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Literature Search for Extraction and Characterization of Fragrant Compounds from Ten Flowering Plants

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By

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WE, THE UNDERSIGNED MEMBERS OF THE COMMITTEE,
HAVE APPROVED THIS THESIS

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Abstract

This capstone literature project conducted a literature search on the extraction of essential oils from the leaves of ten different flowering plants using steam distillation and/or solvent extraction methods. Additionally, the project focused on characterizing and identifying the fragrant compounds present in the essential oils of these ten plants. By conducting a comprehensive literature search, this project provides a summary of the methods employed for extraction and the composition of fragrant compounds in each essential oil. A diverse range of fragrant compounds were found in various plants and flowers, including major and minor compounds such as alcohols, aldehydes, ketones, terpenes, and esters. The plants of interest in this capstone project focused on included Oriental Lily, Tuberose, Neroli, Ylang-Ylang, Gardenia, Catalpa tree, Locust flower, Eucalyptus, Viburnum, and Wisteria Vine.

Introduction

Fragrant compounds are crucial in plants and flowers, as they heavily contribute to the distinctive scent profiles found in distinct plants. This comprehensive literature search project explores the fascinating world of plant fragrances and delves deep into the unique scents produced by ten different flowers: Oriental Lily, Tuberose, Neroli, Ylang-Ylang, Gardenia, Catalpa tree, Locust flower, Eucalyptus, Viburnum, and Wisteria Vine. Each flower has its own distinct fragrance, and the project meticulously examines the various aromatic components that make up these fragrances. The project also investigated two common extraction methods such as steam distillation and solvent extraction to gain a better understanding of the composition of these fragrances.

Common Extraction Methods of Essential Oils

The literature search project found that various extraction methods are present, but steam distillation or solvent extraction is most demonstrated throughout the literature to obtain essential oils. A better understanding of the process of extracting essential oils and the characteristics of the fragrant compounds were presented in each plant giving optimal extraction methods for obtaining a high yield of essential oils.

Steam Distillation Extraction

Based on the literature search, steam distillation was a common technique for obtaining essential oils from plant sources. In this method, the leaves were heated with steam, causing the volatile fragrant chemicals to volatilize. This technique was found to be prevalent for extracting essential oils from plants, including the ten species studied in this report. The process involved using steam to vaporize the fragrant and volatile molecules within the plant material. The resulting mixture of steam and essential oil vapor was then condensed and collected separately.

While known for its simplicity and ability to preserve the plant's fragrance, steam distillation might not have been suitable for delicate floral species due to potential heat damage that could lead to fragrance loss. The steam distillation setup typically included a distillation flask, a condenser, and a receiving flask. The distillation flask, made of heat-resistant glass, held the plant material. The condenser, a coiled tube cooled by running cold water, aided in condensing the vapor by cooling it, causing it to revert to a liquid state. The condensed liquid was collected in the receiving flask.

The studies emphasized the importance of incorporating a steam generator into the setup to ensure the passage of high-quality steam, free from impurities, through the plant material. During steam distillation, the process involved adding plant material and water to the distillation flask, heating the mixture to generate steam, and carrying volatile compounds to the condenser, where they condensed back into a liquid. The resulting mixture was collected in the receiving flask and separated into essential oil and aqueous layers. Despite the relatively straightforward equipment needed for steam distillation, its quality and maintenance were crucial factors for achieving accurate and dependable results.

Solvent Extraction

An alternative approach frequently discussed in the literature for obtaining essential oils was through solvent extraction. This method involved dissolving aromatic compounds from plant materials using a suitable solvent, such as hexane or ethanol. After the solvent evaporated, the resulting essential oil was collected. To optimize the process, flower leaves were initially macerated or ground, increasing the surface area available for extraction. The plant material was combined with the chosen solvent, and this mixture was left to rest for a specific duration to encourage efficient extraction. Subsequently, the solvent was separated from the plant material via filtration or centrifugation, yielding the essential oil-solvent mixture.

In contrast, solvent extraction employed a solvent to dissolve the aromatic compounds within the plant material. Following this step, the solvent evaporated, leaving the pure essential oil behind. This technique was especially valuable for delicate floral species that couldn't withstand the elevated temperatures of steam distillation. It also proved advantageous for extracting essential oils from materials unsuitable for steam distillation. However, it's worth noting that the quality of the essential oil obtained could suffer due to residual impurities from the solvent, which could impact both fragrance and overall quality.

Choosing the appropriate solvent for extraction necessitated consideration of factors like solvent polarity, boiling point, target compound solubility, and toxicity. Solvent polarity determined which compounds would dissolve, while boiling point affected extraction efficiency and the final product's purity. The solubility of target compounds guided solvent selection, with toxicity being a critical safety consideration. Ultimately, the choice of solvent hinged on the specific target compounds, the chosen extraction technique, and the desired purity of the product.

Characterization of Fragrant Compounds

The literature search project provided information on the extraction yields of essential oils from different flower plants and the analytical methods used to characterize their fragrant chemicals. The extraction yield, which represented the percentage of essential oil obtained relative to the initial mass of the plant material, was determined using the collected essential oil weighed after separation from the solvent or distillate.

Analytical methods used throughout the such as gas chromatography-mass spectrometry (GC-MS), Gas Chromatography/ Flame Ionization Detection-Mass Spectrometry (GC/FID-MS) and additional analysis techniques were used to identify and characterize the fragrant compounds found in the essential oils of the chosen flower plants. The articles found these methods offer details about the chemical makeup and structural characteristics of the fragrant components and are commonly used in the study of fragrances.

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis

The literature search revealed that fragrant components within essential oils were identified and measured using gas chromatography-mass spectrometry (GC-MS) analysis. GC-MS was a frequently utilized technology for isolating and studying volatile chemicals within complex mixtures. In this process, a small aliquot of the essential oil sample was injected into the gas chromatograph for GC-MS analysis.

By exploiting the gas chromatograph, the wide range of compounds were separated based on their volatility and chemical characteristics. Subsequently, the mass spectrometer generated a mass spectrum for each of the separated chemicals. These mass spectra were then compared to a reference database, enabling the identification of fragrant chemicals present in the essential oils. Determining the relative abundance of each compound involved integrating peak areas in the chromatogram. These integrated peak areas facilitated the calculation of the relative percentage composition of fragrant compounds within the essential oils, a crucial element in characterizing the fragrant composition of each flower within the literature project.

The studies incorporated various column types and sizes for GC-MS analysis, including DB-5MS, DB-Wax, HP-5MS, and Rtx-5MS. The choice of column type and size played a significant role in separating and identifying volatile compounds. Similarly, the injector and carrier gas varied across studies, with some utilizing splitless or split injection and employing helium as the common carrier gas. Additionally, specific parameters such as initial and final temperatures, ramp rates, and time intervals demonstrated variability depending on the context of each study.

For instance, common analysis conditions that were consistently encountered across the studies included the use of a DB-5MS column and helium as the carrier gas. Typically, the initial temperature was set at 40°C, and the final temperature ranged from 280°C to 320°C. The ramp rate usually fell within the range of 5 to 10°C/min, and the total analysis time varied from 30 to 60 minutes. Furthermore, the injector temperature was typically maintained around 250°C to 260°C.

Gas Chromatography/ Flame Ionization Detection-Mass Spectrometry (GC/FID-MS) Analysis

The studies also examined the analysis technique for GC-FID/MS. This technique is a powerful tool for identifying and quantifying volatile compounds in a sample by combining gas chromatography (GC), mass spectrometry (MS), and flame ionization detection (FID). This technique is known to be used in various industries, such as perfumery, cosmetics, and flavoring, to analyze fragrances and essential oils.

Samples were vaporized and injected into the GC column, which is packed with a stationary phase that separates the sample components based on their physical and chemical properties. The separated components were then passed through a detector, which identifies and quantifies the individual components. The detector used in GC-FID/MS analysis has a combination of a flame ionization detector (FID) and a mass spectrometer (MS).

The FID is a highly sensitive and selective technique that detects a wide range of organic compounds, including hydrocarbons, alcohols, esters, and fatty acids, present in the sample by ionizing them when they pass through the flame. The intensity of the ionization is proportional to the concentration of the compound, allowing for the quantification of the individual components. The MS detects the mass-to-charge ratio of the sample components by fragmenting them and separating the fragments based on their mass-to-charge ratio before detecting them. The resulting mass spectrum allows for the identification of the compound present.

Across the studies, the different parameters for GC/FID-MS were discussed. In the GC/FID-MS analyses, the common parameters were employed, including column types such as SLB-5MS (silphenylene polymer), HP-5 (High-Polarity 5% Phenyl Methyl Siloxane), and BPX-5MS capillary (Bonded Phase Crosslinked 5% Phenyl Methyl Siloxane). Helium and hydrogen were utilized as carrier gases. The initial temperature was generally set at 50°C, while the final temperature varied within the range of 250-265°C. The ramp rate typically ranged from 3-10°C/min, with the time varying from 3-10 minutes. The injector temperature exhibited a range of 250-265°C. Flow rates were observed to be1 mL/min, and the split flow ratio was found to vary between 1:20 and 1:100. These consistent parameters facilitated accurate compound separation and detection but also contributed to the overall reliability and comparability of the results obtained across numerous studies.

Additional Analytical Technique

Additional analytical techniques were found in some articles used to examine the essential oils more thoroughly. Depending on the article's specific aim and the resources at hand, these additional techniques worked hand in hand previous analytical methods stated above. The additional methods mentioned included mass spectrometry (MS), Ultra-High-Performance Liquid chromatography quadrupole time-of-flight mass spectrometry (UHPLC/MS). This technique is like GC-MS but is used to analyze compounds that are not volatile enough for GC-MS analysis. UHPLC/MS involves separating the components of a complex mixture using liquid chromatography and then analyzing the individual components using mass spectrometry. In the UHPLC/MS analysis of fragrant compounds, several consistent parameters were also used across some studies. The selected column type was C18 with a particle size of 1.8 µm, measuring 100 mm in length and 2.1 mm in diameter. The mobile phase consisted of water containing 0.1% formic acid and acetonitrile with 0.1% formic acid. The gradient utilized initiated with 5% acetonitrile and progressed to 95% acetonitrile over a duration of 20 to 30 minutes. For mass spectrometry detection, electrospray ionization (ESI) was commonly utilized, alternating between positive and negative ion modes. The mass range for analysis spanned from 100 to 1000 m/z, with a scan rate of 1 to 2 Hz. These standardized parameters offered a consistent foundation for conducting UHPLC/MS analyses of fragrant compounds, ensuring comparability and reliability across the different studies. These techniques played a role in the characterization of the essential oils by offering more precise structural details about the fragrant components and their interactions.

The core objective of this project revolves around the identification and characterization of major and minor fragrant compounds presented in the essential oils of Oriental Lily, Tuberose, Neroli, Ylang-Ylang, Gardenia, Catalpa tree, Locust flower, Eucalyptus, Viburnum, and Wisteria Vine. By delving into the extraction techniques and the fragrant compound composition within each essential oil, a comprehensive overview emerges, showcasing the diverse array of fragrant compounds inherent to various plants and flowers. This exploration highlights their distinct contributions to the overall aroma profile.

Methods

Literature Search Method

The literature search for this project was conducted using various online databases, including SciFinder, Web of Science, and Google Scholar. The search was performed using the following keywords: "extraction methods", "Gas Chromatography/GC-MS", "fragrant compounds," "volatile organic compounds," "aroma profile," "floral scent," and "plant fragrance." The search was limited to articles that exhibited these qualifications.

To find articles specific to Oriental Lily, the keywords "Oriental Lily fragrant compounds" were used in the search. The initial search yielded approximately ten articles across all databases (see Appendix A full list of articles). Each article was screened based on its title and abstract to determine its relevance to the project. Articles that did not discuss standard extraction techniques, GC-MS analysis, fragrant compounds, or fragrant profiles of Oriental Lily were excluded. After the initial screening, eight articles were deemed relevant and included in the project (see Appendix A relevant list of articles).

The chosen articles were analyzed for information on the fragrant compounds found in Oriental Lily. The major and minor compounds were identified, and their contributions to the overall aroma profile were noted. Factors that can affect the composition of fragrant compounds, such as extraction method and source of plant material, were also considered. The information gathered from the selected articles was then collected and presented in the results section of this report.

The following information for the remaining flower articles underwent the same method as Oriental Lily. The appendices demonstrate the articles that were obtained during the pieces search and separated by a complete list of articles and relevant articles providing the information for the capstone project. Refer to appendices B-J for the list of articles found for each flower.

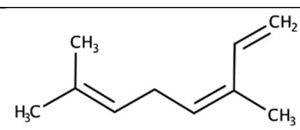
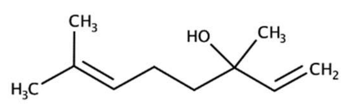
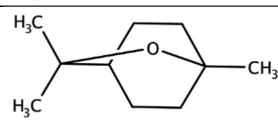
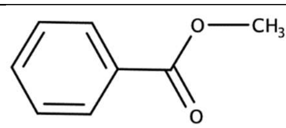
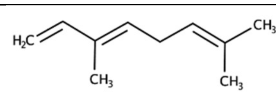
Results

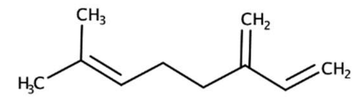
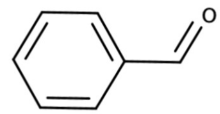
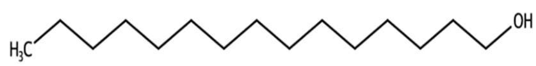
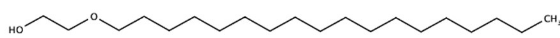
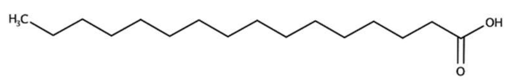
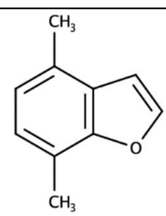
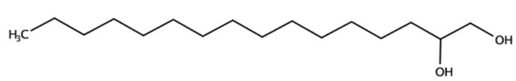
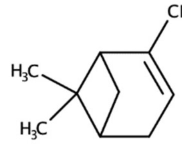
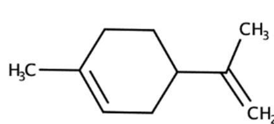
After conducting a literature search using specific keywords to find articles that met the criteria, the results were analyzed for relevance. The relevant articles were then reviewed to summarize the extraction and characterization of compounds that were found analyzed and identified as fragrant compounds found in the essential oils of ten selected flower plants. The plants are presented below in no significant order:

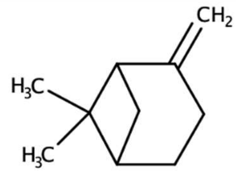
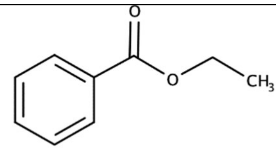
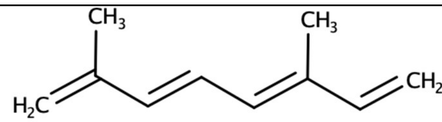
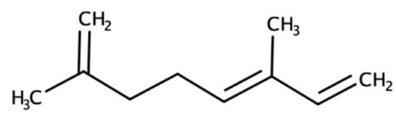
Oriental Lily

The dazzling beauty and alluring aroma are the characteristics that define oriental lilies. These flowers are part of the genus *Lilium*[1] and are known for their large, trumpet-shaped blooms that can reach up to 6 inches in diameter. It comes in vibrant colors like white, pink, and deep red and has a pleasant fragrance. This lily grows on tall, sturdy stems and can reach heights of 3 to 6 feet[2]. The plant is native to East Asia, particularly Japan, Korea, and China, but has since been widely cultivated and naturalized in other parts of the world. Oriental lilies are prized for their potent, sweet aroma and are highly sought-after in the floral industry. The commonality found within the literature-based search for the essential oil of Oriental lily was obtained through steam distillation and analyzed through GC-MS analysis, revealed the presence of the compound found was (*Z*)-beta-ocimene, followed by linalool, 1,8-cineole, and methyl benzoate.

Table 1: Compounds identified in Oriental lilies. (Appendix A)

No.	Compound Name	Structure	% Composition
1	(*Z*)-β-ocimene		0.39-2.12
2	linalool		4.50-57.33
3	1,8-cineole; eucalyptol		16.27-75.62
4	methyl benzoate		0.27-38.21
5	(*E*)-β-ocimene		8.40-20.97

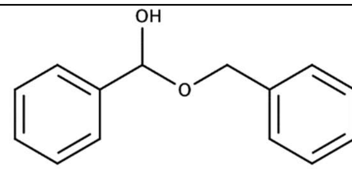
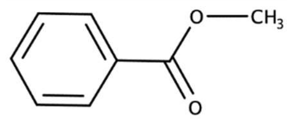
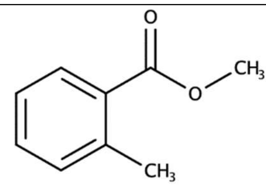
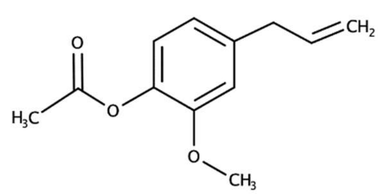
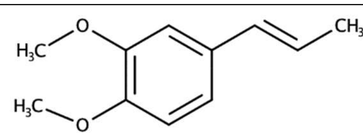
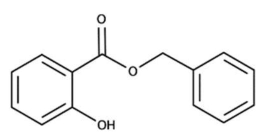
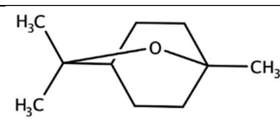
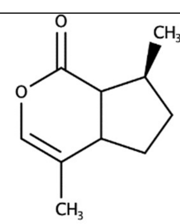
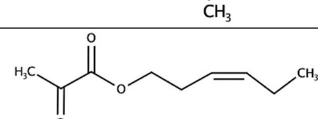
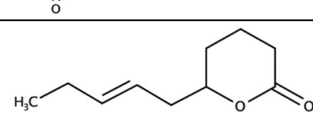
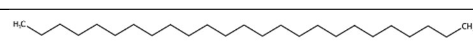
6	myrcene		0.64-5.33
7	benzaldehyde		0.24-8.30
8	1-dodecene		8.04
9	1-docosene		7.35
10	1-hexadecanol		5
11	2-(9-octadecenyloxy)-(*Z*)-ethanol		4.22
12	n-hexadecanoic acid		3.27
13	4,7-dimethyl-benzofuran		3.26
14	hexadecane-1,2-diol		3.09
15	α -pinene		0.58-11.76
16	limonene		1.05-7.88

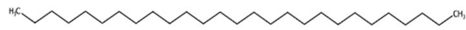
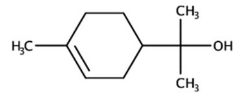
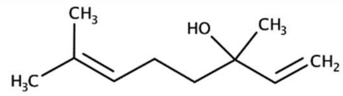
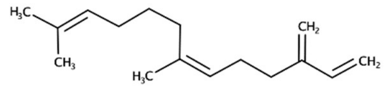
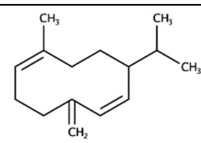
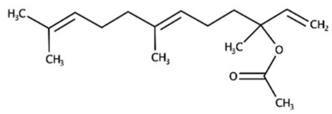
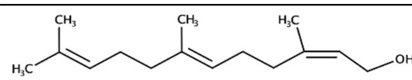
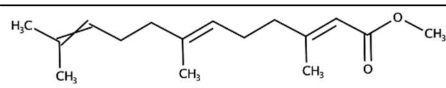
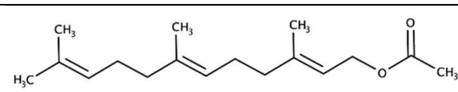
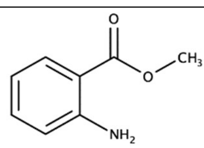
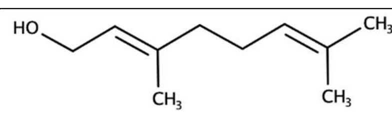
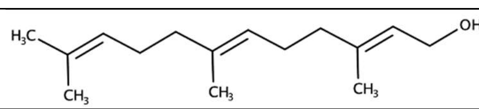
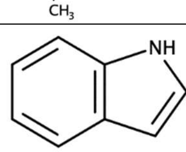
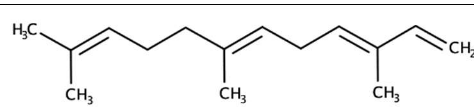
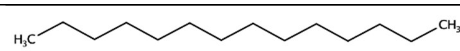
17	β -pinene		0.11-1.51
18	ethyl benzoate		0.11-1.51
19	(*E, E*)-2,6-dimethyl-1,3,5,7-octatetraene		-
20	α-ocimene		-
21	unidentified terpene	N/A	-

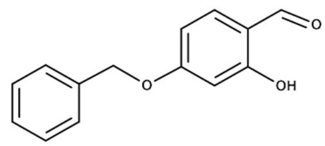
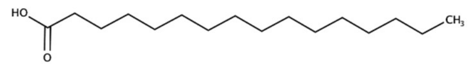
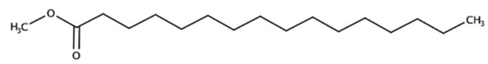
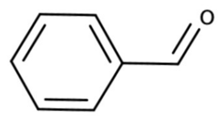
Tuberose (*Polianthes tuberosa*)

The next is a lovely flower native to Mexico called tuberose, or *Polianthes tuberosa,* as its genus. The Tuberose is a tall, elegant flower with long, slender stems. It features clusters of small, waxy white flowers that are shaped like tubes. Tuberose plants can grow to be around 2 to 3 feet in height and are known for their graceful and delicate appearance [3]. Rich and sweet flower tones make up its alluring fragrance. The flower is native to Central America and Mexico but is now cultivated in many other regions of the world for its ornamental and medicinal properties. Due to its scent, tuberose blooms are commonly used in aromatherapy and perfumes[4]. The literature search found that the essential oil of tuberose was extracted using solvent extraction. GC-MS analysis identified key compounds, including methyl benzoate, benzyl salicylate, and methyl anthranilate, which are the major volatile organic compounds responsible for the characteristic sweet, floral, and slightly spicy aroma of tuberose. In addition, p-cresol methyl ether, phenol, and indole are minor compounds found in smaller quantities in tuberose, which contribute to the rich and intense floral fragrance of tuberose.

Table 2: Compounds identified in Tuberose. (Appendix B)

No.	Compound Name	Structure	% Composition Range
1	benzyl benzoate		8.85- 57.77
2	methyl benzoate		11- 53.51
3	methyl salicylate		6.7-12.11
4	eugenyl acetate		6.1-18.6
5	*trans*-methyl isoeugenol		9.4-31.9
6	benzyl salicylate		8.79
7	1,8-cineole		8.2-29
8	nepetalactone		13.5
9	(*Z*)-3-hexenyl 2-oxopropanoate		27.38
10	7-decen-5-olide		13.33-18.13
11	pentacosane		7.73-29.44

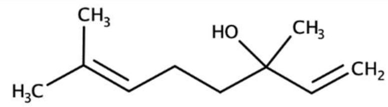
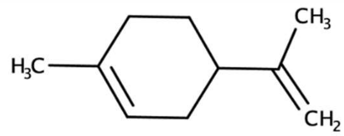
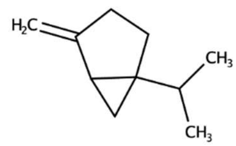
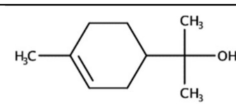
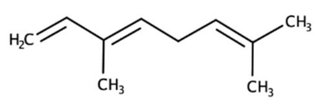
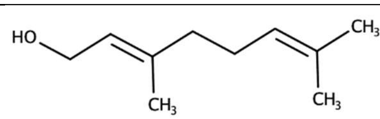
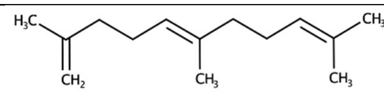
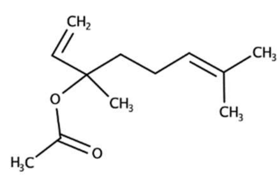
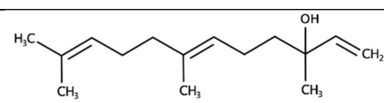
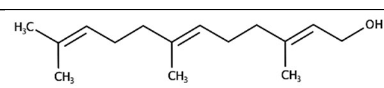
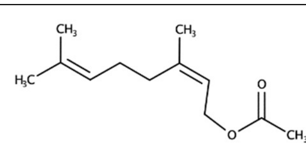
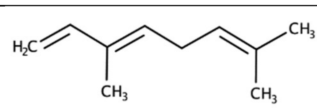
12	heptacosane		12.53
13	α-terpineol		5
14	linalool		-
15	*cis*-β-farnesene		-
16	germacrene D		7.68
17	*trans*-nerolidol acetate		-
18	2-*cis*-6-*trans*-farnesol		-
19	2-*trans*-6-*trans*-methyl farnesoate		-
20	2-*trans*-6-*trans*-farnesyl acetate		-
21	methyl anthranilate		3-8.29
22	geraniol		-
23	farnesol		27.23 - 54.98
24	indole		6.65
25	α-farnesene		4.92-49.19
26	tetradecane		41.35 - 54.9

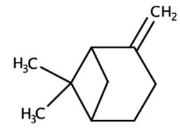
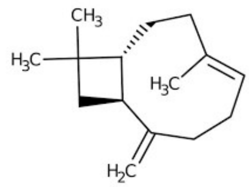
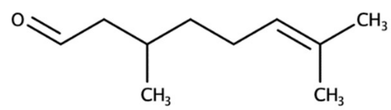
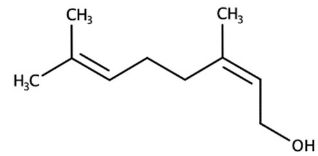
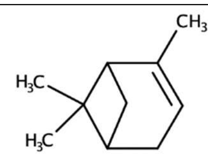
27	benzaldehyde, 2-hydroxy-4-(phenylmethoxy)		32.09 - 54.9
28	palmitic acid		-
29	methyl palmitate		24.46
30	benzaldehyde		16.50

Neroli (*Citrus aurantium var. amara*)

The *Citrus aurantium var. amara* flower is the source of neroli, a popular fragrance component. Neroli is a small, white flower with a delicate and intricate appearance. It has multiple petals that are arranged in a star-like formation, giving it a unique and captivating look. Neroli flowers are typically small in size, with a diameter of about 1 inch[5]. They grow on small, slender stems and are often clustered together. It has a distinct aroma that is both floral and lemony and is gentle[6]. It is native to Southeast Asia and is now commonly cultivated in Mediterranean countries such as Italy, Spain, and Morocco[7]. Neroli essential oil was obtained through steam distillation as a common method found throughout the articles. It is further detailed GC-MS as the analysis used throughout the studies revealing that the most abundant fragrant compounds found in neroli essential oil were linalool, limonene, sabinene, and linalyl acetate. These compounds contribute to the citrusy and floral aroma characteristic of neroli. Other fragrant compounds commonly found in neroli essential oil include α-Terpineol, (E)-β-ocimene, geraniol, and geranyl acetate. α-Terpineol has a fresh, floral, and slightly spicy aroma and is commonly found in many essential oils, including pine, lavender, and eucalyptus. Minor fragrant compounds that were also identified were neryl acetate, geranyl acetate, and β-pinene.

Table 3: Compounds identified in Neroli flower. (Appendix C)

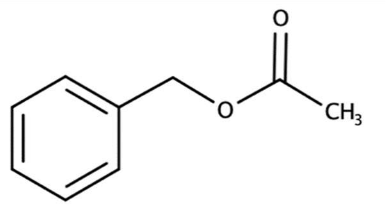
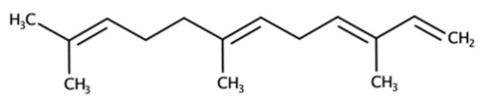
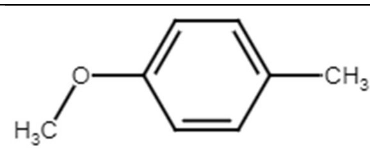
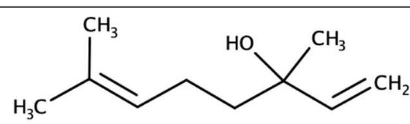
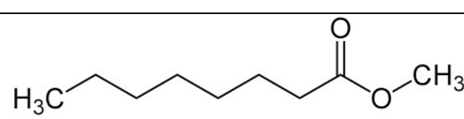
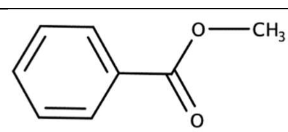
No.	Compound Names	Structure	% Compound Composition Range (if present)
1	linalool		15.59 -53
2	limonene		8-24.57
3	sabinene		20.22
4	α-terpineol		5-6
5	*(E)*-β-ocimene		3-5
6	geraniol		3-4
7	geranyl acetate		~3
8	linalyl acetate		2-15
9	*(E)*-nerolidol		2-5
10	*(E, E)*-2,6-farnesol		2-5
11	neryl acetate		~1.5
12	*(E)*-β-ocimene		3-5

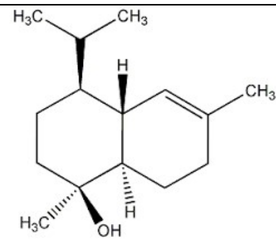
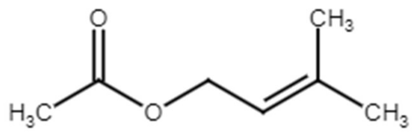
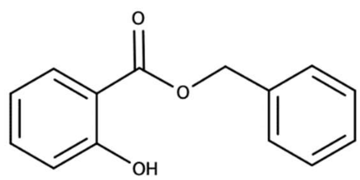
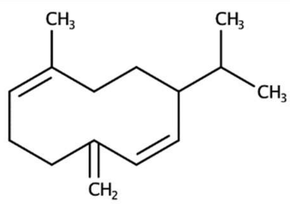
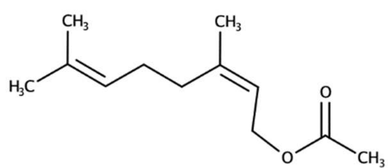
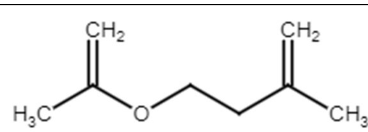
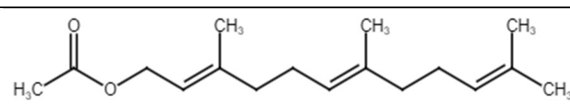
13	β-pinene		2-4
14	β -caryophyllene		0.6-0.9
15	citronellal		-
16	nerol		-
17	α-pinene		-

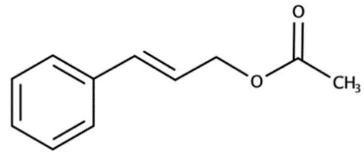
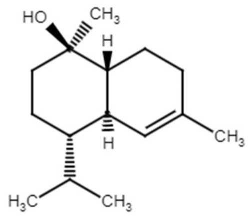
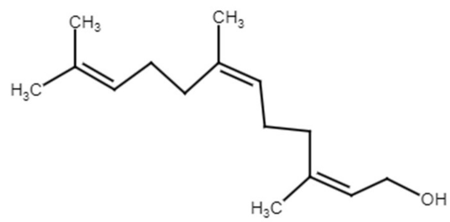
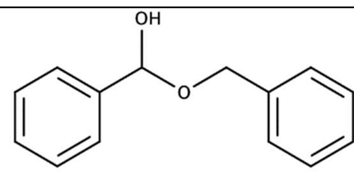
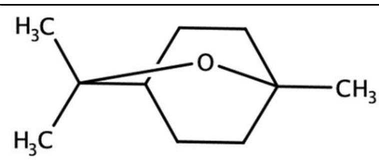
Ylang-Ylang (*Cananga odorata*)

Cananga odorata, also known as ylang-ylang, is a tropical flower with an appealing scent. Ylang-ylang features large, star-shaped blossoms with vibrant yellow petals. The petals are narrow and elongated where they grow on small, delicate stems [8] . The blossoms are frequently hand-picked in the early morning when their scent is the strongest [9]. It is a well-known plant native to Southeast Asia, renowned for its fragrant flowers that have been widely used in cosmetics, perfumes, and traditional medicine for centuries [10]. The common extraction method discussed throughout the relevant articles found on the essential oil of ylang-ylang is steam distillation. GC-MS analysis identified the major fragrant compounds found are linalool, geranyl acetate, farnesene, benzyl acetate, geraniol, methyl benzoate, and benzyl benzoate. These are known for their sweet, floral, and slightly spicy aroma. The minor fragrant compounds found in ylang-ylang include *p*-cresyl methyl ether, benzyl salicylate, and eugenol. These compounds also contribute to the overall aroma profile of ylang-ylang, but they are present in smaller quantities compared to the major compounds. These compounds contribute to the exotic and sweet floral fragrance of ylang-ylang.

Table 4: Compounds identified in Ylang-Ylang flower. (Appendix D)

No.	Compound Name	Structures	% Composition
1	benzyl acetate		27.48
2	(*E, E*)-*α*-farnesene		10.1
3	*p*-cresyl methyl ether		9.7
4	linalool		8.95
5	methyl caprylate		7.24
6	methyl benzoate		6.05

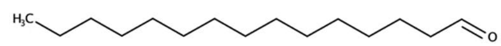
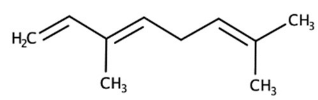
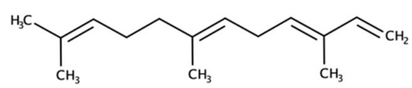
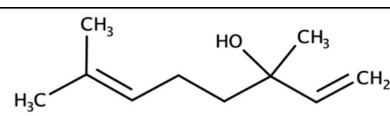
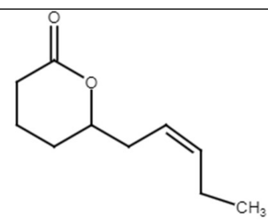
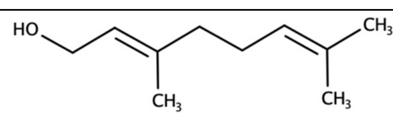
7	*τ*-murolol		4.43
8	3-methyl-2-butenyl acetate		4.24
9	benzyl salicylate		4.18
10	germacrene D		2.76
11	neryl acetate		2.74
12	3-methyl-3-buten-1-ol acetate		2.16
13	(*2E,6E*)-farnesyl acetate		2.05

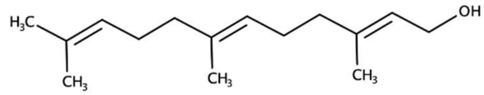
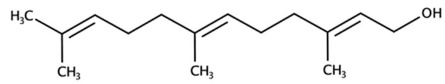
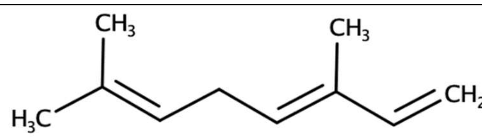
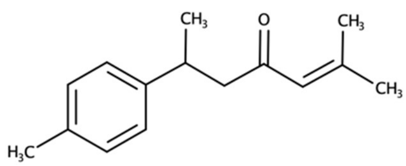
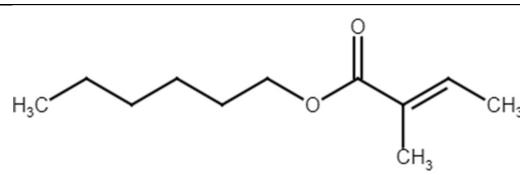
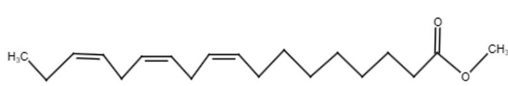
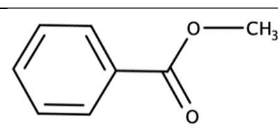
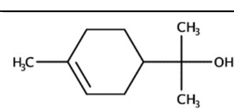
14	cinnamyl acetate		1.59
15	*α*-cadinol		1.52
16	(*2Z,6Z*)-farnesol		1.43
17	benzyl benzoate		1.24
18	1,8-cineole		1.11

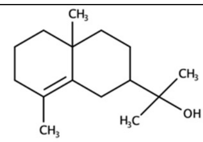
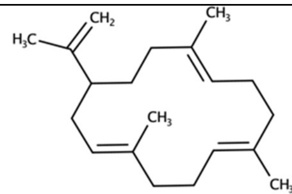
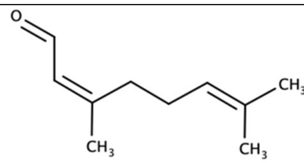
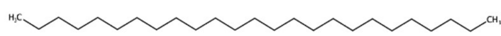
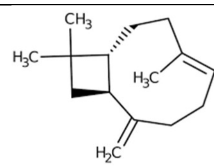
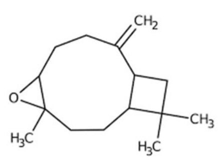
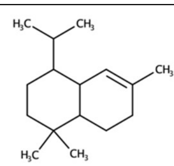
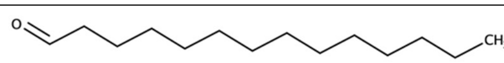
Gardenia (*Gardenia jasminoides*)

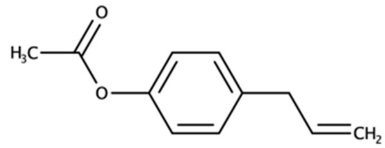
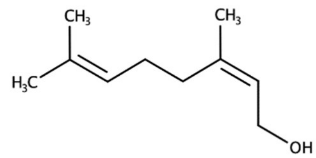
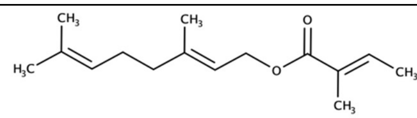
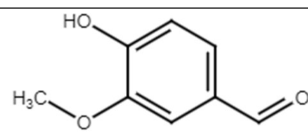
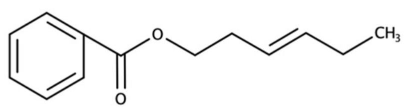
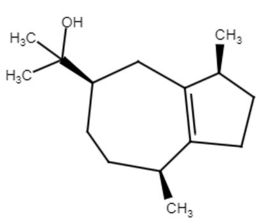
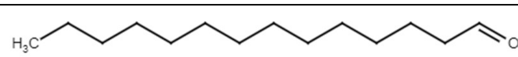
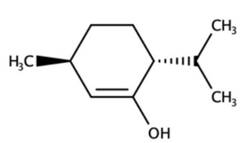
The *Gardenia jasminoides* plant of gardenias is highly regarded for both its magnificent beauty and alluring aroma. Gardenia is a rubiaceae family flowering plant genus native to Asia, Africa, and the Pacific Islands[11]. This plant has large, creamy white blossoms where the petals of the Gardenia are velvety and smooth, giving them a soft texture. The flower itself is typically medium-sized, with a diameter ranging from 2 to 4 inches. Gardenias grow on sturdy, green stems and are often accompanied by glossy, dark green leaves [12]. The flowers give off a strong, sweet aroma that inspires sentiments of romance and peace[13]. Due to its fragrance qualities, gardenia essential oil is highly sought after. Gardenia essential oil was obtained through solvent extraction. GC-MS analysis revealed the presence of compounds such linalool, phenylethyl alcohol, and benzyl alcohol, all known for their sweet, floral, and slightly spicy aroma. Meanwhile, benzaldehyde, methyl benzoate, and indole are among the minor compounds found in gardenia.

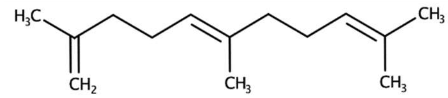
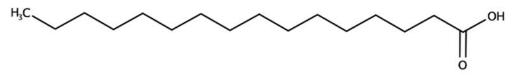
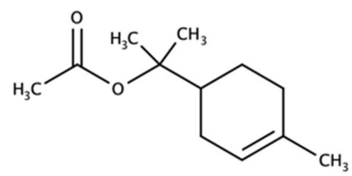
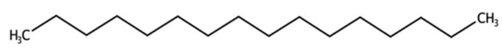
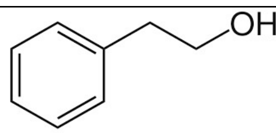
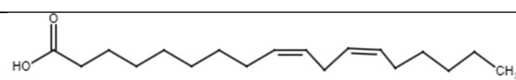
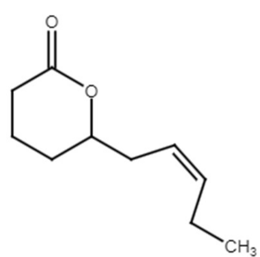
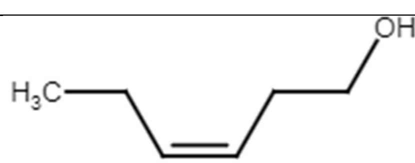
Table 5: Compounds identified in Gardenia flower. (Appendix E)

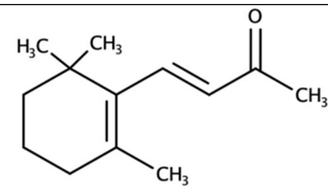
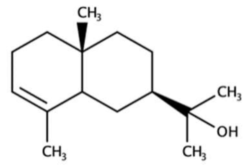
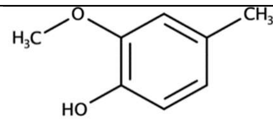
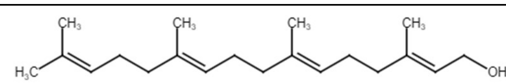
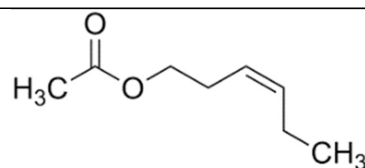
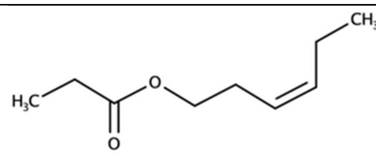
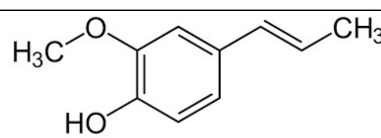
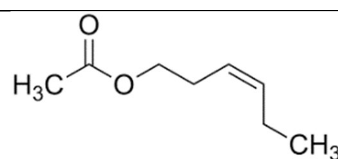
No.	**Compound name**	**Structure**	**% Composition**
1	pentadecanal		49.2
2	*(E)*-β-ocimene		45.8
3	α-farnesene		42.1-10.24
4	linalool		38.23-1.7
5	jasmine lactone		20.5-8.0
6	geraniol		19.9-1.93

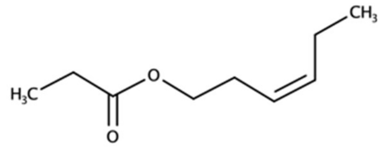
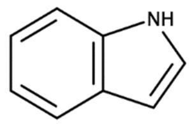
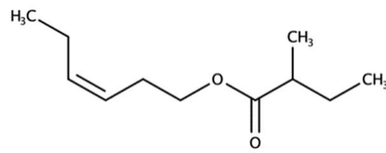
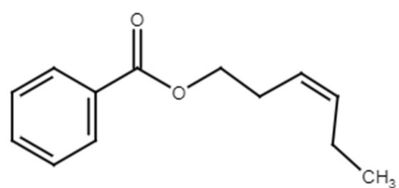
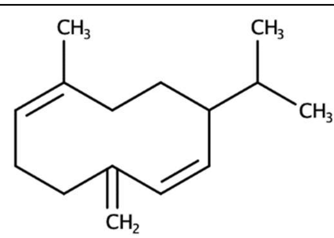
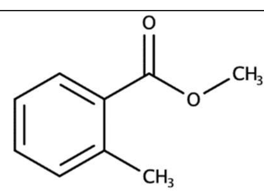
7	farnesol		13.2
8	geranial		12.3
9	heneicosane		10.8
10	*trans*-beta-ocimene		9.50
11	ar-turmerone		8.2
12	cis-3-hexenyl tiglate		8.02-2.4
13	methyl linolenate		8.0
14	methyl benzoate		6.4
15	α-terpineol		6.3-2.40

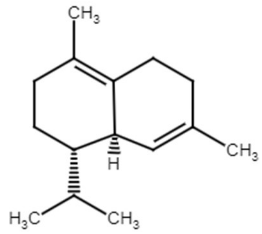
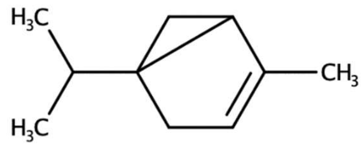
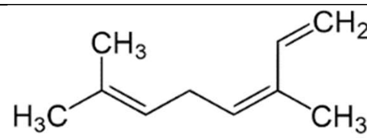
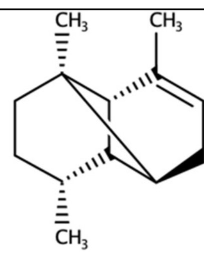
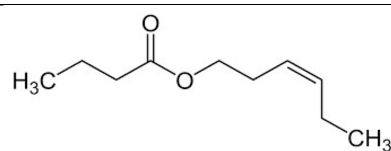
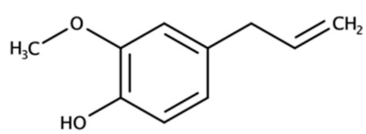
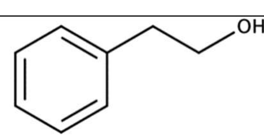
16	10-epi-γ-eudesmol		6.2
17	cembrene A		5.8-3.13
18	neral		4.6
19	pentacosane		3.0
20	*trans*-caryophyllene		2.84
21	caryophyllene oxide		2.6
22	*tau*-cadinol		2.40-1.77
23	tetradecanal		2.2

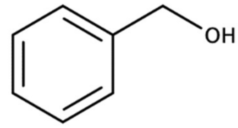
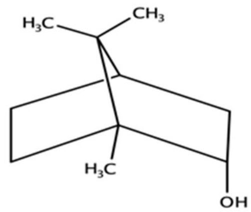
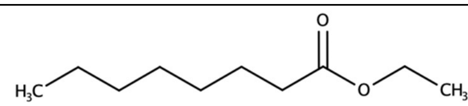
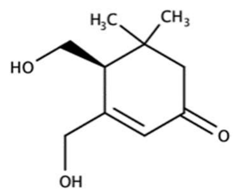
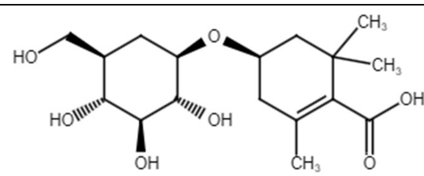
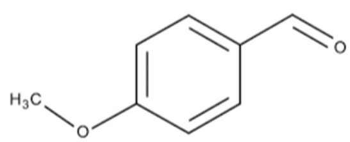
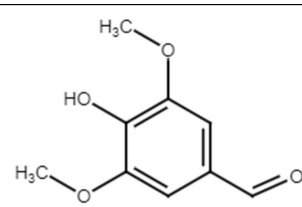
24	4-(2-propenyl) phenol		2.1
25	nerol		2.0
26	geranyl angelate		1.9
27	tricosane		1.9
28	vanillin		1.8
29	(*Z*)-3-hexen-1-ol benzoate		1.76
30	guaiol		1.73
31	myristaldehyde		1.7
32	trans-*p*-mentha-2,8-dienol		1.5

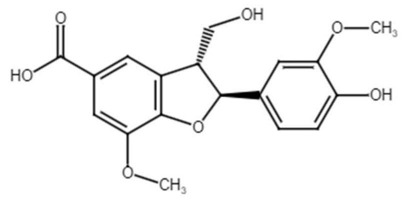
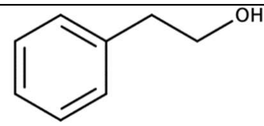
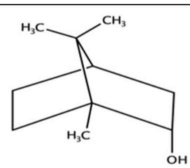
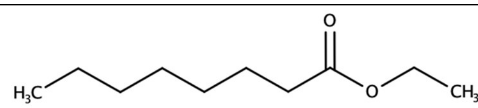
33	geranyl acetate		1.4
34	*n*-hexadecanoic acid		1.3
35	alpha-terpinyl acetate		1.2
36	*n*-heptadecane		1.1
37	phenylethyl alcohol		1.0
38	Linoleic acid		0.78
39	6-(Pent-2'-enyl)-tetrahydropyran-2-one		0.76
20	*cis*-3-hexenol		0.76

41	(*E*)-β-ionone		0.7
42	α-eudesmol		0.7
43	2-Methoxy-4-vinylphenol		0.66
44	geranyl geraniol		0.6
45	*Z*-3-hexenyl acetate		0.06
46	z-3-hexenyl propionate		0.05
47	*trans*-isoeugenol		0.31
48	*Z*-3-hexenyl acetate		0.06

49	*Z*-3-hexenyl propionate		0.05
50	indole		0.29-0.15
51	*Z*-3-hexenyl 2-methylbutanoate		0.25
52	*Z*-3-hexenyl benzoate		0.22-0.08
53	germacrene D		0.20
54	methyl salicylate		0.15

55	delta-cadinene		0.10
57	*alpha*-thujene		0.06
58	*cis*-ocimene		0.03
59	*alpha*-copaene		0.03
60	*z*-3-hexenyl butyrate		0.02
61	eugenol		-
62	2-Phenylethanol		-

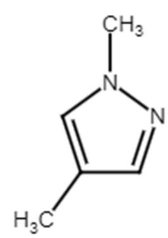
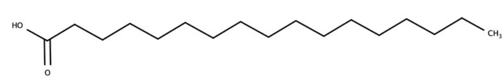
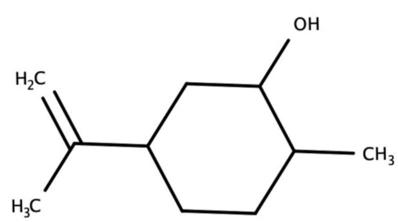
63	benzyl alcohol		-
64	borneol		-
65	ethyl octanoate		-
66	jasminodiol		-
67	picrocrocinic acid		-
68	4-methoxy- benzaldehyde		-
69	syringaldehyde		-

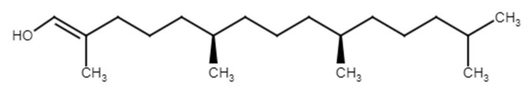
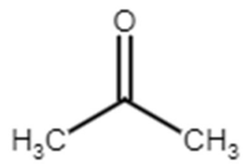
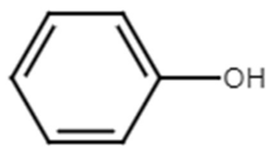
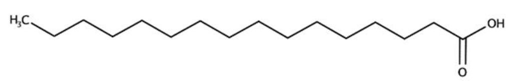
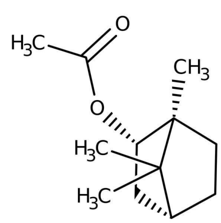
70	ceplignan		-
71	2-phenylethanol		-
72	borneol		-
73	ethyl octanoate		-

Catalpa Tree

The Catalpa tree, found in various plants, produces clusters of bell-shaped flowers with a pleasing fragrance. It is a genus of eight tree plants found in eastern North America, eastern Asia, and the West Indies (family bignoniaceae). Because their seed pods resemble beans, the southern and northern catalpa plants, *Catalpa bignonioides* [14], and *Catalpa speciosa* [15], are known to as Indian bean tree and cigar tree, respectively. The blossoms are well renowned for their peculiar perfume, which is sometimes characterized as vanilla or honey-like [16]. The Catalpa tree flower is a distinctive and unique blossom with large, bell-shaped flowers. The petals of these flowers are usually white or cream-colored and may have purple or yellow spots, enhancing their visual appeal. Catalpa tree flowers grow in clusters and bloom in late spring or early summer. Essential oils from catalpa flowers are recognized to have distinctive fragrant qualities. The essential oil of catalpa flowers was extracted using steam distillation described in the relevant articles found. The compounds identified were ethyl salicylate, phytol, and isobornyl acetate. Ethyl salicylate has a sweet, floral, and slightly spicy fragrance and is commonly used in perfumes and fragrances. Phytol is a diterpene alcohol with a mild, sweet, and slightly floral scent. Although it is not commonly used as a fragrance ingredient, it can contribute to the overall fragrance of certain plants or essential oils. Isobornyl acetate is an ester with a woody, menthol-like, and slightly floral fragrance. It is often used in perfumes and fragrance compositions for its pleasant scent.

Table 6: Compounds identified in Catalpa Tree (Appendix F)

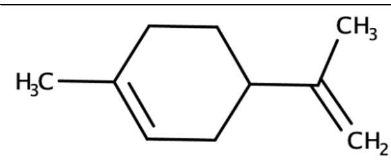
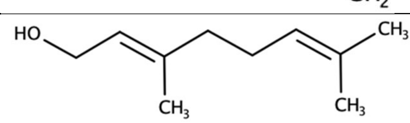
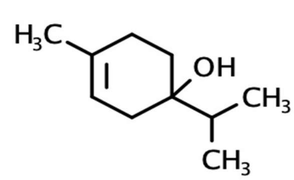
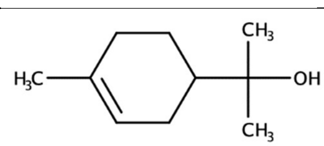
No.	Compound	Structure	% Composition
1	1, 4-dimethyl pyrazole		6.69
2	octadecanoic acid		4.81
3	cyclohexanol, 2-methyl-5- (1-methylethenyl)		4.43

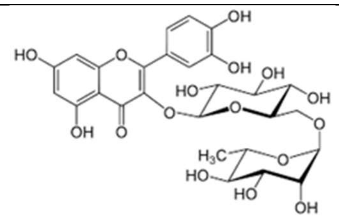
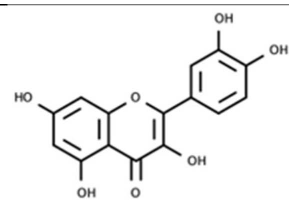
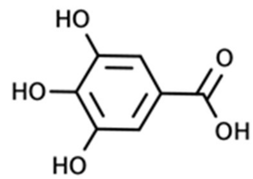
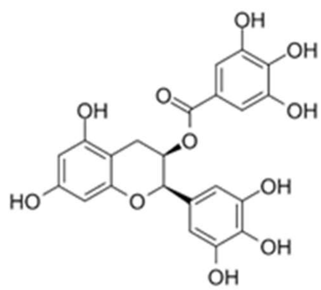
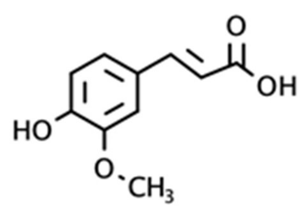
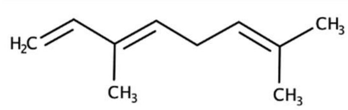
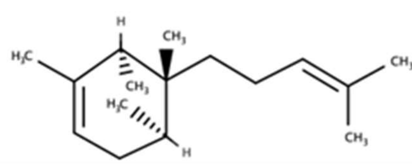
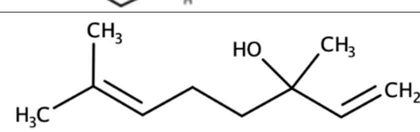
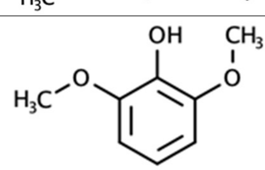
4	phytol		3.35
5	acetic acid		4.23
6	phenol		2.30
7	n-hexadecanoic acid		2.27
8	isobornyl acetate		2.15

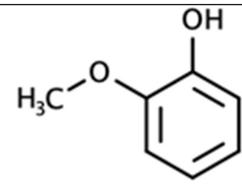
Locust Flower (*Robinia pseudoacacia*)

Locust flowers, derived from the *Robinia pseudoacacia* tree, possess a delightful fragrance that resembles the scent of sweet pea blossoms [17]. The Locust Tree flower, *Robinia pseudoacacia*, is native to the eastern region of North America but can be found in other parts of the world, such as Europe. The flower of the Locust tree blossoms consists of small clusters of white flowers. The petals of the Locust tree flower are typically tube-shaped and are arranged in a cylindrical cluster. These blossoms produce essential oils with a soft, floral scent[18]. The use of locust flower essential oil in the fragrance industry makes its extraction interesting. The articles found demonstrated how the essential oil of locust flowers were extracted using solvent extraction while the analysis identified major compounds such as limonene, linalool, *cis*-β-ocimene, and (*E*)-α-bergamotene, which are fragrant and have a sweet, floral, rosy, fresh, woody, and lilac-like aroma. Other fragrant compounds present in the extract include geraniol, terpinen-4-ol, and α-terpineol. However, rutin, quercetin, gallic acid, epigallocatechin, ferulic acid, syringol, and guaiacol are not typically associated with fragrant properties. Rutin and quercetin are odorless flavonoid compounds that are known for their health benefits, while gallic acid is an organic acid with a sour taste but no distinctive fragrance. Epigallocatechin is a catechin found in green tea that does not have a distinct fragrance, and ferulic acid has a slightly sweet and fragrant scent, but it is not typically described as a fragrant compound. Lastly, syringol and guaiacol are phenolic compounds found in wood smoke that have a smoky, charred, and phenolic odor rather than a conventional fragrance.

Table 7: Compounds identified in Locust flower. (Appendix G)

No.	Compound Name	Structure	Composition Percentage
1	limonene		20.4%
2	geraniol		2.0%
3	terpinen-4-ol		1.7%
4	α-terpineol		1.5%

5	rutin		-
6	quercetin		-
7	gallic Acid		-
8	epigallocatechin		-
9	Ferulic Acid		-
10	*cis*-β-ocimene		-
11	(*E*)-α-bergamotene		-
12	linalool		-
13	syringol		-

14	guaiacol		-

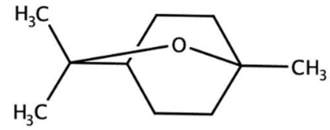
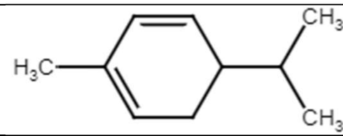
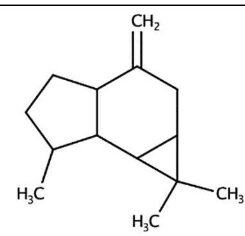
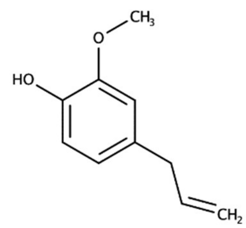
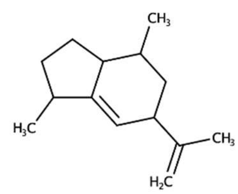
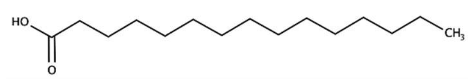
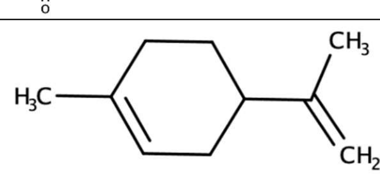
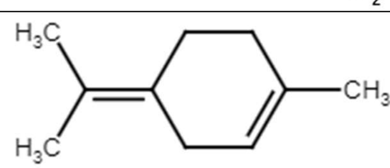
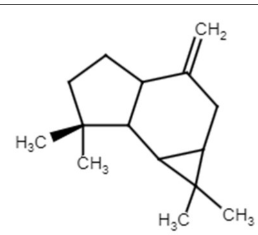
Eucalyptus

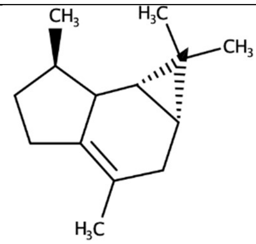
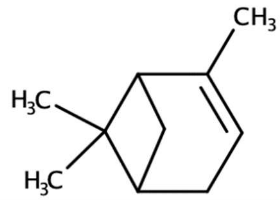
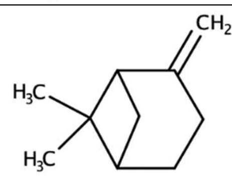
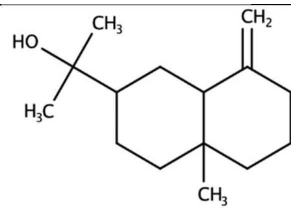
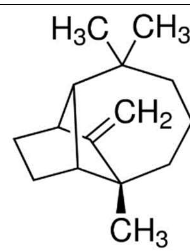
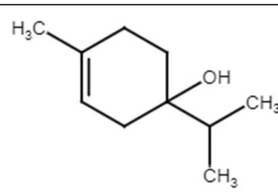
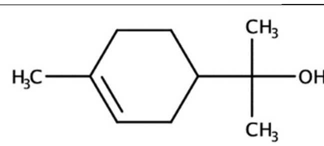
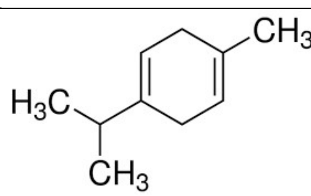
Eucalyptus is a broad plant comprising numerous plants known for their fragrant leaves [19]. It is a versatile and fast-growing plants native to Australia but is now cultivated in many parts of the world, like Asia, Africa, Europe, and the Americas Eucalyptus trees provide a distinctive scent that has notes of both refreshment and medicine [20]. The tree leaves have a unique and recognizable look. It is characterized by its long and slender leaves, which are typically a bluish-green shade. These leaves are shaped like a lance and hang down vertically from the branches, giving the tree a flowy appearance. The bark of the Eucalyptus tree is smooth and can vary. in color, ranging from white to gray to brown, depending on the specific species giving it a tall and slender silhouette Because of its widespread therapeutic uses, eucalyptus essential oil is a subject of research for extraction and characterization.

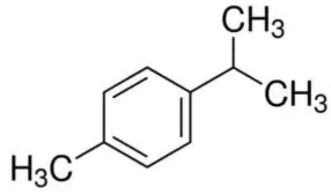
The literature search gave the following information for Eucalyptus essential oil was obtained through steam distillation and the analysis revealed the presence of compounds such as (1,8-cineole) and α-pinene. The composition percentage range for eucalyptol is 0.17-55.43%, and for α-pinene is 0.85-23.62%. These compounds contribute to the refreshing, medicinal, and camphoraceous aroma associated with eucalyptus [21]. Other compounds that are fragrant in eucalyptus include α-phellandrene, aromadendrene, eugenol, γ-gurjunene, pentadecanoic acid, limonene, terpinolene, spathulenol, ledene, β-pinene, α-eudesmol, longifolene, p-cymene, D-limonene.

Table 8: Compounds identified in Eucalyptus (Appendix H)

No.	Compound Name	Structure	Composition Percentage

1	eucalyptol (1,8-cineole)		0.17-55.43%
2	α-phellandrene		2.06-40.31%
3	aromadendrene		6.45–15.02%
4	eugenol		7-22%
5	γ-gurjunene		8.40–10.08%
6	pentadecanoic acid		11%
7	limonene		5.69%
8	terpinolene		1.98–8.39%
9	spathulenol		1.42–8.34%

10	ledene		0.94–6.72%
11	α-pinene		0.85-23.62%
12	β-pinene		10%
13	α -eudesmol		4.68%
14	longifolene		0.07–6.22%
15	terpinen-4-ol		-
16	α-terpineol		-
18	γ-terpinene		-

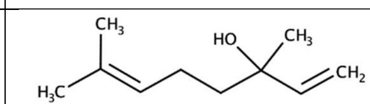
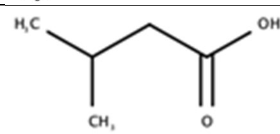
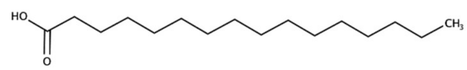
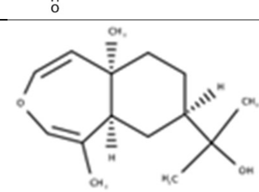
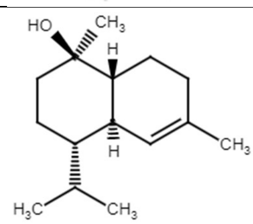
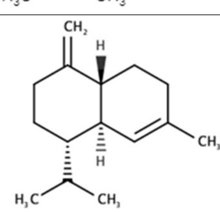
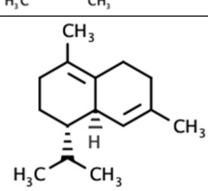
19	*p*-cymene		1.60%

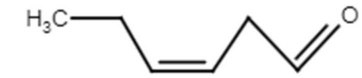
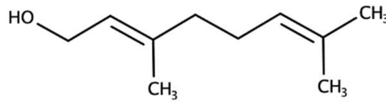
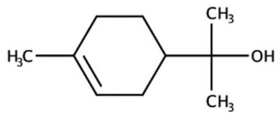
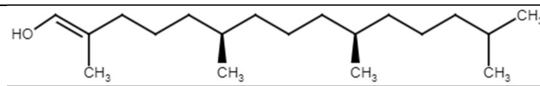
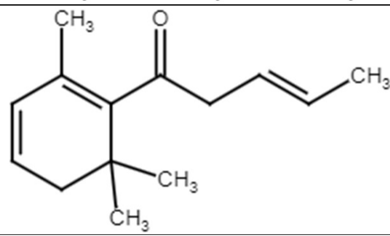
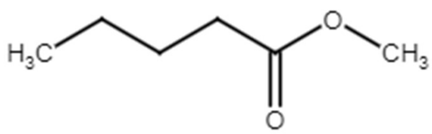
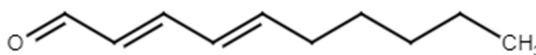
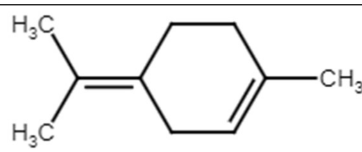
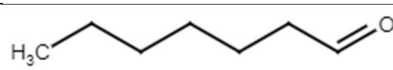
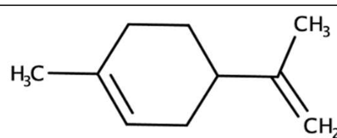
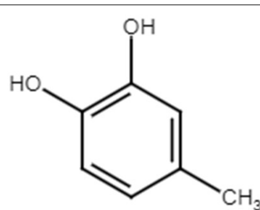
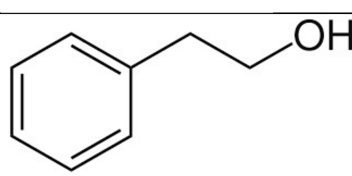
Viburnum

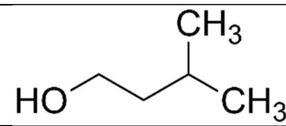
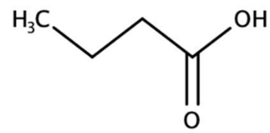
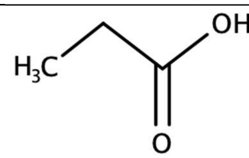
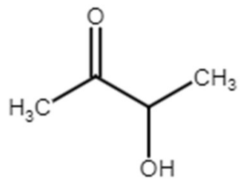
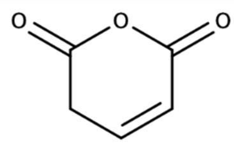
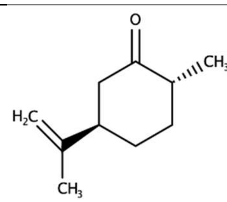
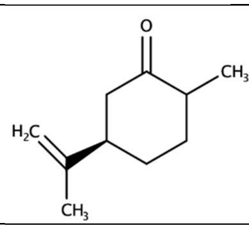
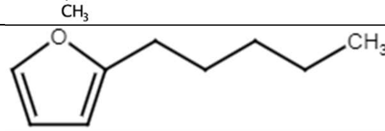
There are many plants of *Viburnum opulus* each of which produces fragrant flowers with distinctive aromas. These flowers exhibit a range of scents, from sweet and spicy to fruity and floral [22]. Viburnum flower has over 150 plants native to North America and Asia. The flower is a collection of dainty and delicate blossoms. Each flower is composed of numerous small petals that are typically arranged in a rounded or dome-like shape. These petals come in various shades, including white, pink, and light purple, which give the flower a gentle and refined appearance. The clusters of Viburnum flowers are often dense and abundant, creating a lush and full look. They grow on slim stems and their size can vary depending on the specific type of Viburnum [23]. Essential oils from viburnum plants can be extracted and studied to get important knowledge about their various fragrant constituents. The articles presented information on the essential oil of viburnum flowers extracted using steam distillation. GC-MS analysis showed key compounds including linalool, α-cadinol, γ-cadinene, and Δ-cadinene. This linalool is a monoterpene with a floral profile while α-cadinol, γ-cadinene, and Δ-cadinene are sesquiterpenes that can contribute to the overall fragrant profile of viburnum. These compounds are often associated with floral, woody, earthy, and slightly spicy aromas. Phenylethyl alcohol is another compound known for its pleasant floral fragrance. However, compounds such as isovaleric acid, butanoic acid, propanoic acid, 4-methyl catechol, isoamyl alcohol, acetoin, 2*H*-pyran-2,6(3*H*)-dione, *(E)*-Dihydrocarvone, d-carvone, and 2-pentyl furan may not have distinctive fragrant properties or are typically associated with non-pleasant odors.

Figure 9: Viburnum (*Viburnum opulus*)[21]

Table 9: Compounds identified in Viburnum (appendix I)

No.	Compound Name	Structure	Area %	% Composition
1	L-linalool		2.1	58.5-10.8
2	isovaleric acid		-	-
3	palmitic acid		-	18.3
4	occidenol		26.3-6.3	-
5	α-cadinol		9.1-4.8	5.6
6	γ-cadinene		20.8-4.6	-
7	Δ-cadinene		4.5-3.4	-

8	3-*Z*-hexenal		-	12.7
9	geraniol		-	12.53-5.77
10	α-terpineol		-	20.98-12.63
11	phytol		8.7-7.8	-
12	*trans*-β-damascenone		5.9	-
13	methyl pentanoate		32.2-4.1	-
14	2*E*,4*E*-decadienal		32.3-4.5	-
15	terpinolene		0.5	-
16	*n*-heptanal		3.9	-
17	limonene		0.9	-
18	4-methyl catechol		-	-
19	phenylethyl alcohol		-	-

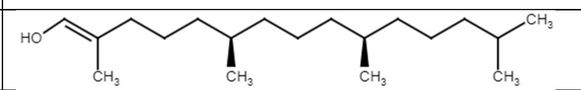
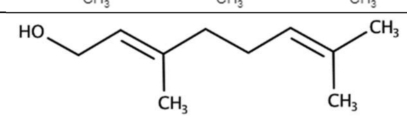
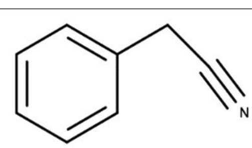
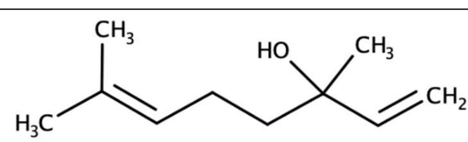
20	isoamyl alcohol		-	-
21	butanoic acid		-	-
22	propanoic acid		-	-
23	acetoin		-	-
24	2*H*-pyran-2,6(3*H*)-dione		-	-
25	(*E*)-dihydrocarvone		-	-
26	d-carvone		-	-
27	2-pentyl furan		-	-

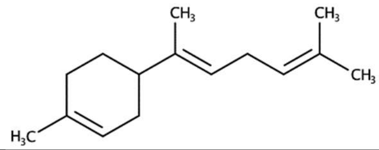
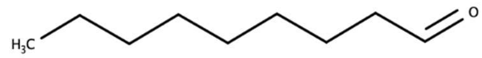
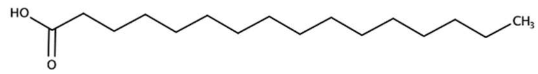
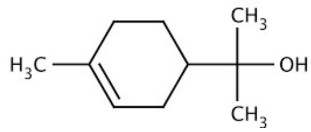
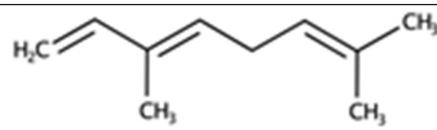
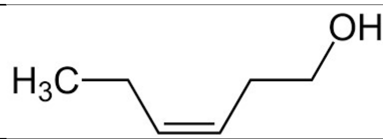
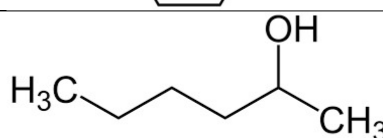
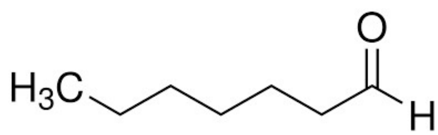
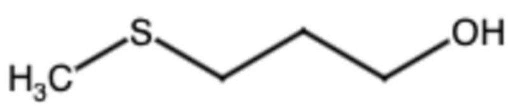
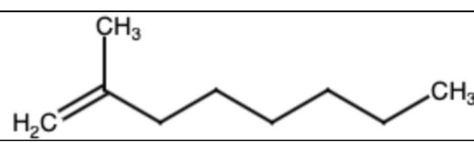
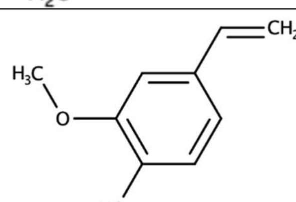
Wisteria Vines

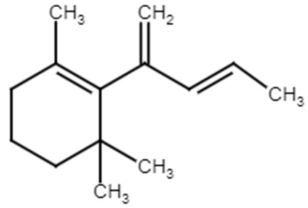
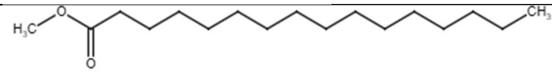
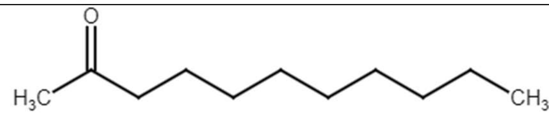
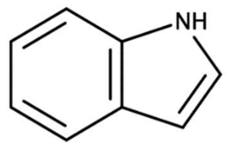
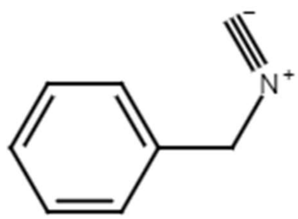
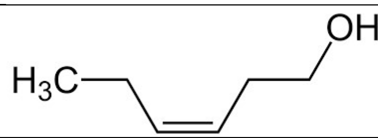
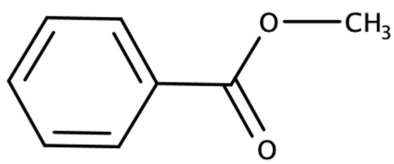
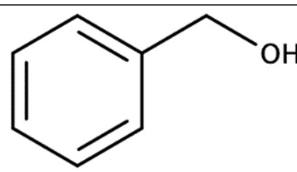
The elegant, cascading petals and an aroma evocative of grapes and spring buds are the characteristics that define Wisteria Vines [24]. Wisteria Vine originated in parts of Asia and migrated to North America when settlers set on their exhibitions in 1803. In Japan, wisteria is a symbol of love and longevity. Each Wisteria Vine flower has a unique shape similar to a pea, with petals that are slightly curved and overlap each other. Wisteria flowers come in various shades like lavender, purple, pink, and white. The Wisteria Vine is known for its strong and vigorous growth and reaches impressive heights [25]. The articles presented were interested in examining information about the fragrant elements that give wisteria blossoms their unique aroma because of their delicate scent. Wisteria essential oil was obtained through solvent extraction. Based on the literature research, wisteria plants contain major fragrant compounds such as phytol, geraniol, benzyl cyanide, and linalool. Additionally, there are also minor fragrant compounds such as (Z)-g-bisabolene, nonanal, palmitic acid, α-terpineol, (2E)-hexanal, (E)-β-ocimene, (3Z)-hexenol, hexanol, heptanal, 3-(methylthio)-propanol, 1-octen-3-ol, 4-vinyl-o-guaiacol, (E)-β-damascone, methyl hexadecanoate, ethyl hexadecanoate, and indole.

While some of these compounds are associated with a pleasant fragrance, others may not necessarily contribute to a noticeable scent. For example, phytol can contribute to a green, leafy fragrance, while geraniol has a sweet, floral aroma. Benzyl cyanide has a bitter almond-like fragrance and is used as a synthetic fragrance ingredient. Linalool has a floral scent with hints of citrus. Among the minor fragrant compounds, α-terpineol is known for its floral fragrance, while indole has a distinct floral and jasmine-like scent. (E)-β-ocimene and (3Z)-hexenal are volatile compounds with herbaceous and green notes.

Table 10: Compounds identified in Wisteria Vines (Appendix J)

No.	Compound Name	Structure	% Composition
1	phytol		46.0
2	geraniol		32.8-3.0
3	benzyl cyanide		31.7
4	linalool		22.1-5.0

5	(*Z*)-γ -bisabolene		8.4
6	nonanal		7.5-5.7
7	palmitic acid		8.7-8.2
8	α-terpineol		3.0
10	(*E)*-β-ocimene		-
11	(3*Z)*-hexenol		-
12	hexanol		-
13	heptanal		-
14	3-(methylthio)-propanol		-
15	1-octen-3-ol		9.3
16	4-vinyl-o-guaiacol		-

17	(*E*)-β-damascone		-
18	methyl hexadecanoate		-
19	2-undecanone		-
20	indole		-
21	benzyl isocyanide		-
22	(3*Z*)-hexenal		-
23	methyl benzoate		-
24	benzyl alcohol		-

The results show the varied and complex composition of fragrant compounds found in the essential oils of the selected flower plants. The extraction methods employed, whether steam distillation or solvent extraction, successfully captured these compounds, allowing for their characterization and identification.

Discussion

Overall, the literature search shows how the essential oils of the ten chosen flower plants have a complex and variable composition of fragrant molecules. The compounds were successfully collected by the extraction techniques used, including solvent and steam distillation, enabling their characterization and identification. A comparative analysis of the fragrant compounds identified in the essential oils of the ten flower plants reveals both commonalities and distinct characteristics. Percent compositions were summarized for each flower by establishing a range encompassing the lowest and highest numbers from all the studies, thereby creating a comprehensive percent composition range. However, some articles presented only stated the detection of fragrant compounds being present but did not state exactly how much of the percent composition is present. This could be due to the study's goal since these specific articles are not just examining chemical makeup of the flowers. For instance, when looking at Table 1 where a table summary for the chemical composition for oriental lily is given majority of the compounds had a percentage composition except three compounds: (*E,E*)-2,6-dimethyl-1,3,5,7-octatetraene, *alpha*-ocimene, and an unidentified terpene. These compounds were detected in Oriental Lily, but their percentage composition was not given. Compounds without percentage composition were noted because the overall goal is to determine what fragrant compounds are found within each flower of study based on the relevant articles.

Many compounds, including linalool, benzyl acetate, and geraniol, were discovered in a variety of flower plants, suggesting they are frequently present in floral scents. Each flower plant did, however, also display distinctive substances that contribute to their smells.

Based on their application, flowers with rich, potent floral aromas, such as tuberose, gardenia, and ylang-ylang, are highly prized in the perfume industry. On the other hand, flowers like eucalyptus and neroli have energizing and therapeutic scents that are often found in aromatherapy and personal care products. It is possible to use these flower plants specifically in a variety of applications by being aware of the distinctive fragrance chemicals.

In this literature search project, both steam distillation and solvent extraction were used, with each method showing its advantages and limitations. Steam distillation proved effective in capturing a wide range of volatile compounds, particularly in flowers with high essential oil content. Solvent extraction, on the other hand, provided an alternative approach for extracting essential oils from flowers with lower oil yields. The choice of extraction method should consider the specific characteristics of the flower plants and the desired outcome. From the research, the identified compounds offer insightful information to the fragrance business, enabling the creation of fresh fragrances and scented goods. Further investigation into the biological functions and potential therapeutic advantages of fragrant chemicals is also made possible by this literature research project.

Conclusion

In conclusion, the literature search project investigated the extraction and characterization of fragrant compounds from the essential oils of ten different flower plants. The search found that by using steam distillation and solvent extraction methods, the fragrant compounds present in the flower plants, including Oriental lily, tuberose, neroli, ylang-ylang, gardenia, catalpa tree, locust flower, eucalyptus, viburnum, and Wisteria Vine, were successfully extracted and analyzed.

This project also found that each flower plant contains a wide variety of fragrant chemicals that contribute to their distinctive smells. The summary revealed both shared and unique chemicals among the flowers, revealing information about their fragrant characteristics. The research has applications in a variety of fields, such as perfumery, aromatherapy, and cosmetics, where essential oils might be used for their distinctive scents and conceivable therapeutic properties.

Given the characteristics of each flower plant, the extraction techniques used in this investigation proved effective in obtaining fragrant chemicals. The findings and analyses in this capstone literature project serves as a foundation for future investigation and study in the field of natural fragrances, including the study of additional flower plants, improvement of extraction techniques, and investigation of the biological activities of the fragrant compounds. This literate research can advance our understanding of the fragrant chemicals present in flowers, supplying valuable information for the creation of novel fragrances and promoting developments in natural fragrances.

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Appendices

Please note that the Appendix comprises a comprehensive list of articles organized by the keywords used in the search and a compilation of pertinent articles aligned with the project's goals. This section is do demonstrate the number of articles found in the method section only.

Appendix A:

Oriental Lily Full Article List

1. Kong, Y.; Lang, L.; Bai, J.; Dou, X.; Wang, N. Floral scent composition of nine Oriental× Trumpet hybrid lilies. *Acta Horticulturae*, **2016**, (1127), 425-430.
2. Hui-Tang, P.; Xia, L.; Zi-Lin, J.; Ming, S.; Jia, W.; Wei-Ru, Y.; Qi-Xiang, Z. Major aroma ingredients of oriental lily 'Siberia' and their effect on humans. *Acta Horticulturae* **2011**, *925*, 307-313.
3. Kong, Y.; Sun, M.; Pan, H. T.; Zhang, Q. X. Composition and emission rhythm of floral scent volatiles from eight lily cut flowers. *J. Am. Soc. Hort. Sci.* **2012**, *137*(6), 376-382.
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Oriental Lily Relevant Article List

1. Kong, Y.; Lang, L.; Bai, J.; Dou, X.; Wang, N. Floral scent composition of nine Oriental× Trumpet hybrid lilies. *Acta Horticulturae*, 2016, (1127), 425-430.
2. Hui-Tang, P.; Xia, L.; Zi-Lin, J.; Ming, S.; Jia, W.; Wei-Ru, Y.; Qi-Xiang, Z. Major aroma ingredients of oriental lily 'Siberia' and their effect on humans. *Acta Horticulturae* **2011**, *925*, 307-313.
3. Kong, Y.; Sun, M.; Pan, H. T.; Zhang, Q. X. Composition and emission rhythm of floral scent volatiles from eight lily cut flowers. *J. Am. Soc. Hort. Sci.* **2012**, *137*(6), 376-382.
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composition using a multivariate approach applied to average mass spectra and segmented average mass spectral data. *Journal of Chromatography A* **2020**, *1618*, 460853.
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Appendix E:

Gardenia Full Article List

1. Khammee, T.; Phoonan, W.; Ninsuwan, U.; Jaratrungtawee, A.; Kuno, M. Volatile constituents, in vitro and in silico anti-hyaluronidase activity of the essential oil from gardenia carinata wall. ex roxb. Flowers. *Journal of Essential Oil Research* **2019**, *31*(1), 18-27.
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Appendix I:

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1. Yilmaz, N.; Yayli, N.; Misir, G.; Karaoglu, S.; Yayli, N. Chemical composition and antimicrobial activities of the essential oils of *Viburnum opulus*, *Viburnum lantana* and *Viburnum orientala*. *Asian Journal of Chemistry* **2008**, *20*(5), 3324.
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Appendix J:

Wisteria Vine Full Article List

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1. Jiang, Y.; Chen, X.; Lin, H.; Wang, F.; Chen, F. Floral scent in Wisteria: chemical composition, emission pattern, and regulation. *Journal of the American Society for Horticultural Science* **2011**, *136*, 307-314.

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