

Ultrasound Assisted Extraction of Lavender Essential Oil and its Potential Applications in Perfumery

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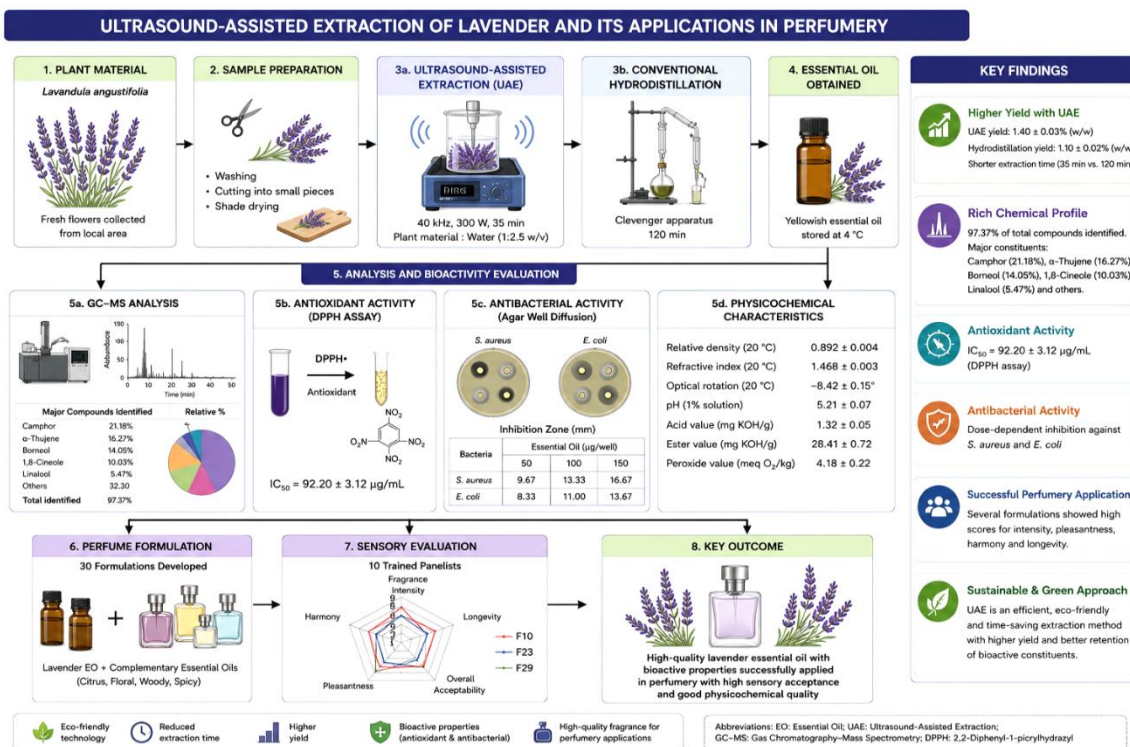
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Summary: Lavender essential oil was well known for its pleasant scent and wide range of uses in the fragrance business. This study contrasted traditional steam distillation with ultrasound-assisted extraction (UAE), an alternate method for extracting lavender essential oil. The extracted oil's chemical makeup, antioxidant activity, antibacterial qualities, extraction yield, and potential for perfume formulation were all examined. UAE outperformed steam distillation in terms of extraction yield at the experimental conditions used. According to GC-MS analysis, the most common volatile chemicals found in the extracted oil were camphor (21.18%), α -thujene (16.27%), and endo-borneol (14.05%). When tested against the bacteria, the lavender essential oil shown significant antimicrobial and antioxidant action. During hedonic evaluation, perfume compositions made with the extracted oil showed acceptable sensory qualities. Under the conditions examined, UAE needed less time for extraction and less solvent than steam distillation. According to the results, ultrasound-assisted extraction may be a viable substitute method for extracting lavender essential oil and using it in perfumery. It was suggested that more research be done to assess its environmental performance and large-scale usability.

Key words: Lavender essential oil, Linalool, Perfume creation, Sensory evaluation, Stability, Ultrasound assisted extraction.

Graphical Abstract:



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Introduction

Perfume, from the Latin *perfumare*, “to smoke through”, has always been used to cover unacceptable odor (Zhang et al., 2013) and to perfume oneself and the environment with the mixture of aromatic compounds, essential oils, solvents, and fixatives (Mahajan, 2022; Schubert, 2006). The characteristic aroma and biological properties of essential oils make them widely used in perfumery, cosmetics, pharmaceuticals, and personal care products. Lavender (*Lavandula angustifolia*) is one of the most commercially important among aromatic plants due to its pleasant floral fragrance and its wide use in perfume formulations. Lavender essential oil is composed of a number of volatile compounds that confer its aromatic quality, as well as its biological activities such as antioxidant and antimicrobial properties (Chemat et al., 2017a).

The extraction method is important for the yield and quality of essential oils. Steam distillation is the most common method used to extract lavender oil, but it can lead to loss or alteration of some volatile compounds due to prolonged heat exposure, and it can require relatively long extraction times. In order to increase extraction efficiency, different extraction techniques have drawn more and more attention (Tiwari, 2015).

Because it can improve mass transfer by acoustic cavitation, which makes it easier for intracellular chemicals to be released from plant tissues, ultrasound-assisted extraction (UAE) has become a potential extraction method. According to earlier research, UAE may increase extraction efficiency while cutting processing time when compared to traditional extraction techniques (Chen & Liu, 2019).

Although lavender essential oil extraction has been the subject of several studies, little is known about the evaluation of extraction yield, chemical composition, biological activities, and perfume formulation performance all at once. Additionally, there are relatively few research that compare steam distillation and ultrasound-assisted extraction for applications linked to perfumery.

Thus, the purpose of this study was to compare the extraction performance of ultrasound-assisted lavender essential oil extraction with that of traditional steam distillation. GC-MS analysis was used to describe the extracted oil, and its antibacterial qualities, antioxidant activity, and appropriateness for perfume formulation were also examined.

Experimental

Study Site and Plant Materials

This research was conducted at the Department of Chemistry, Riphah International University, Faisalabad. Fresh flowers of *Lavandula angustifolia* were sourced from Islamabad and authenticated by a qualified botanist. Fresh (about 1 kg of each) *Lavandula angustifolia* (lavender), *Citrus aurantifolia* (Lemon), *Citrus sinensis* (orange), *Citrus bergamia* (bergamot), *Jasmine grandiflorum* (jasmine), and *Cananga odorata* (ylang-ylang), *Mentha piperita* (peppermint), *Pogostemon cablin* (patchouli), *Melaleuca alternifolia* (Tea tree) were collected from Online stores and Nursery Site from Faisalabad. The collected plant materials were washed to remove unwanted dust material, crushed into a smaller size to make it easier for the extraction and stored overnight in shade and depend on the plant essential oils were extracted from the samples by steam distillation and Ultrasound Assisted Extraction technique (Coelho et al., 2012).

Chemicals and Reagents

This investigation employed only analytical-grade chemicals and reagents. All analytical reagents and 98% ethanol were purchased from Sigma-Aldrich (St. Louis, MO, USA). Methanol, sodium sulfate (anhydrous), dimethyl sulfoxide (DMSO), and other substances utilized in GC-MS analysis, antioxidant, antibacterial, and perfume formulation tests were of analytical grade.

Ultrasound Assisted Extraction (UAE) Method

An ultrasonic bath (VEVOR, Model JPS-08A, 40 kHz, 300 W; China) was used to extract fresh lavender (*Lavandula angustifolia*) flowers (1 kilogram) after they had been cleaned with distilled water and chopped into small pieces. After combining the plant material with 2.5 L of distilled water (1:2.5, w/v), it was sonicated at $30 \pm 2^\circ\text{C}$ for 35 minutes. Essential oil compounds were released more easily and cell wall disintegration was improved by ultrasonic cavitation. After being sonicated, the mixture was hydrodistilled using a Clevenger-style device. The extracted essential oil was placed in amber glass vials, dried over anhydrous sodium sulfate, and kept at 4°C for additional examination. The data were reported as mean $\pm$ standard deviation (SD), and each experiment was conducted in triplicate ($n = 3$) (Tongnuanchan & Benjakul, 2014).

In order to optimize the procedure for optimum oil recovery, this parameter was utilized to compare the efficiency of various extraction conditions.

$$\text{Yield (\%)} = \frac{\text{Weight of essential oil extracted (grams)}}{\text{Weight of dry plant material used (grams)}} \times 100$$

Steam Distillation

As a comparison extraction procedure, fresh *Lavandula angustifolia* flowers (1 kg) were treated to traditional hydrodistillation using a Clevenger-type apparatus. After submerging the flowers in 3.0 L of distilled water (plant-to-water ratio: 1:3, w/v), they were distilled under atmospheric pressure for three hours until no more essential oil could be extracted.

After being extracted from the aqueous phase, the distilled essential oil was dried over anhydrous sodium sulfate, its oil yield was determined gravimetrically, and it was kept in amber glass vials at 4°C until additional physicochemical, GC-MS, antioxidant, antimicrobial, and perfume formulation analyses were performed (Ivanova et al., 2025).

Every extraction was performed in triplicate (n = 3), and the mean ± standard deviation (SD) was used to express the results. In order to compare ultrasound-assisted extraction with the traditional extraction method, the steam distillation process was used (Clevenger, 1928).

Gas Chromatography Mass Spectrometry (GC-MS) Analysis

A GC-MS system (Agilent 7890B GC paired with an Agilent 5977A Mass Selective Detector, Agilent Technologies, Santa Clara, CA, USA) fitted with an HP-5MS capillary column (30 m × 0.25 mm ×

0.25 µm) was used to analyze the chemical composition of lavender essential oil. The carrier gas was 99.999% helium at a steady flow rate of 1.0 mL min⁻¹. Split mode (1:20) was used to inject a 1 µL diluted sample while keeping the injector temperature at 250°C. The temperature of the oven was set between 50°C and 250°C. Over the m/z range of 40–500, mass spectra were obtained via electron ionization (70 eV). By comparing their retention indices (RI) with values found in published literature and their mass spectra with the NIST 17 Mass Spectral Library, volatile chemicals were identified. Every analysis was carried out in triplicate (n = 3) (P. Chen et al., 2019).

Perfume Formulation

Lavender (*Lavandula angustifolia*) essential oil produced by ultrasound-assisted extraction (UAE) was used as the primary fragrance ingredient in 30 perfume compositions (F1–F30). Citrus sinensis, Citrus bergamia, Citrus aurantifolia, Jasminum grandiflorum, Mentha piperita, Pogostemon cablin, Melaleuca alternifolia, and Cananga odorata are some of the essential oils that were mixed with lavender to represent top, medium, and base aroma notes. Table-1 summarizes the fragrance compositions with different aromatic properties that were created using different ratios of lavender essential oil and complimentary essential oils (e.g., 50:50 and 40:60). The essential oil mixes were diluted with 10% distilled water and 90% ethanol. In certain formulations, acetone (<0.5%, v/v) was used to enhance scent fixation and solubility. Before being subjected to sensory evaluation, each formulation was properly mixed by gently shaking it for three to five minutes. It was then put into amber glass bottles and allowed to mature for fourteen days at 4°C in the dark to stabilize the scent (Burger et al., 2019; Hatwar et al., 2024). This maturation procedure improved the fragrance's depth and balance as shown in Table-1

Table-1: Composition of perfume formulas made with the essential oil of lavender (*Lavandula angustifolia*).

Formulation	Lavender EO (%)	Essential Oil Blend (%)	Top/Middle-Base Notes
F1	80	10 <i>Citrus sinensis</i> + 10 <i>Pogostemon cablin</i>	Orange-Patchouli
F2	60	20 <i>Citrus sinensis</i> + 20 <i>Pogostemon cablin</i>	Orange-Patchouli
F3	50	40 <i>Citrus sinensis</i> + 10 <i>Pogostemon cablin</i>	Orange-Patchouli
F4	40	30 <i>Citrus sinensis</i> + 30 <i>Pogostemon cablin</i>	Orange-Patchouli
F5	30	40 <i>Citrus sinensis</i> + 30 <i>Pogostemon cablin</i>	Orange-Patchouli
F6	80	10 <i>Citrus bergamia</i> + 10 <i>Melaleuca alternifolia</i>	Bergamot-Tea tree
F7	60	20 <i>Citrus bergamia</i> + 20 <i>Melaleuca alternifolia</i>	Bergamot-Tea tree
F8	50	40 <i>Citrus bergamia</i> + 10 <i>Melaleuca alternifolia</i>	Bergamot-Tea tree
F9	40	30 <i>Citrus bergamia</i> + 30 <i>Melaleuca alternifolia</i>	Bergamot-Tea tree
F10	30	40 <i>Citrus bergamia</i> + 30 <i>Melaleuca alternifolia</i>	Bergamot-Tea tree
F11	80	10 <i>Jasminum grandiflorum</i> + 10 <i>Mentha piperita</i>	Jasmine-Peppermint
F12	60	20 <i>Jasminum grandiflorum</i> + 20 <i>Mentha piperita</i>	Jasmine-Peppermint
F13	50	40 <i>Jasminum grandiflorum</i> + 10 <i>Mentha piperita</i>	Jasmine-Peppermint
F14	40	30 <i>Jasminum grandiflorum</i> + 30 <i>Mentha piperita</i>	Jasmine-Peppermint
F15	30	30 <i>Jasminum grandiflorum</i> + 40 <i>Mentha piperita</i>	Jasmine-Peppermint
F16	80	10 <i>Citrus aurantifolia</i> + 10 <i>Cananga odorata</i>	Lemon-Ylang-ylang

F17	60	20 <i>Citrus aurantifolia</i> + 20 <i>Cananga odorata</i>	Lemon-Ylang-ylang
F18	50	40 <i>Citrus aurantifolia</i> + 10 <i>Cananga odorata</i>	Lemon-Ylang-ylang
F19	40	30 <i>Citrus aurantifolia</i> + 30 <i>Cananga odorata</i>	Lemon-Ylang-ylang
F20	30	30 <i>Citrus aurantifolia</i> + 40 <i>Cananga odorata</i>	Lemon-Ylang-ylang
F21	80	10 <i>Jasminum grandiflorum</i> + 10 <i>Cananga odorata</i>	Jasmine-Ylang-ylang
F22	60	20 <i>Jasminum grandiflorum</i> + 20 <i>Cananga odorata</i>	Jasmine-Ylang-ylang
F23	40	40 <i>Jasminum grandiflorum</i> + 20 <i>Cananga odorata</i>	Jasmine-Ylang-ylang
F24	40	30 <i>Jasminum grandiflorum</i> + 30 <i>Cananga odorata</i>	Jasmine-Ylang-ylang
F25	30	30 <i>Jasminum grandiflorum</i> + 40 <i>Cananga odorata</i>	Jasmine-Ylang-ylang
F26	80	10 <i>Citrus sinensis</i> + 10 <i>Melaleuca alternifolia</i>	Orange-Tea tree
F27	60	20 <i>Citrus aurantifolia</i> + 20 <i>Pogostemon cablin</i>	Lemon-Patchouli
F28	50	30 <i>Jasminum grandiflorum</i> + 20 <i>Citrus bergamia</i>	Jasmine-Bergamot
F29	40	30 <i>Cananga odorata</i> + 30 <i>Mentha piperita</i>	Ylang-ylang-Peppermint
F30	30	40 <i>Jasminum grandiflorum</i> + 30 <i>Pogostemon cablin</i>	Jasmine-Patchouli

Sensory Evaluation

A panel of ten volunteers assessed the developed scent formulas on a 5-point hedonic scale. The compositions were evaluated for overall preference, longevity, pleasantness, and aroma intensity. Every formulation was given in the same way, and each panelist assessed the samples on their own. All individuals gave their informed consent before the sensory evaluation. Mean $\pm$ standard deviation (SD) was used to express the average sensory scores. Table-2 lists the evaluation standards for sensory assessment (Guo & Wang, 2020; Kliszcz et al., 2021).

Table-2: Panelist evaluation criteria for perfume scent intensity.

Sr.No	Score	Hedonic response
1	Like extremely	5
2	Like moderately	4
3	Neither like nor dislike	3
4	Dislike slightly	2
5	Dislike extremely	1

A panel of ten skilled evaluators assessed perfume formulas according to their overall preference, longevity, pleasantness, and intensity of scent.

Antioxidant Activity (DPPH Assay)

The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging experiment was used to assess lavender essential oil's antioxidant activity. A methanol solution containing 0.1 mM DPPH was made. The DPPH solution was combined with various amounts of lavender essential oil and allowed to sit at room temperature for half an hour in the dark. Using a UV-visible spectrophotometer, the absorbance was determined at 517 nm. The blank was methanol containing DPPH, while the positive control was ascorbic acid. Using the following formula, radical scavenging activity was determined (Danh et al., 2012):

$$\text{DPPH inhibition (\%)} = [(A_0 - A_1)/A_0] \times 100$$

where A_0 stands for the control's absorbance and A_1 for the sample's absorbance. Every analysis was carried out in triplicate ($n = 3$) and reported as mean $\pm$ SD.

Antimicrobial Effects

Antimicrobial activity of lavender essential oil was tested against *Escherichia coli* and *Staphylococcus aureus* by agar well diffusion method. Freshly prepared bacterial cultures were inoculated onto sterile Mueller–Hinton agar plates. Wells of 6 mm diameter were bored in the agar and filled with essential oil sample. Plates were incubated at 37 °C for 24 h and the inhibition zones were measured in millimetres (mm). All experiments were performed in triplicate ($n = 3$) and the results are expressed as mean $\pm$ standard deviation (SD) (Ibrahim et al., 2021).

Results and Discussion

Yield Comparison: Ultrasound-Assisted vs. Traditional Extraction

When compared to conventional steam distillation, the ultrasound-assisted extraction (UAE) approach showed a noticeably larger yield of essential oils. UAE produced a 1.4% yield, which was explained by improved solvent penetration brought on by cavitation effects and increased cell wall disintegration (Mihalcea et al., 2020). The yield via steam distillation, on the other hand, was lower, mostly as a result of the volatiles' partial degradation and extended heat exposure as shown in table 3.

Table-3: Comparing the yield of essential oils produced by traditional hydrodistillation with ultrasound-assisted extraction.

Extraction Method	Extraction Time (min)	Essential Oil Yield (% w/w)
Ultrasound-assisted extraction (40 kHz, 300 W)	35	1.40 $\pm$ 0.03
Conventional hydrodistillation	120	1.10 $\pm$ 0.02

UAE's effectiveness is demonstrated not only by increased yield but also by shorter extraction times and better thermo labile component preservation.

Chemical Composition: Enhanced Retention of Aromatics

Eleven volatile components were found in the lavender essential oil that was extracted using ultrasound assistance, according to GC-MS analysis. Camphor (21.18%), α -thujene (16.27%), and endo-borneol (14.05%) were the most common chemicals, followed by 1,8-cineole (10.03%), β -pinene (9.25%), and α -pinene (7.09%). As seen in Table 4, the other components were found at lower relative abundances (Cimino et al., 2021).

RT = Retention Time; RI = Retention Index. Volatile compounds were identified by comparing their mass spectra with the NIST 17 Mass Spectral Library and their retention indices with published literature values.

Table-4: Volatile Constituents Identified in Lavender Essential Oil by GC-MS.

Plant material	Essential oil yield (g EO/100 g)	Refractive index (n _D ²⁰)	Optical rotation (α _D ²⁰)
Fresh flowers	1.57 $\pm$ 0.044 g	1.4654 $\pm$ 0.00023	-3.508 $\pm$ 0.0147
Dried flowers	2.85 $\pm$ 0.151 g	1.4647 $\pm$ 0.00012	-5.552 $\pm$ 0.0208
Fresh aerial parts	0.72 $\pm$ 0.038 g	1.4612 $\pm$ 0.00013	-4.836 $\pm$ 0.0127
Dried aerial parts	1.40 $\pm$ 0.015 g	1.4652 $\pm$ 0.00022	-3.718 $\pm$ 0.0012
Fresh stems	0.06 $\pm$ 0.003 g	1.4791 $\pm$ 0.00037	-4.342 $\pm$ 0.0021

Physical and Sensory Analysis

Lavandula angustifolia essential oil's physical properties, such as extraction yield, refractive index (n_D²¹), and optical rotation (α _D²¹), changed depending on the part of the plant and its moisture content (Table 5). Fresh stems yielded the least amount of essential oil (0.06 $\pm$ 0.003 g EO/100 g), whereas dried flowers yielded the most (2.85 $\pm$ 0.151 g EO/100 g). Fresh flowers produced 1.57 $\pm$ 0.044 g EO/100 g, suggesting that drying improved the recovery of essential oils by lowering the plant material's moisture content. Aerial parts showed similar tendencies, with dried samples yielding more oil than fresh samples. The refractive index and optical rotation of the various plant components also varied slightly, indicating variances in the stereochemical properties and chemical makeup of the extracted essential oils. The higher essential oil yield seen in dried flowers is in line with earlier findings that found that removing moisture increased the concentration of

volatile compounds, improving the efficiency of essential oil extraction. Due to variations in plant part, drying circumstances, and chemical composition, lavender essential oils have also been found to exhibit similar variations in refractive index and optical rotation.

Table-5: The physical characteristics of essential oil produced from various *Lavandula angustifolia* sections.

Compound	RT (min)	Experimental RI	Literature RI	Composition (%)
α -Pinene	6.082	912	910	7.09
β -Phellandrene	7.264	1005	1009	1.84
β -Pinene	7.367	964	961	9.25
β -Myrcene	7.841	980	977	3.64
α -Thujene	9.223	903	906	16.27
β -Ocimene	9.573	1025	1020	1.92
1,8-Cineole	9.582	1018	1020	10.03
Linalool	11.982	1077	1089	2.54
Camphor	13.918	1119	1127	21.18
Endo-borneol	14.818	1136	1155	14.05
α -Terpineol	15.781	1170	1161	3.46

The mean $\pm$ standard deviation (SD) of triple determinations (n = 3) is used to present the values.

Fragrance Profile: Sensory Quality and Stability

A panel of ten skilled assessors used a 5-point hedonic scale to evaluate the sensory qualities of the thirty lavender perfume compositions. The formulas were evaluated according to their general acceptability, longevity, pleasantness, and strength of aroma. Significant variances were found between the formulations, suggesting that the overall scent profile was impacted by differences in the content of lavender essential oil and complementary essential oils (Tongnuanchan & Benjakul, 2014). The formulations with the highest sensory scores among those studied were F1, F6, F17, F21, and F24 (Table 6). When compared to the other formulations, these ones showed better aroma strength, pleasantness, longevity, and general acceptance. The balanced blend of lavender essential oil with citrus, floral, and woody essential oils may have contributed to the enhanced sensory performance by creating a more pleasing and long-lasting smell profile. Formulations with somewhat unbalanced fragrance combinations, on the other hand, scored worse on the sensory scale. Overall, the findings showed that customer preference and scent quality were significantly influenced by the composition and ratio of essential oils (Ameh et al., 2021).

Table-6: The five most popular lavender perfume formulas' sensory ratings.

Formulation ID	Top Note	Middle Note	Base Note	Fragrance Intensity	Pleasantness	Longevity	Overall Acceptance (%)
F1	Lavender	Orange	Patchouli	4.8 / 5	4.7 / 5	4.5 / 5	88
F6	Lavender	Bergamot	Tea Tree	4.6 / 5	4.5 / 5	4.4 / 5	85
F17	Lavender	Jasmine	Peppermint	4.5 / 5	4.6 / 5	4.3 / 5	83
F21	Lavender	Lemon	Ylang-Ylang	4.7 / 5	4.6 / 5	4.4 / 5	86
F24	Lavender	Jasmine	Ylang-Ylang	4.6 / 5	4.7 / 5	4.5 / 5	87

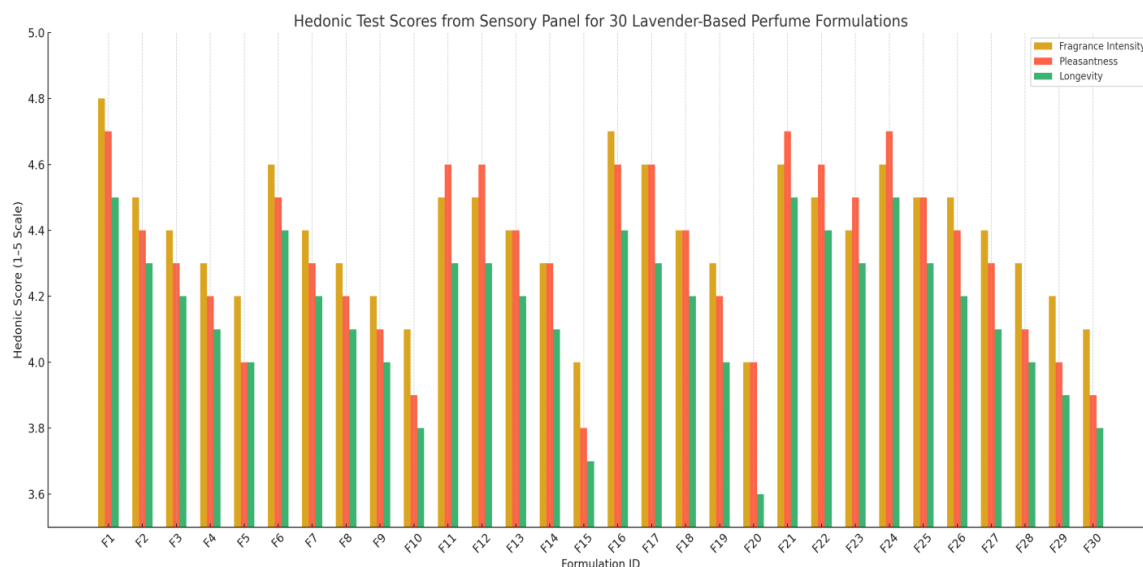


Fig. 1: Ten trained panelists used a 5-point hedonic scale to assess the hedonic sensory ratings (fragrance intensity, pleasantness, & longevity) of 30 lavender-based perfume compositions.

Using a 5-point hedonic scale, ten trained panelists assessed the hedonic sensory scores of all thirty lavender-based perfume compositions, as shown in Fig. 1. When the aroma intensity, pleasantness, & longevity of the formulations were evaluated, the various perfume compositions showed discernible differences.

F1, F6, F17, F21, and F24 had the highest overall sensory scores of all the formulations, suggesting that they were more well-liked by consumers. Formulations F21 and F24 had the highest pleasantness scores (4.7), and formulation F1 had the highest scent intensity score (4.8). Formulations F10, F15, F20, F29, and F30, on the other hand, displayed relatively lower sensory ratings, indicating that their essential oil blends resulted in less appealing scent characteristics.

The findings also showed that scent strength, pleasantness, and longevity were often enhanced in formulations with *Lavandula angustifolia* serving as the predominant top note and balanced citrus, floral, as well as woody essential oils. These results show that the essential oils' ratio and compatibility had a major impact on the perfumes' overall sensory quality & customer choice. As indicated in Table 6, the top-

ranked formulations were thus chosen for more discussion.

Biological Properties: Antimicrobial and Antioxidant Potential

The agar well diffusion method demonstrated the antibacterial activity of lavender essential oil produced by ultrasound-assisted extraction (UAE) against *Escherichia coli* and *Staphylococcus aureus*. The inhibition zones against *S. aureus* and *E. coli* were roughly 20 and 15 mm, respectively, as shown in Table 7. With a 75–80% DPPH radical scavenging activity, the essential oil also showed significant antioxidant activity, suggesting its potential as a natural bioactive component for perfumery and related uses.

Table-7: UAE-Extracted Lavender Essential Oil's Antimicrobial and Antioxidant Properties.

Biological activity	Results
<i>S. aureus</i> inhibition zone(mm)	~20
<i>E. coli</i> inhibition zone(mm)	~15
DPPH Radical Scavenging	75–80

The presence of oxygenated monoterpenes found by GC–MS analysis, including camphor, endo-borneol, and 1,8-cineole, may be responsible for the

antibacterial activity of lavender essential oil. These substances have been shown to damage microbial cell membranes and prevent the growth of bacteria. The essential oil's potential application as a natural antioxidant in perfumery and other value-added compositions is further supported by the significant DPPH radical scavenging activity, which shows the oil's capacity to neutralize free radicals.

Sustainability

Due to its ability to improve mass transfer through acoustic cavitation and shorten extraction times as compared to traditional hydrodistillation, ultrasound-assisted extraction (UAE) is widely acknowledged as a potential green extraction approach. In the current investigation, traditional steam distillation took about 2 h to recover oil, while UAE required 35 min of sonication, showing a significant reduction in processing time. Additionally, UAE was carried out without the use of dangerous organic solvents during extraction by employing distilled water as the extraction medium. Previous research suggests that UAE's shorter extraction time and lower processing temperature may help preserve thermolabile volatile chemicals better and consume less energy and solvent. However, as energy consumption, solvent waste, environmental impact, and worker safety were not directly measured in this study, these factors should be viewed as potential benefits of the UAE that have been supported by prior research rather than as empirically validated findings (Chemat et al., 2017b)

Applications in Perfumery

Perfume Formulation: Role of Lavender Oil

The essential oil of *Lavandula angustifolia* (lavender) has a balanced aromatic composition that makes it useful in perfumery. Along with other ingredients like jasmine, *Citrus oils* (orange, bergamot, lemon), or woody bases (patchouli, tea tree and ylang-ylang), lavender can be used as a top note in fragrance compositions, providing an instant fresh, herbaceous aroma, and a middle note, adding floral depth and heart note longevity. The usage of lavender as the main top note in created mixes (such as F1 and F6), in conjunction with *Citrus & herbal oils*, produced better results and increased consumer approval (88% for F1).

Fixative Role and Chemical Interactions

The main volatile components found in the UAE-extracted lavender essential oil, such as

camphor, borneol, 1,8-cineole, α -thujene, and linalool, interacted with complementary essential oils like patchouli and ylang-ylang to affect the fragrance performance of the developed perfume formulations. By facilitating the transition between top, middle, & base notes, these elements helped to balance the overall smell character. Specifically, patchouli & ylang-ylang, which are known to be base-note oils that have lower volatility, probably improved the perfume formulations' overall sensory perception and increased, smell persistence. Nevertheless, the fixative mechanism or molecular interactions of particular drugs were not directly assessed in this investigation.

Consumer Trends and Market Relevance

Nowadays, fragrance producers target using natural, free-from allergens and ecologically friendly ingredients in their products.

- Its biodegradable and non-toxic profile.
- Widespread regulatory acceptance (e.g., ISO 3515:2002 for lavender oil quality)
- Consumers demand familiar, safe and natural fragrances in the products.

Simultaneously, increased awareness regarding synthetic fragrances allergies and their impact on the environment has propelled plant-based perfumery more attractive securing the UAE produced lavender's standing as part of the clean label and environment aware brands.

Conclusion

This study showed that *Lavandula angustifolia* can produce high-quality essential oil using ultrasound-assisted extraction (UAE). The extracted oil was rich in oxygenated monoterpenes, with camphor, α -thujene, borneol, and 1,8-cineole being the main components, according to GC-MS analysis. The essential oil's promise as a naturally occurring bioactive ingredient was supported by its encouraging antibacterial and antioxidant properties. Selected blends from the thirty perfume compositions had good sensory acceptance, suggesting that the right mixes of lavender essential oil with complementary essential oils improved the intensity, pleasantness, and longevity of the scent. Overall, the results indicate that lavender essential oil produced from the UAE has a great deal of promise for use in perfume formulation and other scent applications. To assist potential industrial application, more research on long-term stability, pilot-scale processing, and techno-economic evaluation is advised.

References

1. Ameh, O., Achika, J., Bello, N., & Owolaja, A. (2021). Extraction and formulation of perfume from *Cymbopogon citratus* (lemongrass). *Journal of Applied Sciences and Environmental Management*, 25(8), 1461-1463.
2. Burger, P., Plainfossé, H., Brochet, X., Chemat, F., & Fernandez, X. (2019). Extraction of natural fragrance ingredients: History overview and future trends. *Chemistry & biodiversity*, 16(10), 1900424-1190078.
3. Chemat, F., Rombaut, N., Sicaire, A.-G., Meullemiestre, A., Fabiano-Tixier, A.-S., & Abert-Vian, M. (2017a). Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review. *Ultrasonics sonochemistry*, 34, 540-560.
4. Chemat, F., Rombaut, N., Sicaire, A.-G., Meullemiestre, A., Fabiano-Tixier, A.-S., & Abert-Vian, M. (2017b). Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review. *Ultrasonics sonochemistry*, 34(11), 540-560.
5. Chen, & Liu, B., Jihong. (2019). Ultrasound-assisted extraction and dispersive liquid-liquid microextraction coupled with gas chromatography-mass spectrometry for the sensitive determination of essential oil components in lavender. *Analytical Methods*, 11(11), 1541-1550.
6. Chen, P., Liu, B., Liu, X., & Fu, J. (2019). Ultrasound-assisted extraction and dispersive liquid-liquid microextraction coupled with gas chromatography-mass spectrometry for the sensitive determination of essential oil components in lavender. *Analytical Methods*, 11(11), 1541-1550.
7. Cimino, C., Maurel, O. M., Musumeci, T., Bonaccorso, A., Drago, F., Souto, E. M. B., . . . Carbone, C. (2021). Essential oils: Pharmaceutical applications and encapsulation strategies into lipid-based delivery systems. *Pharmaceutics*, 13(3), 327-345.
8. Clevenger, J. (1928). Apparatus for the determination of volatile oil. *The Journal of the American Pharmaceutical Association* (1912), 17(4), 345-349.
9. Coelho, J., Cristino, Matos, Rauter, Nobre, B. P., Mendes, R. L., . . . Fareleira. (2012). Extraction of volatile oil from aromatic plants with supercritical carbon dioxide: experiments and modeling. *Molecules*, 17(9), 10550-10573.
10. Danh, L. T., Triet, N. D. A., Zhao, J., Mammucari, R., & Foster, N. (2012). Antioxidant activity, yield and chemical composition of lavender essential oil extracted by supercritical CO₂. *The Journal of Supercritical Fluids*, 70(13), 27-34.
11. Guo, X., & Wang, P. (2020). Aroma characteristics of lavender extract and essential oil from *Lavandula angustifolia* mill. *Molecules*, 25(23), 5541-5576.
12. Hatwar, P., Dandge, P., Jagtap, P., Gaikwad, S., Jadhav, P., Sonawane, V., & Sanap, G. (2024). Formulation and evaluation of solid perfumes. *Journal of agricultural and food chemistry*, 5(3), 77-108.
13. Ibrahim, M., Ankwai, G., Taave, P., Gungshik, J., & Wapwera, J. (2021). Optimization of essential oil extraction of *Cymbopogon* spp (LEMON GRASS) and its applications in perfume formulation. *Journal of Chemical Society of Nigeria*, 46(6), 65-89.
14. Ivanova, S., Ivanov, K., Gvozdeva, Y., Staynova, R., Grekova-Kafalova, D., Hristozova, M., & Koleva, N. (2025). Essential oils—a review of the regulatory framework in the European Union. *Pharmacia*, 72, 1-12.
15. Kliszcz, A., Danel, A., Puła, J., Barabasz-Krasny, B., & Możdżeń, K. (2021). Fleeting beauty—The world of plant fragrances and their application. *Molecules*, 26(9), 2473.
16. Mahajan, V. K. (2022). Perfumes and associated allergens: A brief review. *Cosmoderma*, 2(1), 222-234.
17. Mihalcea, L., Aprodu, I., Socaci, S. A., Cotârlet, M., Enachi, E., Crăciunescu, O., . . . Alexe, P. (2020). Fostering lavender as a source for valuable bioactives for food and pharmaceutical applications through extraction and microencapsulation. *Molecules*, 25(21), 5001-5034.
18. Schubert, H. j. (2006). Skin diseases in workers at a perfume factory. *Contact Dermatitis*, 55(2), 81-83.
19. Tiwari, B. K. (2015). Ultrasound: A clean, green extraction technology. *TrAC Trends in Analytical Chemistry*, 71, 100-109.
20. Tongnuanchan, P., & Benjakul, S. (2014). Essential oils: extraction, bioactivities, and their uses for food preservation. *Journal of food science*, 79(7), R1231-R1249.
21. Zhang, Satinder Kaur, Yan, S., Tyagi, R. D., & Surampalli, R. Y. (2013). Fate and transport of fragrance materials in principal environmental sinks. *Chemosphere*, 93(6), 857-869.