International
Journal of Agriculture Innovations
and Cutting-Edge Research

Comparative Quality Evaluation of Commercial Essential Oil Brands Using Phytochemical Profiling, FTIR Spectroscopy, Antioxidant Capacity, and Antibacterial Assessment

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Abstract

Essential oils are being widely used in the pharmaceutical, cosmetic, food, and aromatherapy industry due to their varied biological activities. However, increased commercial need for these oils has resulted in concerns related to the quality, authenticity, and variations in composition of products available in the market. The present study was conducted to compare the chemical properties and quality of two commercial brands of Rosmarinus officinalis, Lavandula angustifolia, and Rosa damascena essential oils available in Daska city, Pakistan. Six commercial essential oil samples from two brands of three plant species were collected. Oil fractions were made in methanol, ethanol, and distilled water, whereas chloroform and n-hexane failed to form oil fractions. Phytochemical analysis was conducted qualitatively for the detection of secondary metabolites; infrared spectroscopy (4000-400 cm^{-1}) was conducted to identify functional groups; total phenolic content (TPC) was measured by the Folin-Ciocalteu method, and antibacterial potential was tested against the bacterial strains. Variations in the amounts of phytochemicals were seen in the essential oil fractions, including alkaloids, flavonoids, tannins, proteins, carbohydrates, cardiac glycosides, phenols, reducing sugars, saponins, and amino acids, but with Rosa damascena (NB brand) having the largest number of phytochemicals detected. FTIR analyses detected some functional groups including O–H, C–H, C=O, C–O, C=C, and C–N. The methanolic fraction of Rosmarinus officinalis (HM brand) contained the highest amount of total phenolic content (434.075 ± 0.004), while the lowest amount was found in the ethanolic fraction of Lavandula angustifolia (NB brand) (0.055 ± 0.003). No antibacterial activity was demonstrated by any of the samples used. These results reveal variations in the compositions of commercially available essential oils and indicate the need for further authentication of the products by using chromatographic methods, for example, GC-MS or GC-FID.

Keywords: Essential oils; Adulteration; Quality assessment; Phytochemical screening; FTIR analysis; Antioxidant activity; Antibacterial activity; Total phenolic content; Bioactive compounds; Quality control.

CrossRef. DOI:	10.67244/jai.bwo-researches.v4i3.a259
Journal Link:	https://jai.bwo-researches.com/index.php/jwr/index
Paper Link:	https://jai.bwo-researches.com/index.php/jwr/article/view/259
Video Overview TeLink:	https://youtu.be/QV2bx3dY_OY
Publication Process	Received: 17 May 2026/ Revised: 29 June 2026/ Accepted: 08 July 2026/ Published: 11 July 2026
ISSN:	Online [3007-0929], Print [3007-0910]

| *Indexing:* | Academia.edu, DRJI, Google, INDEX COPERNICUS INTERNATIONAL, Crossref |

Joint Publishers: BWO Research Pvt. Ltd., Islamabad, and BWO International, Ontario, Canada https://www.bwo-researches.com

Graphical Abstract

Annexure (A)

Introduction

For many years, essential oils (EOs) have been exploited due to their healing, cosmetic, anti-fungal, anti-parasitic, and anti-bacterial characteristics. In the contemporary world, essential oils are commonly used in the pharmaceutical, food, agricultural, and cosmetic industries owing to their antioxidant and other biological activities, which vary according to their composition and concentrations (Husnu et al., 2007). Essential oils are aromatic and volatile substances obtained from plants mainly through the process of steam distillation (Ríos et al., 2016). These substances are produced through specific secretion organs, and their compositions differ depending on the type of plant, geographical location, environmental conditions, extraction procedures, and preservation (Bakkali et al., 2008). The growing demands for EOs across the globe have led to the issue of adulteration of these essential oils through dilution, substitution, synthetic adulterants, or even solvents. This is likely to alter the chemical composition of the EOs and thus compromise their biological effectiveness. Consequently, it is imperative to adopt reliable and economical methodologies to assess the quality and authenticity of EOs (Do et al., 2015; Ghaffar et al., 2026).

The identification of active compounds for the biological activity of plants through phytochemical analysis is an important technique that can be used in several sectors, including the pharmaceutical, cosmetic, nutraceutical, and food industry. The Fourier Transform Infrared Spectroscopy (FTIR) technique is rapid, nondestructive, eco-friendly, and extensively used for characterization of phytochemical composition and identification of functional groups in plant products (Brangule et al., 2020). FTIR can also be helpful in sustainable research on medicinal plants and biodiversity (Arora & Mishra, 2009; Brangule et al., 2020). Different methods, including GC–MS, GC–FID, HPLC, FTIR, phytochemical analysis, antioxidant, and antibacterial testing, have been used in the evaluation of essential oils (Do et al., 2015). From these methods, FTIR offers a rapid and economical means of identifying functional groups and compositional differences, while phytochemical analysis and TPC offer initial information about bioactive compounds and antioxidant activities (Cozzolino, 2014; Brangule et al., 2020). Rosmarinus officinalis and Lavandula angustifolia, two representatives of the Lamiaceae family, are important aromatic plants used by food, pharmaceutical, and cosmetic industries. Rosemary essential oil exhibits antimicrobial, antifungal, antioxidative, and preservative activity and is known since ancient times for its use both as a spice and medicine (Hernández et al., 2016; Ribeiro-Santos et al., 2015). In the same way, L. angustifolia essential oil is famous for its low toxicological effect, nice fragrance, and anxiolytic, antimicrobial, antioxidative, and antiseptic properties, which are associated with its main components, linalool and linalyl acetate (Silva et al., 2023; Erland et al., 2016). This Mediterranean plant is commonly used in phytotherapy, aromatherapy, cosmetology, hygiene care, and the food industry (Erland & Mahmoud, 2016).

In like manner, Rosa damascena, also known as Damask rose, generates one of the most expensive essential oils due to its unique scent and medicinal benefits. Rose essential oil has antioxidant and antibacterial properties and has been utilized in different industries such as the food, pharmaceutical, cosmetic, and perfumery industries to preserve quality

and increase the aroma (Nasery et al., 2016). Despite a significant amount of research on the composition, antioxidant activity, and medicinal uses of essential oils isolated under laboratory conditions, there is comparatively a lack of research regarding the quality and purity of commercially available essential oils that are being sold in the Pakistani markets, especially in Daska. Additionally, there is very little literature that combines studies on phytochemical screening, FTIR analysis, antioxidant activity, and antibacterial activity in commercially available essential oils (Shaojie Yang et al., 2023; Ghaffar et al., 2026).

Thus, the present study has been conducted to compare commercially available essential oils of Rosmarinus officinalis, Lavandula angustifolia, and Rosa damascena by employing qualitative phytochemical analysis, FTIR spectroscopic analysis, total phenolic content (TPC), antioxidant assay, and antibacterial assays. The results of the current study will help in establishing scientific proof regarding the quality, authenticity, phytochemical composition, antioxidant property, and antibacterial property of commercially available essential oils.

Materials and Methods

Research Design

This experiment was conducted as an experimental comparison study aimed at assessing the chemical quality of commercially available brands of essential oil. A comparison of these brands was carried out through phytochemical screening, Fourier Transform Infrared Spectroscopy (FTIR), determination of total phenolic content (TPC), and antibacterial studies.

Collection of Essential Oil Samples:

Six samples of Rosmarinus officinalis, Lavandula angustifolia, and Rosa damascena essential oils, available in the market, were obtained from two local companies (HM & NB) from Daska, Punjab, Pakistan. These samples were kept in their original bottles at room temperature and were subjected to phytochemical screening, FTIR spectrophotometry, total phenolic content (TPC), and antibacterial activity tests to assess their quality and purity.

Sample Preparation

The collected essential oil samples were prepared for phytochemical analysis by dissolving 20 mL of each oil in 20 mL of solvents of varying polarity (methanol, ethanol, distilled water, chloroform, and n-hexane). After thorough mixing, phase separation was observed only with methanol, ethanol, and distilled water; chloroform and n-hexane failed to form distinct layers. The resulting fractions were labeled according to plant species, solvent type, and commercial brand.

Phytochemical analysis and pre-treatment:

Took 20ml of oil, dissolved in 20ml of different solvents according to their increasing polarity index value. Took 20ml of different oils and dissolve in methanol, ethanol, distilled water, chloroform, and n-hexane, and separated the layers one by one. And then marked them with the solvent and essential oil name with the brand name. There was no formation of layers in essential oils with n-hexane and chloroform. After obtaining the active fractions from different essential oils, the following tests were performed to get an idea about the type of phytochemicals present in the fractions.

Qualitative Phytochemical Screening

The qualitative analysis of the phytochemicals in the essential oil fractions was conducted using different qualitative tests for the determination of alkaloids, glycosides, tannins, saponins, flavonoids,

phenols, amino acids, proteins, reducing sugars, and carbohydrates. The presence of alkaloids was determined using Wagner's reagent, while glycosides were detected through acid hydrolysis and Fehling's test. Tannins were determined using the potassium hydroxide test, while saponins were determined using the standard qualitative test. Flavonoids were determined using concentrated sulfuric acid and alcohol; phenols were detected using sodium hydroxide. Amino acids were detected using the ninhydrin test, while proteins were detected using the Biuret test.

Fourier Transform Infrared Spectrophotometer (FTIR) Analysis:

The identification of functional groups within the essential oils was carried out through FTIR spectroscopy analysis using the infrared absorption peaks of the essential oils. This was done by mixing 0.5 mL of the essential oils with 100 mg of KBr to make transparent pellets. The essential oils of Lavandula angustifolia, Rosmarinus officinalis, and Rosa damascena (NB and HM brands) were analyzed using an FTIR spectrometer over the spectral region of 4000-400 cm^{-1}.

Antioxidant activity of EOs:

Determination of total phenolic content (TPC)

The Folin-Ciocalteu (FC) assay was performed for determination of total phenolic content (TPC) of the essential oils as an indication of their antioxidant activity (Kaur and Kapoor, 2002). A brief description of the procedure is as follows: one milliliter of essential oil was taken and diluted with 9 mL of 10% sodium carbonate (Na_2CO_3) solution, after which 1 mL of 2 N Folin-Ciocalteu reagent was added to the mixture. Then, the mixture was kept at 25°C for 40 minutes, and the absorbance was measured at 725 nm using a spectrophotometer. A calibration graph with gallic acid standard was constructed, and TPC was calculated from the calibration equation. Gallic acid was the reference compound for the calibration curve preparation, while the reagent blanks were used as a control. Absorbance readings were taken in triplicate for accuracy and reproducibility of results.

Y= 0.004 X - 0.0513

X= TPC value

Y= Absorbance value

Quality Assurance

To obtain reliable data, all laboratory apparatus was washed before the experiment; only the reagents of analytical purity were used; and all the measurements were done under the same laboratory conditions. All experiments were repeated three times for verification and elimination of possible analytical mistakes.

Annexure (B)

Results

The findings of this study have been described in four main parts, namely phytochemical screening, FTIR analysis, TPC, and antibacterial activities. Objectively, the findings have been described based on the observations made during the analysis of commercially available essential oils of Lavandula angustifolia, Rosmarinus officinalis, and Rosa damascena of NB and HM brands. Interpretation of the findings and comparison with previous studies have been described in the discussion part of the paper.

Phytochemical screening:

The essential oils of Rosmarinus officinalis, Lavandula angustifolia, and Rosa damascena were obtained from Daska City, Pakistan, and the fractions were extracted through the use of methanol, ethanol, and distilled water. Phase separation could not be seen with the use of n-hexane and chloroform. These fractions

were then analyzed through phytochemical screening, FTIR, TPC, and antibacterial tests. The following are the results of the analyses.

Annexure (C)

Annexure (D)

Annexure (E)

Determination of Fourier Transform Infrared Spectroscopy (FTIR) analysis:

Figure 3: FTIR spectrum of liquid sample of Lavandula angustifolia oil of NB brand.

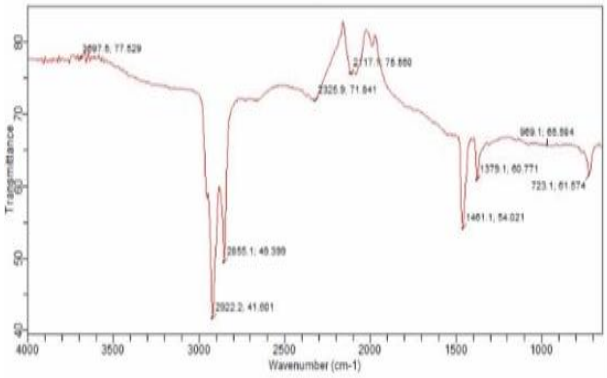

Figure 4: FTIR spectrum of liquid sample of Lavandula angustifolia oil of HM brand.

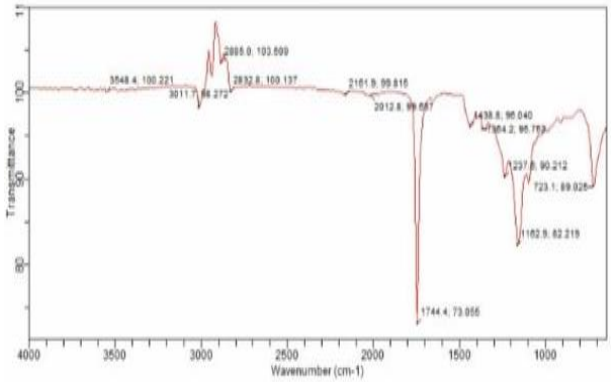

Figure 5: FTIR spectrum of liquid sample of Rosmarinus officinalis oil of NB brand.

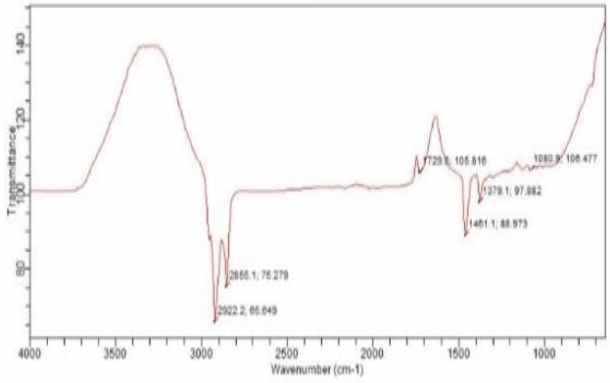

Figure 6: FTIR spectrum of liquid sample of Rosmarinus officinalis oil of HM brand.

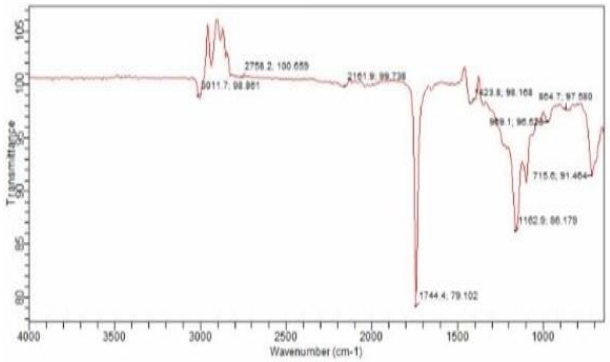

Figure 7: FTIR spectrum of liquid sample of Rosa damascena oil of NB brand.

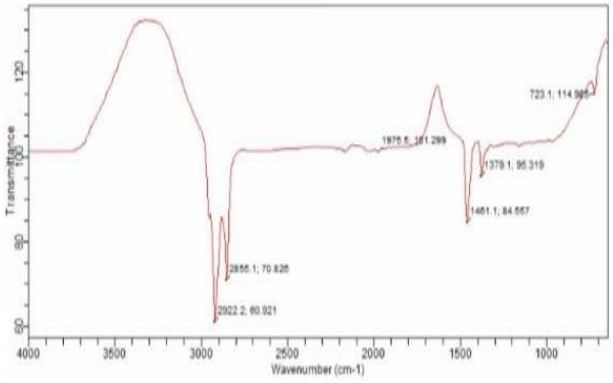

Figure 8: FTIR spectrum of liquid sample of Rosa damascena oil of HM brand**.**

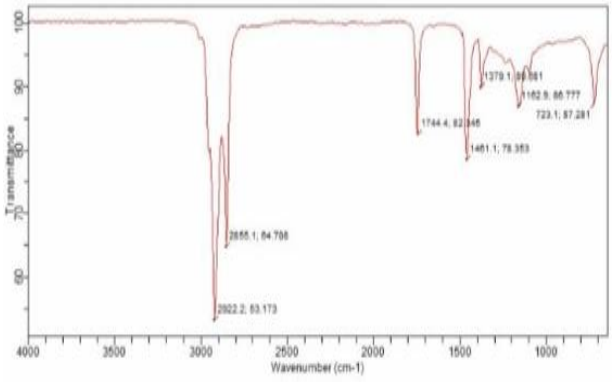

Table 4: FTIR peak values and their assigned functional groups present in essential oils of Lavandula angustifolia of NB Brand.

Sr. No.	Wavenumber (cm^{-1}) (Test Sample)	Wavenumber Range (cm^{-1})	Assigned Functional Group	Phytochemicals Identified
1	3697	4000–3500	O–H Stretching	Alcohol, free
2	2922	3000–2500	C–H Stretching	Alkane

3	2855	3000–2500	C–H Stretching	Alkane
4	2325	2500–2000	–	–
5	2117	2500–2000	C≡C Stretching	Alkyne
6	1461	1500–1000	C–H Bending	Methylene group
7	1379	1500–1000	O–H Bending	Phenol
8	969	1000–650	C=C Bending	Alkene
9	723	1000–650	C=C Bending	Alkene

The FTIR spectrum of the Lavandula angustifolia essential oil (NB brand) revealed the presence of functional groups using the corresponding absorption frequencies. Functional groups include the O–H stretch at 3697 cm^{-1}, C–H stretches at 2922 and 2855 cm^{-1}, C≡C stretch at 2117 cm^{-1}, C–H bend at 1461 cm^{-1}, O–H bend at 1379 cm^{-1}, and C=C bend at 969 and 72.

Table 5: FTIR peak values and their assigned functional groups present in the essential oil of Lavandula angustifolia of HM Brand.

Sr. No.	**Wavenumber (cm^{-1}) (Test Sample)**	**Wavenumber Range (cm^{-1})**	**Assigned Functional Group**	**Phytochemicals Identified**
1	3548	3500–3000	O–H Stretching	Alcohol
2	3011	3500–3000	O–H Stretching	Alcohol
3	2885	3000–2500	C–H Stretching	Alkane
4	2832	3000–2500	–	–
5	2161	2500–2000	S–C≡N Stretching	Thiocyanate
6	2012	2500–2000	N=C=S Stretching	Isothiocyanate
7	1744	2000–1500	C=O Stretching	Conjugated anhydride
8	1438	1500–1000	O–H Bending	Alcohol
9	1237	1500–1000	C–N Stretching	Amine

FTIR study of the L. angustifolia essential oil (HM brand) identified the major functional groups present, which include O-H stretching at 3548 and 3011 cm^{-1}, C-H stretching at 2885 cm^{-1}, S-C=N at 2161 cm^{-1}, N=C=S stretching at 2012 cm^{-1}, and C=O stretching at 1744 cm^{-}. The identified functional groups are presented in Table 5.

Table 6: FTIR peak values and their assigned functional groups present in the essential oil of Rosmarinus officinalis of NB Brand.

Sr. No.	**Wavenumber (cm^{-1}) (Test Sample)**	**Wavenumber Range (cm^{-1})**	**Assigned Functional Group**	**Phytochemicals Identified**
1	2922	3000–2500	C–H Stretching	Alkane
2	2855	3000–2500	C–H Stretching	Alkane
3	1729	2000-1500	C-H Bending	Aromatic Compound
4	1461	2000-1500	-	-
5	1379	2000-1500	O-H Bending	Phenol
6	1080	1500-1000	C-O Stretching	Primary alcohol

The FTIR spectrum of the essential oil of Rosmarinus officinalis (NB brand) revealed the important functional groups present, such as C-H stretching (2922 and 2855 cm-1), C-H bending (1729 cm-1), and O-H bending (1379 cm-1). The identified functional groups are presented in Table 6.

Table 7: FTIR peak values and their

assigned functional groups present in essential oil of Rosmarinus officinalis of HM Brand.

Sr. No.	Wavenumber cm-1 (Test Sample)	Waenumber cm-1 Range	Assigned Functional Group	Phytochemicals Identified
1	3011	3000-2500	O-H Stretching	Alcohol
2	2758	3000-2500	C-H Stretching	Aldehyde
3	2161	2500-2000	S-C=N Stretching	Thiocyanate
4	1744	2000-1500	C=O Stretching	Conjugated anhydride
5	1423	1500-1000	C-H Bending	Alkane Methyl group
6	1162	1500-1000	S=O Stretching	Anhydrous hydrate
7	969	1000-650	C=C Bending	Alkene
8	804	1000-650	C=C Bending	Alkene
9	715	1000-650	-	-

The results obtained from FTIR analysis of Rosmarinus officinalis essential oil (HM brand) included identification of the functional groups present in the substance such as O-H stretching (3011 cm^{-1}), C-H stretching (2756 cm^{-1}), C-N stretching (2161 cm^{-1}), C-O stretching (1744 cm^{-1}), C-C stretching (1423 cm^{-1}), N-O stretching (11), The identified functional groups are presented in Table 7.

Table 8: FTIR peak values and their assigned functional groups present in the essential oil of Rosa damascena of NB Brand.

Sr. No	Wavenumber cm-1 (Test Sample)	Wave number cm-1 Range	Assigned Functional Group	Phytochemicals Identified
1	2922	3000-2500	C-H Stretching	Alkane
2	2855	3000-2500	C-H Stretching	Alkane
3	1976	2000-1500	C-H Bending	Aromatic compound
4	1461	1500-1000	-	-
5	1379	1500-1000	-	-
6	723	1000-650	-	-

The main functional groups in the Rosa damascena essential oil of the NB brand were determined by using FTIR analysis. The medium band at 2922 cm indicates the C-H stretching functional group. The medium peak at 2855 cm showed a C-H aromatic stretching bond. The weak peak at 1976 cm' revealed the presence of a C-H bending functional group. These results are shown in Table 8.

Table 9: FTIR peak values and their assigned functional groups present in the essential oil of Rosa damascena of HM Brand.

Sr. No	Wavenumber cm-1 (Test Sample)	Wavenumber cm-1 Range	Assigned Functional Group	Phytochemicals Identified
1	2922	3000-2500	C-H Stretching	Alkane
2	2855	3000-2500	C-H Stretching	Alkane
3	1744	2000-1500	C-H Bending	Aromatic compound
4	1461	1500-1000	-	-
5	1379	1500-1000	-	-
6	1162	1500-1000	C-O Stretching	Tertiary alcohol
7	723	1000-650	-	-

The main functional groups in the Rosa damascena essential oil of HM brand were

determined by using FTIR analysis. The medium band at 2922 cm indicated the C-H stretching group. The medium peak at 2855 cm revealed a C-H aromatic stretching group. The weak peak at 1744 cm showed the presence of a strong C-H bond. The band observed at 1162 cm may be due to a C-O bond. These results are shown in Table 9.

Phenolic Content of different brands.

Table 10: Total Phenolic Content of different fractions of Lavandula angustifolia essential oil of NB and HM brands.

Solvents	Essential oil of NB brand		Essential oil of HM brand	
	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error
Methanol	0.552 ± 0.004	150.9 ± 0.004	1.888 ± 0.005	484.825 ± 0.005
Ethanol	0.789 ± 0.003	0.0553 ± 0.003	1.226 ± 0.002	319.325 ± 0.002
Aqueous	0.277 ± 0.004	82.225 ± 0.004	0.285 ± 0.003	84.15 ± 0.003

The TPC of Lavandula angustifolia essential oil fractions is presented in Table 10. The methanolic fraction of the HM brand showed the highest TPC (484.825 ± 0.005 µg GAE/mL), while the ethanolic fraction of the NB brand showed the lowest (0.0553 ± 0.003 µg GAE/mL).

Annexure (F)

Table 11: TPC of different fractions of Rosmarinus officinalis essential oil of NB and HM brands.

Solvents	Essential oil of NB brand		Essential oil of HM brand	
	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error
Methanol	0.43 ± 0.040	120.325 ± 0.040	1.685 ± 0.004	434.075 ± 0.004
Ethanol	0.913 ± 0.003	241.15 ± 0.003	1.225 ± 0.005	319.15 ± 0.005
Aqueous	0.464 ± 0.004	128.9 ± 0.004	0.623 ± 0.029	168.65 ± 0.029

Table 11 shows the total phenol content (TPC) of the Rosmarinus officinalis essential oil fractions. The highest TPC value was found in the methanolic fraction of HM (434.075 ± 0.004 µg GAE/mL), while the lowest TPC value was obtained in the methanolic fraction of NB (120.325 ± 0.040 µg GAE/mL.

Annexure (G)

Table 12: TPC of different fractions of Rosa domascena essential oil of NB and HM brands.

Solvents	Essential oil of NB brand		Essential oil of HM brand	
	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error	Absorbance 725nm Mean/St. error	GAE µg/ml ± St Error
Methanol	0.882 ± 0.005	233.325 ± 0.005	1.386 ± 0.006	359.475 ± 0.006
Ethanol	1.337 ± 0.005	347.15 ± 0.005	1.865 ± 0.006	479.15 ± 0.006
Aqueous	0.278 ± 0.003	82.325 ± 0.003	0.056 ± 0.008	26.975 ± 0.008

The total phenolic content (TPC) of Rosa damascena essential oil fractions is presented in Table 12. The ethanolic fraction of the HM brand exhibited the highest TPC (479.15 ± 0.006 µg GAE/mL), while the aqueous fraction of the HM brand showed the lowest TPC (26.975 ± 0.008 µg GAE/mL).

Annexure (H)

Graphical Result

Annexure (I)

Discussion

In the current study, the variability in relation to phytochemical composition, FTIR spectroscopy parameters, and the total phenol content of commercially available essential oils of Lavandula angustifolia, Rosmarinus officinalis, and Rosa damascena from two commercial brands was established. This information shows significant variability in the

chemical characteristics of commercially available essential oils, which depends on numerous factors, including the origin of plant materials, methods of extraction, storage, and production. In particular, based on qualitative phytochemical analysis of the essential oils, variability in relation to the presence of alkaloids, flavonoids, tannins, proteins, carbohydrates, and cardiac glycosides was identified. Although the two tested brands contained similar phytochemicals, the distribution of these compounds showed the different chemical properties of these essential oils and their extraction efficiency. Similar phytochemicals have been previously reported in Lavandula, Rosmarinus, and Rosa species (Blažeković et al., 2018; Andrade et al., 2018; Mahboubi, 2016). Moreover, the presence of characteristic functional groups, including O-H, C-H, C=O, C-O, C=C, and C-N groups, was further verified through FTIR. Such functional groups occur in alcohols, phenols, aldehydes, ketones, terpenes, and volatile components of the essential oil. Despite the similarity in the spectra of all the brands, the difference in the intensity of some peaks and the absence/presence of other bands prove that there are varying compositions of the essential oils in the brands. Similar FTIR patterns have also been noted in Lavandula angustifolia, Rosmarinus officinalis, and Rosa damascena essential oils, as mentioned by Massoud et al. (2024), El-Badry et al. (2015), and Berechet et al. (2015). The phenolic content was found to vary widely among different plant species, the ratio of solvent used, and even different brands. In general, the HM brand displayed higher levels of phenolic content than the NB brand, particularly in methanolic fractions, implying a high ability to extract phenolic compounds and therefore antioxidant activity. Phenolic compounds are known to be good antioxidants in essential oils as they are able to donate hydrogen atoms and neutralize reactive oxygen species. This kind of correlation has been reported earlier for essential oils of Lavandula angustifolia, Rosmarinus officinalis, and Rosa species (Nurzynska-Wierdak et al., 2016; Genena et al., 2008; Ghaffar et al., 2026). From the findings, it is clear that commercially available essential oils having the same names related to their plant origin vary in their compositions and phenol content. This underlines the importance of periodic analysis of these products before utilizing them in a commercial or medicinal application. While phytochemical profiling and FTIR analysis provide instant preliminary results with respect to the composition of the oils, these techniques alone are insufficient in establishing the authenticity and contamination of the essential oils. Hence, advanced analytical techniques like GC-MS, GC-FID, NMR, and isotope ratio analysis are needed for further investigations.

Conclusion

The study was carried out to investigate the quality of commercially available essential oils of Rosmarinus officinalis, Lavandula angustifolia, and Rosa damascena through phytochemical screening, FTIR spectrometry, and total phenolic content (TPC). The findings showed differences in chemical constituents, thereby raising suspicion about the quality and possible adulteration. The methanol and water extracts possessed more phytochemicals than the ethanolic extract, while FTIR verified the presence of different functional groups of bioactive compounds. In general, the above analytical techniques serve as credible means of testing the quality of commercial essential oils. None of the tested essential oil samples exhibited measurable

antibacterial activity under the experimental conditions employed. While antioxidant activity revealed that the total phenolic content of Rosmarinus officinalis of the HM brand showed maximum potential 434.075 - 0.004mg/ml in methanol, the lowest total phenolic content 0.055 = 0.003) was shown by Lavandula angustifolia essential oil of the NB brand. The analytical findings indicate considerable variation among commercially available products, suggesting possible differences in quality that require further confirmation using advanced analytical techniques.

Author Contributions

Nayyab Munir conceived the study and prepared the manuscript. Uzma Hanif reviewed the manuscript. Adeel Mustafa, Hafiza Mehak Munawar, and Sarah Maryam Malik assisted with data collection and manuscript preparation. Saira Atta and Yasmin Akhtar performed the statistical analysis. All authors approved the final manuscript.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability:

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

References

Abdel-Hameed, E. S. S., Bazaid, S. A., & Hagag, H. A. (2016). Chemical characterization of Rosa damascena Miller var. trigintipetala Dieck essential oil and its in vitro genotoxic and cytotoxic properties. Journal of Essential Oil Research, 28(2), 121-129.

Akrout, A., Hajlaoui, H., Mighri, H., Najjaa, H., Jani, H. E., Zaidi, S., & Neffati, M. (2010). Chemical and biological characteristics of essential oil of Rosmarinus officinalis cultivated in Djerba. Journal of Essential Oil Bearing Plants, 13(4), 398-411.

Al-Harrasi, A., & Al-Saidi, S. (2008). Phytochemical analysis of the essential oil from botanically certified oleogum resin of Boswellia sacra (Omani Luban). Molecules, 13(9), 2181-2189.

Andrade, J. M., Faustino, C., Garcia, C., Ladeiras, D., Reis, C. P., & Rijo, P. (2018). Rosmarinus officinalis L.: an update review of its phytochemistry and biological activity. Future science OA, 4(4), FSO283.

Arora, N. K., & Mishra, I. (2019). United Nations Sustainable Development Goals 2030 and environmental sustainability: race against time. Environmental Sustainability, 2(4), 339-342.

Aşkun, T., Baser, K., Tümen, G., & Kürkcüoğlu, M. (2010). Characterization of essential oils of some Salvia species and their antimycobacterial activities. Turkish Journal of Biology, 34(1), 89-95.

Bajalan, I., Rouzbahani, R., Pirbalouti, A. G., & Maggi, F. (2017). Antioxidant and antibacterial activities of the essential oils obtained from seven Iranian populations of Rosmarinus officinalis. Industrial Crops and Products, 107, 305-311.

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils--A review. Food and Chemical Toxicology, 46(2), 446-475.

Behbahani, B. A., Noshad, M., & Falah, F. (2019). Cumin essential oil: Phytochemical analysis, antimicrobial activity and investigation of its mechanism of action through scanning electron microscopy. Microbial Pathogenesis, 136, 103716.

Berechet, M. D., Calinescu, I., Stelescu, M. D., Manaila, E., Craciun, G., Purcareanu, B., & Mihai, R. (2015). Composition of the essential oil of Rosa damascena Mill. cultivated in Romania. Rev. Chim, 66(12), 1986-1991.

Blažeković, B., Yang, W. Y., Wang, C., Li, M., Kindl, M., Pepeljnjak, S., & Vladimir-Knežević, S. (2018). Chemical composition, antimicrobial and antioxidant activities of essential oils of Lavandula × intermedia 'Budrovka' and L. angustifolia cultivated in Croatia. Industrial Crops and Products, 123, 173-182.

Blažeković, B., Yang, W., Wang, Y., Li, C., Kindl, M., Pepeljnjak, S., & Vladimir-Knežević, S. (2018). Chemical composition, antimicrobial and antioxidant activities of essential oils of Lavandula× intermedia 'Budrovka'and L. angustifolia cultivated in Croatia. Industrial crops and products, 123, 173-182.

Brangule, A., Šukele, R., & Bandere, D. (2020). Herbal medicine characterization perspectives using advanced FTIR sample techniques–

diffuse reflectance (DRIFT) and photoacoustic spectroscopy (PAS). Frontiers in Plant Science, 11, 356.

Chouhan, S., Sharma, K., & Guleria, S. (2017). Antimicrobial activity of some essential oils: Present status and future perspectives. Medicines, 4(3), 58.

Daferera, D. J., Tarantilis, P. A., & Polissiou, M. G. (2002). Characterizations of essential oils from Lamiaceae species by Fourier transform Raman spectroscopy. Journal of Agricultural and Food Chemistry, 50(20), 5503-5507.

Cozzolino, D. (2014). Use of infrared spectroscopy for in-field measurement and phenotyping of plant properties: instrumentation, data analysis, and examples. Applied Spectroscopy Reviews, 49(7), 564-584.

De Mastro, G., Ruta, C., Mincione, A., & Poiana, M. (2002). Biomorphological and chemical characterization of rosemary (Rosmarinus officinalis L.) biotypes. In XXVI International Horticultural Congress: The Future for Medicinal and Aromatic Plants (Vol. 629, pp. 471-482).

Do, T. K. T., Hadji-Minaglou, F., Antoniotti, S., & Fernandez, X. (2015). Authenticity of essential oils. TrAC Trends in Analytical Chemistry, 66, 146-157.

Dobros, N., Zawada, K., & Paradowska, K. (2022). Phytochemical profile and antioxidant activity of Lavandula angustifolia and Lavandula × intermedia cultivars extracted with different methods. Antioxidants, 11(4), 711.

El-Badry, A. S. and S.S. Ali. (2015) Essential oils: A promising remedy against fungal and bacterial human keratitis. Egyptian Journal of Botany: 403-431.

Erland, L. A., & Mahmoud, S. S. (2016). Lavender (Lavandula angustifolia) oils. In V. R. Preedy (Ed.), Essential oils in food preservation, flavor and safety (pp. 501-508). Academic Press.

Gachkar, L., Yadegari, D., Rezaei, M. B., Taghizadeh, M., Astaneh, S. A., & Rasooli, I. (2007). Chemical and biological characteristics of Cuminum cyminum and Rosmarinus officinalis essential oils. Food Chemistry, 102(3), 898-904.

Ghaffar, F., Hanif, U., Aziz, R., Sohail, S., & Mustafa, A. (2026). Determination of phytochemicals in medicinal plants collected from adjoining areas of Lahore through Fourier Transform Infrared Spectroscopy. International Journal of Agriculture Innovations and Cutting-Edge Research, 4(2), 41-58.

Hammer, K. A., Carson, C. F., & Riley, T. V. (1999). Antimicrobial activity of essential oils and other plant extracts. Journal of Applied Microbiology, 86(6), 985-990.

Hernández, M. D., Sotomayor, J. A., Hernández, A., & Jordán, M. J. (2016). Rosemary (Rosmarinus officinalis L.) oils. In V. R. Preedy (Ed.), Essential oils in food preservation, flavor and safety (pp. 677-688). Academic Press.

Herraiz-Peñalver, D., Cases, M. A., Varela, F., Navarrete, P., Sánchez-Vioque, R., & Usano-Alemany, J. (2013). Chemical characterization of Lavandula latifolia Medik. essential oil from Spanish wild populations. Biochemical Systematics and Ecology, 46, 59-68.

Hüsnü, K., Başer, C., & Demirci, F. (2007). Chemistry of essential oils. In Flavours and fragrances: Chemistry, bioprocessing and sustainability (pp. 43-86). Springer.

Hussain, A. I. (2009). Characterization and biological activities of essential oils of some species of Lamiaceae [Doctoral dissertation, University of Agriculture, Faisalabad].

Li, Y. Q., Kong, D. X., & Wu, H. (2013). Analysis and evaluation of essential oil components of cinnamon barks using GC-MS and FTIR spectroscopy. Industrial Crops and Products, 41, 269-278.

Loizzo, M. R., Saab, A. M., Tundis, R., Statti, G. A., Menichini, F., Lampronti, I., ... & Doerr, H. W. (2008). Phytochemical analysis and in vitro antiviral activities of the essential oils of seven Lebanese species. Chemistry and Biodiversity, 5(3), 461-470.

Mahboubi, M. (2016). Rosa damascena as holy ancient herb with novel applications. Journal of traditional and complementary medicine, 6(1), 10-16.

Massoud, R. I., Bouaziz, M., Abdallah, H., Zeiz, A., Flamini, G., & El-Dakdouki, M. H. (2024). Comparative study on the chemical composition and biological activities of the essential oils of Lavandula angustifolia and Lavandula x intermedia cultivated in Lebanon. ACS Omega, 9(28), 30244-30255.

Moein, M., Zomorodian, K., Almasi, M., Pakshir, K., & Zarshenas, M. M. (2017). Preparation and analysis of Rosa damascena essential oil composition and antimicrobial activity assessment of related fractions. Iranian Journal of Science and Technology, Transactions A: Science, 41, 87-94.

Moussi Imane, M., Houda, F., Said Amal, A. H., Kaotar, N., Mohammed, T., Imane, R., & Farid, H. (2017). Phytochemical Composition and Antibacterial Activity of Moroccan Lavandula

angustifolia Mill. Journal of Essential Oil Bearing Plants, 20(4), 1074-1082.

Murbach Teles Andrade, B. F., Nunes Barbosa, L., da Silva Probst, I., & Fernandes Júnior, A. (2014). Antimicrobial activity of essential oils. Journal of Essential Oil Research, 26(1), 34-40.

Najem, W., M. El Beyrouthy, L. H. Wakim, C. Neema and N. Ouaini. 2011. Essential oil composition of Rosa damascena Mill. From different localities in Lebanon. Acta botanica gallica, 158(3): 365-373.

Nasery, M., Hassanzadeh, M. K., Najaran, Z. T., & Emami, S. A. (2016). Rose (Rosa× damascena Mill.) essential oils. In Essential oils in food preservation, flavor and safety (pp. 659-665). Academic Press.

Neves, J. A., Neves, J. A., & Oliveira, R. D. C. M. (2018). Pharmacological and biotechnological advances with Rosmarinus officinalis L. Expert Opinion on Therapeutic Patents, 28(5), 399-413.

Orav, A., Arak, E., & Raal, A. (2006). Phytochemical analysis of the essential oil of Achillea millefolium L. from various European Countries. Natural Product Research, 20(12), 1082-1088.

Paaver, U., Orav, A., Arak, E., Mäeorg, U., & Raal, A. (2008). Phytochemical analysis of the essential oil of Thymus serpyllum L. growing wild in Estonia. Natural Product Research, 22(2), 108-115.

Pistelli, L., S. Giovanelli, F. D'Angiolillo, K. Karkleva, M. Leonardi, K. Ambryszewska and L. Pistelli. 2018. Antioxidant activity of several essential oils from different Rosmarinus officinalis cultivars grown in Sanremo (Italy). Natural Product Communications, 13(9): 1934578X1801300917.

Rasouli, O., Ahmadi, N., Monfared, S. R., & Sefidkon, F. (2018). Physiological, phytochemicals and molecular analysis of color and scent of different landraces of Rosa damascena during flower development stages. Scientia Horticulturae, 231, 144-150.

Ribeiro-Santos, R., Carvalho-Costa, D., Cavaleiro, C., Costa, H. S., Albuquerque, T. G., Castilho, M. C., ... & Sanches-Silva, A. (2015). A novel insight on an ancient aromatic plant: The rosemary (Rosmarinus officinalis L.). Trends in Food Science & Technology, 45(2), 355-368.

Ríos, J. L. (2016). Essential oils: What they are and how the terms are used and defined. In Essential oils in food preservation, flavor and safety (pp. 3-10). Academic Press.

Robu, S. I. L. V. I. A., Aprotosoaie, A. C., Miron, A., Cioancă, O. A. N. A., Stănescu, U. R. S. U. L. A., & Hăncianu, M. O. N. I. C. A. (2012). In Vitro Antioxidant Activity Of Ethanolic Extracts From Some Lavandula Species Cultivated In Romania. Cell, 60(3), 394-401.

Silva, L. C. D. M. A., f. D. C. De oliveira mendes, f. De castro teixeira, t. E. De lima fernandes, k. R. B. Ribeiro, K. C. da Silva Leal, K. C. e R. A. N. Dantas. (2023). Use of Lavandula angustifolia essential oil as a complementary therapy in adult health care: a scoping review. Heliyon: 9(5).

Silva, N. C. C., L. Barbosa, L. N. Seito and A. Fernandes Junior. (2012). Antimicrobial activity and phytochemical analysis of crude extracts and essential oils from medicinal plants. Natural Product Research, 26(16): 1510-1514.

Skočibušić, M and N. Bezić. (2004). Phytochemical analysis and in vitro antimicrobial activity of two Satureja species essential oils. Phytotherapy Research, 18(12): 967-970.

Wang, W., Wu, N., Zu, Y. G and Y.J. Fu. (2008). Antioxidative activity of Rosmarinus officinalis L. essential oil compared to its main components. Food Chemistry, 108(3): 1019-1022.

Yasa, n. f. Masoumi, R. S. Rouhani and A. A. Haji. (2009). Chemical composition and antioxidant activity of the extract and essential oil of Rosa damascena from Iran, population of Guilan.

Annexure (A)

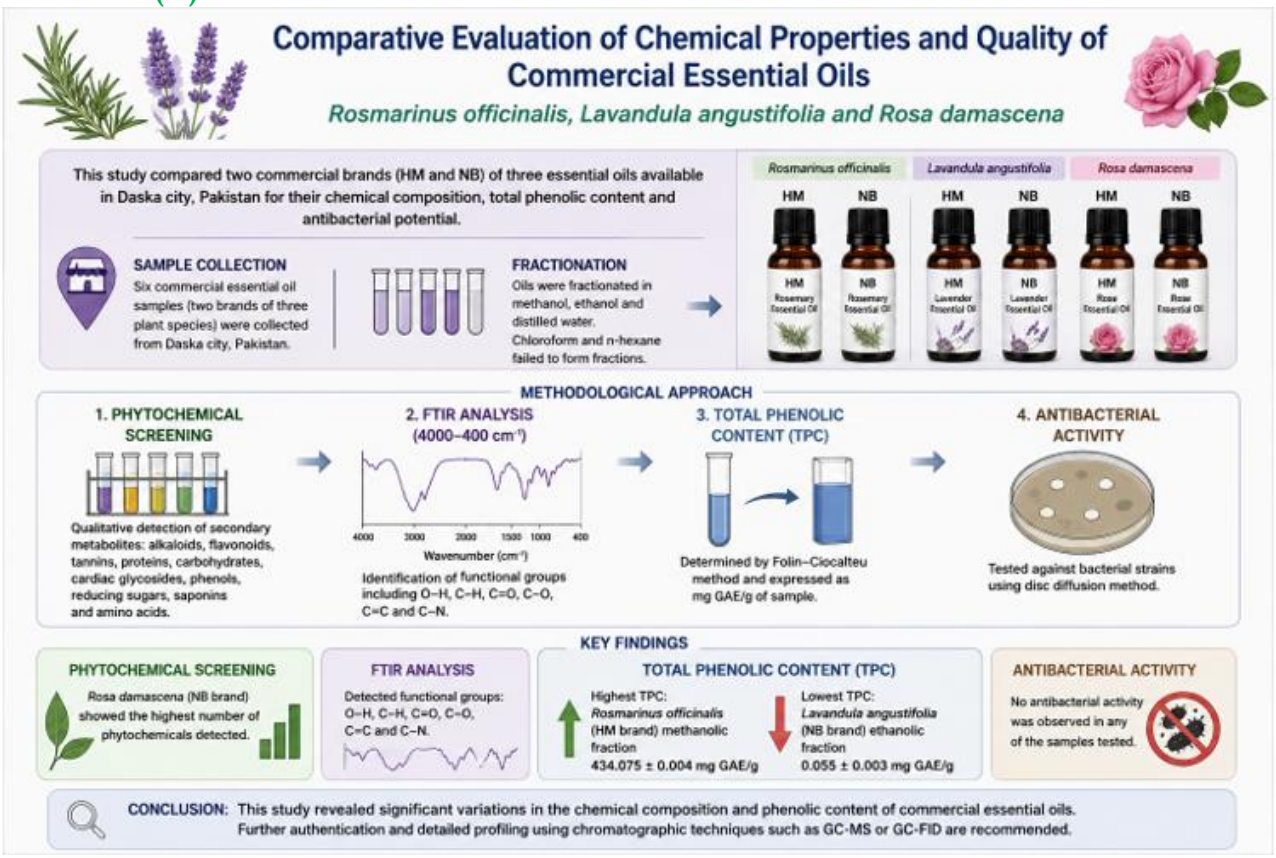

Figure 1: Graphical abstract of the comparative evaluation of commercial essential oils.

Annexure (B)

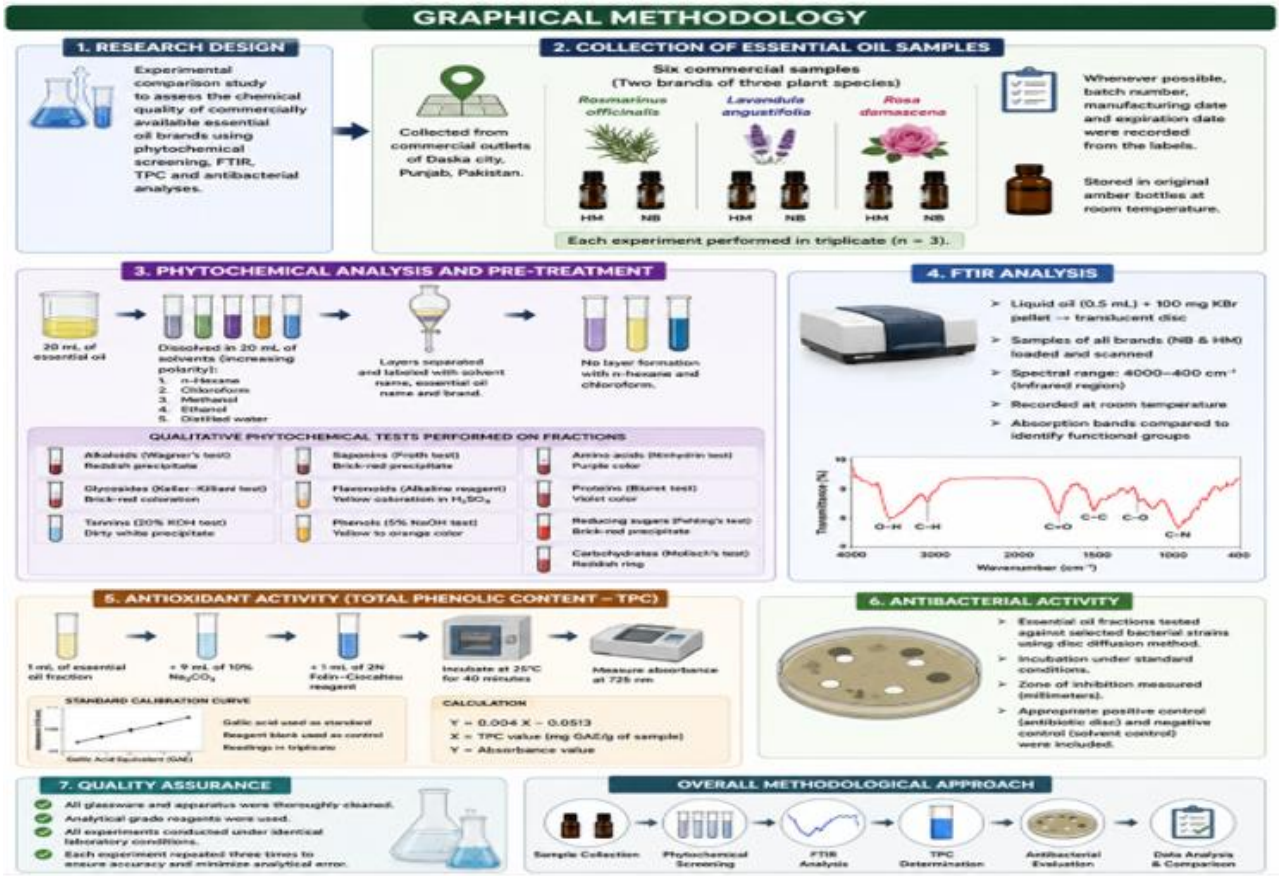

Figure 2: Overview of the experimental design and analytical methods used for the comparative evaluation of commercial essential oils.

Annexure (C)

Table 1: Phytochemical screening of various fractions of EOs of L. angustifolia of NB and HM brands for detection of phytochemical compounds.

Phytochemicals	Tests	Methanol Fraction NB brand	Methanol Fraction HM brand	Ethanol Fraction NB brand	Ethanol Fraction HM brand	Aqueous Fraction NB brand	Aqueous Fraction HM brand
Phenols	Ferric chloride test	–	–	–	–	–	–
Flavonoids	Alkaline reagent test	–	–	–	–	–	–
Alkaloids	Mayer's test	+	–	+	+	–	+
Cardiac glycosides	Keller-Killiani test	–	–	–	–	–	–
Carbohydrates	Molisch's test	–	–	–	–	–	+
Reducing sugars	Fehling's test	–	–	–	–	–	–
Proteins	Burette test	–	–	+	–	+	+
Tannins	Ferric chloride test	+	–	–	+	–	–
Saponins	Froth test	–	–	–	–	–	–
Amino acids	Ninhydrin test	–	–	–	–	–	–

Annexure (D)

Table 2: Phytochemical screening of different fractions of Essential Oil of Rosmarinus officinalis of NB and HM brands for detection of phytochemical compounds.

Phytochemicals	Tests	Methanol Fraction NB brand	Methanol Fraction HM brand	Ethanol Fraction NB brand	Ethanol Fraction HM brand	Aqueous Fraction NB brand	Aqueous Fraction HM brand
Phenols	Ferric chloride test	–	–	–	–	–	–
Flavonoids	Alkaline reagent test	–	–	–	–	–	–
Alkaloids	Mayer's test	+	–	+	–	–	–
Cardiac glycosides	Keller-Killiani test	–	–	–	–	–	–
Carbohydrates	Molisch's test	–	–	–	–	–	–
Reducing sugars	Fehling's test	–	–	–	–	–	–
Proteins	Burette test	–	–	–	+	+	–
Tannins	Ferric chloride test	–	+	+	–	+	–
Saponins	Froth test	–	–	–	–	–	–
Amino acids	Ninhydrin test	–	–	–	–	–	–

Annexure (E)

Table 3: Phytochemical screening of different fractions of Essential Oils of Rosa damascena

of NB and HM brands for detection of phytochemical compounds.

Phytochemicals	Tests	Methanol Fraction NB brand	Methanol Fraction HM brand	Ethanol Fraction NB brand	Ethanol Fraction HM brand	Aqueous Fraction NB brand	Aqueous Fraction HM brand
Phenols	Ferric chloride test	–	–	–	–	–	–
Flavonoids	Alkaline reagent test	+	+	–	–	–	–
Alkaloids	Mayer's test	+	+	+	_	+	+
Cardiac glycosides	Keller-Killiani test	+	–	–	–	–	–
Carbohydrates	Molisch's test	–	–	–	–	–	–
Reducing sugars	Fehling's test	–	–	–	–	–	–
Proteins	Burette test	_	_	_	_	+	+
Tannins	Ferric chloride test	–	–	+	–	+	–
Saponins	Froth test	_	_	_	_	_	_
Amino acids	Ninhydrin test	–	–	–	–	–	–

Annexure (F)

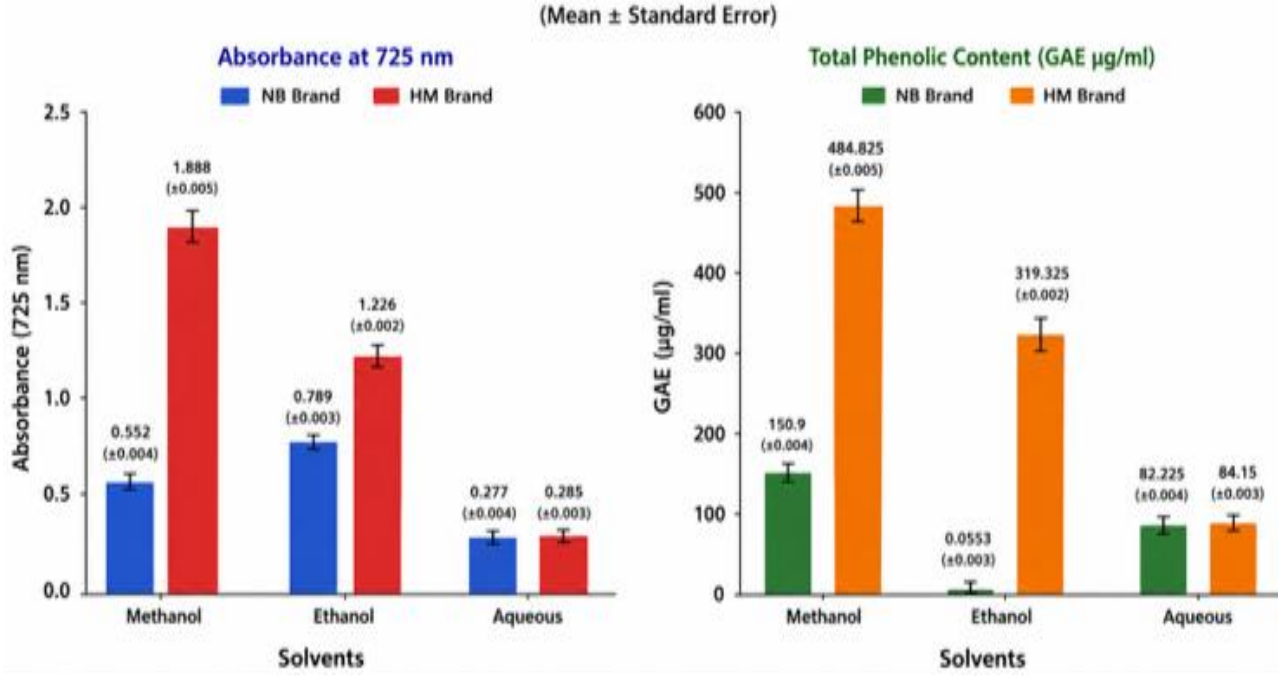

Figure 9: Comparative analysis of absorbance (725 nm) and total phenolic content (µg GAE/mL) of essential oil fractions extracted with methanol, ethanol, and water from NB and HM brands. Values are expressed as mean ± standard error.

Annexure (G)

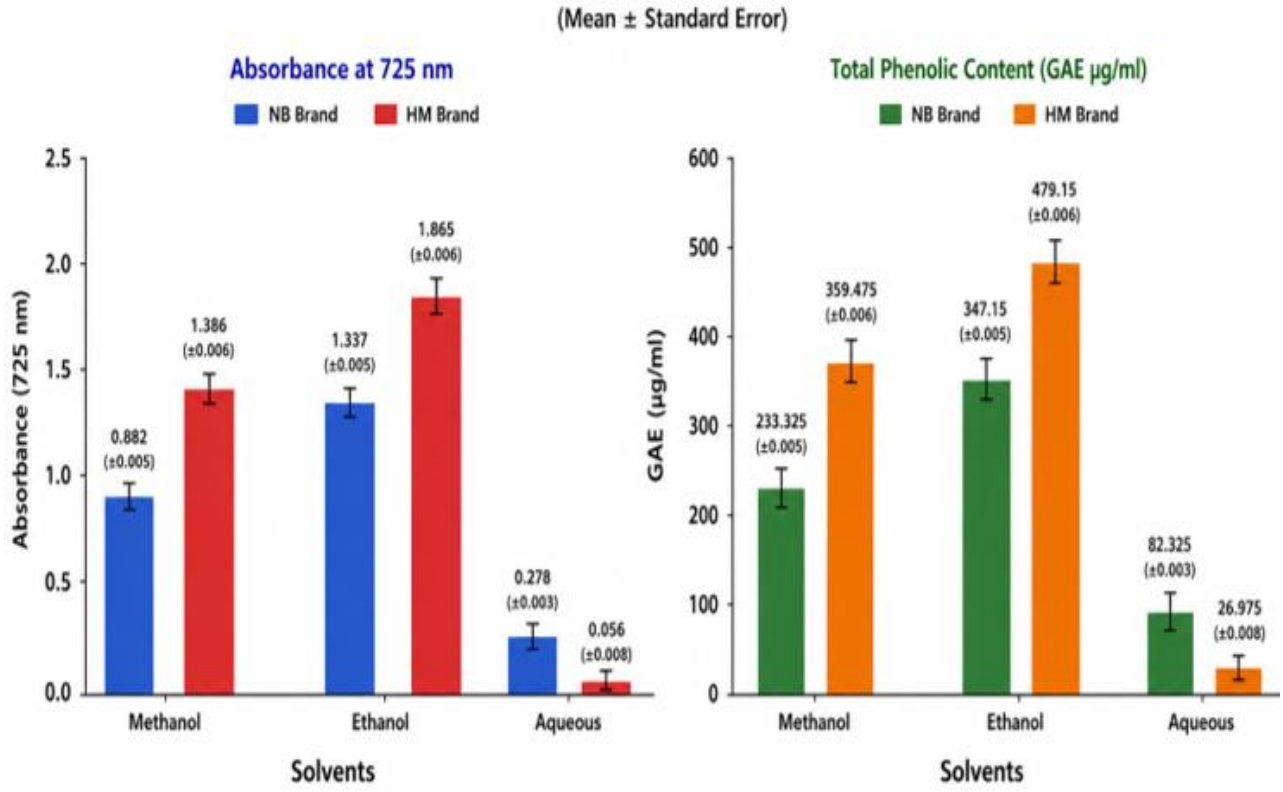

Figure 10: Comparative analysis of absorbance (725 nm) and total phenolic content (µg GAE/mL) of Rosmarinus officinalis essential oil fractions from NB and HM brands. Values are expressed as mean ± standard error.

Annexure (H)

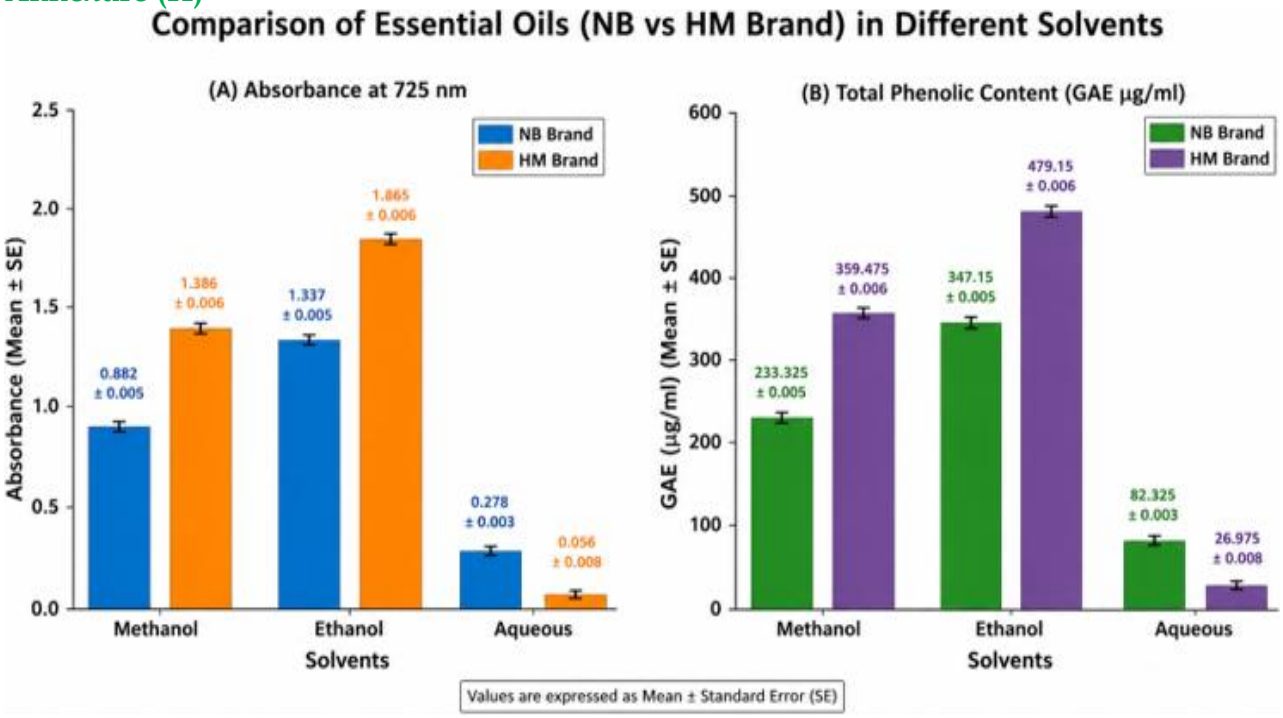

Figure 11: Comparative analysis of absorbance (725 nm) and total phenolic content (µg GAE/mL) of Rosa damascena essential oil fractions from NB and HM brands. Values are expressed as mean ± standard error.

Annexure (I)

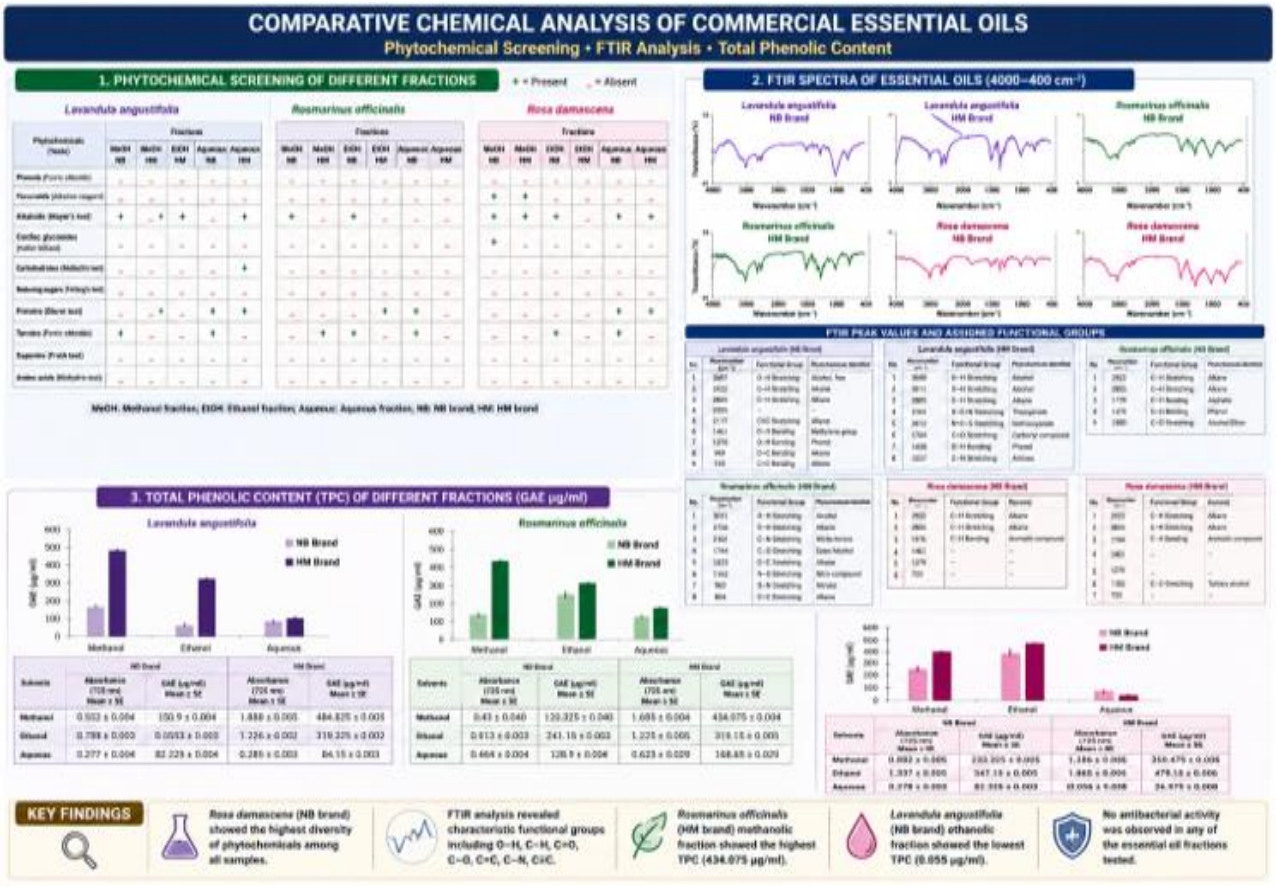

Figure 12: Integrated overview of phytochemical screening, FTIR spectral analysis, and total phenolic content of commercial Lavandula angustifolia, Rosmarinus officinalis, and Rosa damascena essential oils from NB and HM brands.