmacological evidence. Plants. 2021;10:1966.
17. Sharif MK, Ejaz R, Pasha I. Nutritional and therapeutic potential of spices. In: Therapeutic, probiotic, and unconventional foods. Elsevier; 2018; 181-99.
18. Srinivasan K. Cumin (Cuminum cyminum) and black cumin (Nigella sativa) seeds: traditional uses, chemical constituents, and nutraceutical effects. Food Qual and Saf. 2018;2:1-16.
19. Elyemni M, Louaste B, Nechad I, Elkamli T, Bouia A, Taleb M, Chaouch M and Eloutassi N. Extraction of Essential Oils of Rosmarinus officinalis L. by Two Different Methods: Hydrodistillation and Microwave Assisted Hydrodistillation. Sci World J. DOI:10.1155/2019/3659432
20. Ouahabi S, Loukili EH, Elbouzidi A, Taibi M, Bouslamti M, Nafidi HA, Salamatullah A , Saidi N, Bellaouchi R, Addi M, Ramdani M, Bourhia M and Hammouti B. Pharmacological Properties of Chemically Characterized Extracts from Mastic Tree: In Vitro and In Silico Assays. Life. 2023;13:1393.
21. Haida S, Kribii A. Chemical composition, phenolic content and antioxidant capacity of Haloxylon scoparium extracts. S Afr J Bot. 2020;131:151-60.
22. Zrouri H, Elbouzidi A, Bouhrim M, Bencheikh N, Kharchoufa L, Ouahhoud S, Ouassou H, El Assri S and Choukri M. Phytochemical analysis, antioxidant activity, and nephroprotective effect of the Raphanus sativus aqueous extract. Mediterr J Chem. 2021;11:84.
23. Elbouzidi A, Taibi M, Ouassou H, Ouahhoud S, Ou-Yahia D, Loukili EH, Aherkou M, Mansouri F, Bencheikh N , Laaraj S,, Bellaouchi R, Saalaoui E , Elfazazi K , Berrichi A, Abid M and Addi M. Exploring the Multi-Faceted Potential of Carob (Ceratonia siliqua var. Rahma) Leaves from Morocco: A Comprehensive Analysis of Polyphenols Profile, Antimicrobial Activity, Cytotoxicity against Breast Cancer Cell Lines, and Genotoxicity. Pharmaceuticals. 2023;16:840.
24. Taibi M, Elbouzidi A, Ou-Yahia D, Dalli M, Bellaouchi R, Tikent A, Roubi M, Gseyra N, Asehraou A Hano C, Addi M , El Guerrouj B and Chaabane K. Assessment of the Antioxidant and Antimicrobial Potential of Ptychotis verticillata Duby Essential Oil from Eastern Morocco: An In Vitro and In Silico Analysis. Antibiotics. 2023;12.
25. Kandsi F, Elbouzidi A, Lafdil FZ, Meskali N, Azghar A, Addi M, et al. Antibacterial and Antioxidant Activity of Dysphania ambrosioides (L.) Mosyakin and Clemants Essential Oils: Experimental and Computational Approaches. Antibiotics. 2022;11:482.
26. Oubihi A, Ouryemchi I, Nounah I, Tarfaoui K, Harhar H, Ouhssine M, Guessous Z. Chemical composition, antibacterial and antifungal activities of Thymus leptobotrys Murb essential oil. Adv Tradit Med. 2020;20:673-9.
27. Mrabti HN, Hachlafi N El, Al-Mijalli SH, Jeddi M, Elbouzidi A, Abdallah EM, Flouchi R, Assaggaf H , Qasem A, Zengin G, Bouyahya A and Ouazzani Chahdi F Phytochemical profile, assessment of antimicrobial and antioxidant properties of essential oils of *Artemisia herba-alba* Asso., and *Artemisia dracunculus* L.: Experimental and computational approaches. J Mol Struct. 2023;1294:136479.
28. Al-Mijalli SH, Mrabti HN, El Hachlafi N, El Kamili T, Elbouzidi A, Abdallah EM, Flouchi R , Assaggaf H , Qasem A, Zengin G, Bouyahya A and Ouazzani Chahdi Integrated analysis of antimicrobial, antioxidant, and phytochemical properties of *Cinnamomum verum*: A comprehensive *In vitro* and *In silico* study. Biochem Syst Ecol. 2023;110:104700.
29. Oubihi A, Ouryemchi I, Nounah I, Tarfaoui K, Harhar H, Ouhssine M, Guessous Z. Chemical composition, antibacterial and antifungal activities of Thymus leptobotrys Murb essential oil. Advances in Traditional Medicine. 2020;1-7.
30. Rashedi A, Rajabpour A, Sohani NZ, Rasekh A. Prey stage preference and functional response of Orius albidipennis (Hetetroptera, Anthocoridae) to Aphis fabae (Homomoptera, Aphididae). Int J Trop Insect Sci. 2020;40:13-9.
31. Alghamdi AS. Insecticidal effect of four plant essential oils against two aphid species under laboratory conditions. J Appl Biol. 2018;6:27-30.
32. Khandekar C, Yadu YK, Mohanan A. Efficacy of microbial insecticides and plant product against tobacco caterpillar (Spodoptera litura) on soybean in laboratory conditions. J. Pharm. Innov. 2023; 12(3): 4737-4740
33. Petretto GL, Fancello F, Bakhy K, Faiz CAL, Sibawayh Z, Chessa M, Zara S, Sanna M.L, Maldini M, Rourke J.P and Pintore G. Chemical composition and antimicrobial activity of essential oils from *Cuminum cyminum* L. collected in different areas of Morocco. Food Bioscience. 2018;22:50-8.
34. Patil SD, Maknikar PP, Wankhade SJ, Ukesh CS, Rai MK. Chemical composition, antimicrobial and antioxidant activity of essential oils from Cumin and Ajowan. Nusantara Bioscience. 2016;8.
35. Miri Y Ben, Djenane D. Antifungal, anti-aflatoxigenic, antioxidant activity and *in vivo* efficacy of essential oil of the aerial parts of *Thymus capitatus* (L.) Hoffmanns & Link. Phytotherapie. 2019;17:299-309.
36. da Silva Rivas AC, Lopes PM, de Azevedo Barros MM, Costa Machado DC, Alviano CS, Alviano DS. Biological activities of α-pinene and β-pinene enantiomers. Molecules. 2012 May 25;17(6):6305-16.
37. Baldissera MD, Grando TH, Souza CF, Gressler LT, Stefani LM, da Silva AS and Monteiro S. *In vitro* and *in vivo* action of terpinen-4-ol, γ-terpinene, and α-terpinene against Trypanosoma evansi. Exp Parasitol 2016;162:43-8.
38. Khoudali S, Essaqui A, Zertoubi M, Azzi M, Benaissa M. Study of antioxidant activity and anticorrosion action of the methanol extract of dwarf palm leaves (Chamaerops humilis l.) from Morocco J Mater Environ Sci. 5 (3) (2014) 887-898
39. Belkacem M, Kessar I, EttahrI A. Study of the antifungal and antioxidant effect of the essential oil of Cuminum cyminum L. seeds 2022;
40. Hajib A, Nounah I, Oubihi A, Harhar H, Gharby S, Kartah B, Bougrin K and Charrouf Z Chemical Composition and Biological Activities of Essential Oils from the Fruits of *Cuminum cyminum* L. and *Ammodaucus leucotrichus* L. (Apiaceae). J Essent Oil-Bear Plants. 2020;23:474-83.
41. Yaacoube R, Tlidjane I. Yaacoube R, Tlidjane I. Physicochemical characterization and biological analyses of the essential oil of *Cuminum cyminum* L. and *Foeniculum vulgare* Mill grains. Extracted by hydrodistillation and

Supercritical CO2: Comparative study. 2018. Thesis of Master's Degree in Chemical Engineering, Larbi ben M'Hidi University, Oum el Bouaghi, pp: 98.
42. Chen Q, Gan Z, Zhao J, Wang Y, Zhang S, Li J, and Ni Y. In vitro comparison of antioxidant capacity of cumin (*Cuminum cyminum* L.) oils and their main components. LWT-Food Sci and Technol. 2014;55:632-7.
43. Hajib A, Nounah I, Oubihi A, Harhar H, Gharby S, Kartah B Bougrin K and Charrouf Z. Chemical composition and biological activities of essential oils from the fruits of *Cuminum cyminum* L. and *Ammodaucus leucotrichus* L.(Apiaceae). J Essent Oil-Bear Plants. 2020;23:474-83.
44. Aouina A and Khelifi NH. Evaluation of the Repellent Effect of Cuminum Cyminum L. Et Foeniculum Vulgare Mill. On the stored grain insect Tribolium Castaneum (herbst). 2017.
45. Tsitlakidou P, Papachristoforou A, Tasopoulos N, Matzara A, Hatzikamari M, Karamanoli K, and Mourtzinos. Sensory analysis, volatile profiles and antimicrobial properties of *Origanum vulgare* L. essential oils. Flavour Fragr. J.2022;37:43-51.
46. Pinto L, Bonifacio MA, De Giglio E, Cometa S, Logrieco AF, Baruzzi F. Unravelling the antifungal effect of red thyme oil (*Thymus vulgaris* L.) compounds in vapor phase. Molecules. 2020;25:4761.
47. Gold K, Slay B, Knackstedt M, Gaharwar AK. Antimicrobial Activity of Metal and Metal-Oxide Based Nanoparticles. Adv Ther. 2018;1:1700033. DOI:10.1002/adtp.201700033
48. Moumni F, Djalt Houari Si. L' Use of *Rosmarinus officinalis* L against the black aphid (Aphis Fabae) of sugar beet (Beta Vulgaris). Université d'Ain Témouchent Belhadj Bouchaib - UATBB; 2022.
49. Achimón F, Leal LE, Pizzolitto RP, Brito VD, Alarcón R, Omarini AB, and Zygadlo JA. Insecticidal and antifungal effects of lemon, orange, and grapefruit peel essential oils from Argentina. AgriScientia. 2022;39:71-82.
50. Nenaah GE, Almadiy AA, Al-Assiuty BA, Mahnashi MH. The essential oil of Schinus terebinthifolius and its nanoemulsion and isolated monoterpenes: investigation of their activity against Culex pipiens with insights into the adverse effects on non-target organisms. Pest Manag Sci. 2022;78:1035-47.
51. Sosa-Gómez DR, Corrêa-Ferreira BS, Kraemer B, Pasini A, Husch PE, Delfino Vieira CE, Reis Martinez CB, and Negrão Lopes IO. Prevalence, damage, management and insecticide resistance of stink bug populations (Hemiptera: Pentatomidae) in commodity crops. Agric For Entomol. 2020;22:99-118.