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Characterization and Antimicrobial Potential of *Pelargonium Graveolens* Essential Oil In Solid Soap Formulations

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Abstract : The growing concern over antimicrobial resistance and the harmful effects of synthetic antiseptics has increased interest in alternatives. essential oils of *Pelargonium graveolens* possess strong antimicrobial properties in hygiene products. This study aimed to evaluate the antibacterial activity of ***P. graveolens*** essential oil incorporated into solid soap formulations. The essential oil was extracted via hydrodistillation and its composition was analyzed using gaz chromatography mass spectrometry (GC-MS). Citronellol (29.4%), 10-epi-γ-Eudesmol (26%),and geraniol (8.2%) were identified as major components. Soaps enriched with essential oil at concentrations of 1%, 3%, and 5% were tested against *Escherichia coli* ATCC 8739, *Staphylococcus epidermidis* ATCC 12228, and *Pseudomonas aeruginosa* ATCC 9027 using the disc diffusion method. The essential oil-enriched soaps exhibited significant inhibitory effect, with the 5% formulat soaps exhibited significant inhibitory effect, with the 5% formulation showing the highest inhibition against *S. epidermidis* (17.33 mm) and *E. coli* (15.03 mm). However, *P. aeruginosa* demonstrated lower susceptibility.The findings support the potential of *P. graveolens* essential oil as a natural antibacterial agent in hygiene products. This study provides a foundation for further development of plant-based antiseptic formulation, contributing to sustainable healthcare alternatives.

Keywords: antimicrobial activity, *Pelargonium graveolens,* Essential oil, natural antiseptic, solid soap.

1. INTRODUCTION

Infectious diseases, caused by bacteria, viruses, parasites or fungi, pose significant global health challenges[1]. The risk of their emergence and spread has increased due to globalization, urbanization, climate change, and human-animals interactions [2, 3]

One of the critical concerns in modern healthcare and hygiene is the rise of antimicrobial resistance, driven by the overuse and misuse of synthetic antimicrobials and personal care products and pharmaceuticals [4-6].

Health hygiene, particularly through the use of antiseptic soaps, is a vital preventive measure in controlling the transmission of infectious agents[7, 8]. However conventional antiseptic soaps often contain synthetic agents such as triclosan and chloroxylenol, and triclocarbanwhich have been linked to skin irritation, environmental toxicity and bacteria resistance. [9-11]. As sustainable alternative, essential oils derived from medicinal plant offer broad-spectrum antimicrobial properties, biocompatibility, and minimal adverse effects. In fact, the use of soap containing natural antiseptics helps reduce the side effects associated with synthetic antiseptic soaps, such as skin issues like dehydration, eczema, sensitivity, and irritation, which can cause redness and persistent pimples. Additionally, it addresses the problem of bacterial resistance caused by the frequent use of synthetic antiseptics [10, 12,13].

Pelargonium graveolens essential oil is known for its rich composition of bioactive compounds, inclusing citronellol, geraniol, 10-epi- γ-eudesmol, which exhibit various therapeutic uses [14], demonstrating strong antibacterial and antifungal properties[15-17].Indeed, Džamić et al[14] showed that *P. graveolens* oil is highly effective against all clinical isolates of *S. aureus*, including drug-resistant strains. Furthermore, they found that geranium essential oil exhibited significant antifungal activity against various fungal strains. This underscores its potential for use in antiseptic soap formulations, offering a natural alternative to synthetic antiseptics while mitigating potential side effects. Several studies have explored the characterization and efficacy of various natural active compounds in solid soap formulations [10,11, 18]. Kirdi et al[8] investigated the physicochemical properties and microbiological quality of solid soaps enriched with tea tree essential oil. Similarly, Soenarno et al [12] examined the antibacterial activity of Tallow-Based soaps incorporating tea tree and peppermint extracts, highlighting the potential of these natural additives to enhance the antiseptic properties of soap.

Despite its widespread use in aromatherapy and traditional medicine,[19] its potential application in antiseptic soap formulations remains an underexplored. This study aims to evaluate the antimicrobial efficacy of *P. graveolens* essential oil in solid soap formulations, with the objective of developing a natural and eco-friendly alternative to synthetic antiseptics. By incorporating essential oils into hygiene products, this research contributes to the ongoing efforts to mitigate antimicrobial resistance and promote sustainable personal care solutions.

2. EXPERIMENTAL

2.1. Materials

2.1.1. Reagents

All oils used were certified and obtained from a local market. The solvents and chemicals were of analytical grade, purchased from VWR Chemicals and Sigma-Aldrich.

2.1.2. Plant material

Fresh aerial parts (leaves, flowers, and stems) of *P. graveolens* were collected at peak bloom in May 2023 from Chiffa region, Blida province, Algeria (Latitude: 36.42°N, Longitude: 2.83°E, Altitude: 280m). The region is characterized by a Mediterranean climate with mild, humid winters and hot, dry summers, providing optimal conditions for essential oil biosynthesis. The plant material was harvested in the early morning to minimize volatile compound loss due to evaporation.The plant was identified by Dr. F. Lebtahi (Laboratory of Plant Biotechnology, Department of genetic improvement, National Forest Research Institute of Bainem INRF, Algiers, Algeria) from El Hama Test Garden in Algiers where a voucher specimen has been placed in the herbarium of El Hama Test Garden (Algiers, Algeria). Sample was gently washed with distilled water and air dried in a shaded, well ventilated area at room temperature for 7 days.

2.1.3. Test microorganisms

We have tested three strains were acquired from the SAIDAL antibiotic complex located in Medea, Algeria. Including : *Staphilococus épidermique ATCC 12228 ;Pseudomonas aeruginosa ATCC 9027 ; Escherichia coli ATCC 8739.*

2.2. METHODS

2.2.1.Essential Oil Extraction

Essential oil of *P. Graveolens*was extracted using hydrodistillation with a Clevenger-type apparatus, following the European Pharmacopoeia guidelines [20]. Dried plant material was finely chopped and placed in 1L flask with distilled water at a ration of 1:5 (w/v) during 3h.

2.2.2. Essential oil analysis

2.2.2.1.Organoleptic Properties
The essential oil was assessed for its appearance, odor, and color.

2.2.2.2. Physical and Chemical Characterization
All **Physical** and chemical paremeters such as : **Relative Density ;Refractive Index ;**Acid and ester Value **; Miscibility with ethanol and pH were teste d**according to AFNOR standards[21].

2.2.2.3. Chromatographic Analysis (GC-MS)
The chemical composition of the essential oil was performed using chromatography-mass spectrometry (GC-MS) on a Hewlett-Packard 6890 system coupled with an HP5973 mass spectrometer. The column used was a HP-5MS capillary column (30m x 0.25mm) with a film thickness of 0.25 µm. The column temperature was programmed from 50°C to 250°C at a rate of 4°C/min. Helium was used as the carrier gas with a flow rate of 1.5 mL/min. The injection mode was split (1:70). The system was connected to a computer system managing a NIST 98 mass spectrum library and controlled by the "HP ChemStation" software, which allowed the monitoring of the chromatographic analysis. Compounds identification was carried out by comparing their retention indices and mass spectral data with reference libraries (NIST 98) and published literature.

2.2.3. Soap preparation
Solid soaps were prepared using a base formulation enriched with 1%, 3%, and 5% *P.graveolens* essential oil. The oils were incorporated into the soap mixture at the saponification stage to preserve bioactivity according to the traditional method [8, 22]. The semi-solid mixture was poured into a mold and allowed to harden at room temperature. A control soap without essential oil served as a reference.

2.2.4. Antimicrobial assay
Antimicrobial activity was assessed using the disc diffusion method [8], against *Escherichia coli* ATCC 8739, *Staphylococcus epidermidis* ATCC 12228, and *Pseudomonas aeruginosa* ATCC 9027. Inhibition zones were measured in millimiters.

2.2.5.Statistical analysis
Data were analyzed using Minitab software (version 22.1). One-way ANOVA was peformed, followed by Dunnett's post hoc test for comparisons. A significant level of $P < 0.05$ was considered statistically significant.

3. RESULTS AND DISCUSSION
3.1. Essential oil yield and chemical composition
Hydrodistillation yielded 0.22% essential oil, higher than the AFNOR standard [21] and previously reported values for Moroccan geranium [23]. The yield variation could be influenced by geographic origin [25], environmental conditions [27], and other factors, such as relative humidity, temperature, total duration of sunshine, and wind conditions, which have a direct impact, particularly on species with superficial histological storage structures like fragrant pelargoniums [15, 16].

Chromatographica analysis identified 27 compound, withcitronellol (29.4%), 10-epi-γ-Eudesmol (26%), and geraniol (8.2%) as major constituents. The dominance of oxygenated monoterpenes (52%) correlates with strong antimicrobial properties. Previous studies have demonstrated that the volatile hydrocarbon profile of *P. graveolens* essential oils is rich in various monoterpenes. Similar findings were reported in previous researchs [14, 25].

Table 1: Chemical composition of *Pelargonium graveolens* essential oil.

Compounds[A]	KIE KIL	%
α-Pinene	932 930	0.2
Linalool	10981097	0.1
Menthone	11361135	1.1
Nerol	12121210	1.6
Citronellol	12121213	29.4

Geraniol	12361235	8.2
Citronellylformate	12601259	7.6
Geraniolformate	13011305	2.2
β-Bourbonene	13781380	0.7
α-Copaene	13791379	1.4
α-Isoledene	13821381	0.5
cis-β–Caryophyllene	14091410	1.0
trans-β-Caryophyllene	14171418	0.9
Aromadendrene	14431468	1.5
α-Humulene	14551454	0.4
allo-Aromadendrene	14601430	0.5
Germacrene-D	14791437	4.0
Geranylpropionate	14861688	1.0
Cis-β-Guaiene	14921653	3.9
Ledene	14961465	2.6
α-Muurolene	15001599	0.1
γ-Cadinene	15071420	2.2
α-Agarofuran	15371509	0.8
Sapthulenol	15721572	0.4
10-*epi*-γ-Eudesmol	16181620	26.0
γ-Eudesmol	16411643	1.7
Geranyltiglate	16701674	3.7
Chemicalclasses		
Monoterpeneshydrocarbons		7.5
Oxygenatedmonoterpenes		52.1
Sesquiterpenehydrocarbons		12.6
Oxygenatedsesquiterpenes		33.1
Totalidentified		95.3

3.2. Organoleptic characteristics

The obtained essential oil presented a yellow-green color and a pronounced lemon-rose scent. The organoleptic parameters are in line with those listed in AFNOR standards (Table 2). This sensory attributes are important for industrial applications, in cosmetics and aromatherapy, enhancing the commercial value of the oil.

Table 2. Organoleptic properties of *P. graveolens* essential oil.

	AFNOR standards [21]	Our study
Appearance	limpide liquid	Liquid
Color	Amber yellow to yellow-green	yellow-green
Odor	Pinkish, ± minty	Pinkish, slightly lemony

3.3. Physicochemical characteristics

The physicochemical parameters confirmed the quality of the oil. The acid value, indicating the level of free acids was within the acceptable range, suggesting good conservation and low degradation of the essential oil [26, 27]. The refractive index closely related to the content of monoterpenes indicating the presence of substantial proportion of oxygenated monoterpens, which are known for their antimicrobial properties (Table 3). A high refractive index is generally associated with a high monoterpene content. According to Kanko et al [26] a low refractive index of the essential oil suggests a low ability to refract light, which could be an advantage for its use in cosmetic products.

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Table 3: Physicochemical Parametersof of *P. graveolens* essential oil.

Parameters	AFNOR[21]	France [26]	Current study
Acid value	10	4-10	5.4
Ester Value	53-76	46-66	65
Miscibility with Ethanol(v/v)	3-5	2-3	3
Density	0.884	905	0.878
Refractive Index	1461-1470	1.4470	1.465

3.4. Antibacterial activity

The antibacterial activity of the soap containing *P.* graveolens essential oil was evaluated against *Escherichia coli*, *Staphylococcus épidermique*, and *Pseudomonas aeruginosa*. The results showed a significant dose-dependent inhibitory effect, with the highest inhibition observed at 5% essential oil concentration. For *S. epidermidis, a gram-positive bacterium, the soap exhibited a notably higher inhibitory effect compared to E. coli and P. aeruginosa* (Table 4). This difference can be attributed to the structural characteristics of Gram-positive bacterial cell walls, which are more susceptible to the penetration of essential oil constituents. Interestingly, *P. aeruginosa*, known for its resistance to many antimicrobial agents, showed a lower but still measurable inhibition, suggesting that the essential oil could serve as a complementary antibacterial agent in hygiene products.

The results of the current study are consistent with those of Soenarno et al[12] and Kirdi et al[8], who reported enhanced antibacterial activities of soaps in corporating tea tree oil and peppermint extracts. The similarity in findings reinforces the potential of essential oils and extracts as natural antiseptic, offering a safer alternative to synthetic compounds that may cause skin irritation and contribute to antimicrobial resistance.

These findings suggest that incorporating *P. graveolens* essential oil into solid soap formulations not only provides an eco-friendly alternative but also enhances antibacterial efficacy, particularly against *gram-positive bacteria.*

Table 4: Solid Soap antimicrobial activity.

	E. Coli	*S.épidermique*	*P. aeruginosa*
A	*8.30± 0.05a*	7.45 ± 1.18a	8.23 ± 1.02
B	*13.50 ± 0.12a*	14.25 ± 0.25c	11.33 ± 0.94
C	*15.03± 1.02b*	16.34 ± 1.83b	10.16 ± 2.11
D	*14.22 ± 0.80a*	17.33 ± 0.04a	11.78 ±3.12

Note: A = addition of 0% *P.graveolens* essential oil, B = 1% *P.graveolens* essential oil, C = 3% *P.graveolens* essential oil, D = 5% *P.graveolens* essential oil. Distinct letters within the same column signify statistically significant differences ($P < 0.05$).

4. CONCLUSION

The study demonstrates the promising potential of *Pelargonium graveolens* essential oil as an antibacterial agent in solid soap formulations. Its rich composition of bioactive compounds, such as citronellol, 10-epi-γ-Eudesmol and geraniol, not only contributes to its antibacterial properties but also provides an alternative to synthetic antiseptics, reducing risks of skin irritation and bacterial resistance. The formulated soap showed notable inhibitory effects on Gram-positive bacteria, supporting its use in personal hygiene to prevent infectious diseases. *Future research sould explore the long term stability of such formulations, their antifungal properties, and their potential for broader antimicrobial applications.* These advancements could further establish *P. graveolens* essential oil-based soap as a viable tool in combating microbial threats in a sustainable and effective manner.

5. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

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