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Murraya koenigii as a Source of Bioactive Phytochemicals: Antimicrobial Assessment and Compound Profiling

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ABSTRACT

Curry leaf, or Murraya koenigii, is a popular culinary herb and traditional medicinal plant that is prized for its bioactive phytochemicals. The phytochemical composition, GC-MS compound profiling, and antimicrobial potential of M. koenigii leaf extracts in methanol were assessed in this study. After being shade-dried and ground into a powder, fresh leaves were extracted using methanol and cold maceration. Saponins, alkaloids, terpenoids, steroids, phenols, and anthraquinones were detected by phytochemical screening, but tannins and flavonoids were not. Sesquiterpenes (copaene, caryophyllene, germacrene D, spathulenol), fatty acids (tetradecanoic acid), esters (diethyl phthalate, ethyl acetate), and phytosterols (campesterol, γ-sitosterol) were among the 15 main compounds found by GC–MS analysis. Numerous of these substances, including γ-sitosterol and caryophyllene, are said to have cytotoxic, antimicrobial, anti-inflammatory, and antioxidant properties. At 100 µL concentrations, antimicrobial assays employing the pour plate and well diffusion methods showed significant activity against Gram-negative Escherichia coli (14 mm) and Gram-positive Staphylococcus sp. (13 mm inhibition zone). Macrophomina phaseolina (6 mm) and Fusarium sp. (5 mm) were moderately inhibited by antifungal tests. Assays for minimum inhibitory concentration verified dose-dependent reactions in both bacterial and fungal strains. The results validate M. koenigii's pharmacological potential as a naturally occurring source of bioactive substances, especially phytosterols and sesquiterpenes. These findings support the traditional use of curry leaves to treat infections with science and point to their potential for use in the creation of new antimicrobial agents. To clarify mechanisms of action and assess clinical relevance, more research using purified fractions is advised.

Keywords: *Murraya koenigii, phytochemical screening, GC-MS compound profiling, Antimicrobial potential.*

Introduction

Man uses plants to fulfill his basic food, clothing, and shelter requirements in many ways. Rural and urban cultures use wild plants to make medicines, crafts, and cosmetics. Also, rural areas rely on wild plants as sources of revenue and employment [1]. Significant herbal products include spices, herbal teas, functional food components, medical raw materials, aromatic plants, essential oils, flavouring, fragrant items, and dietary supplements. Substances include terpenoids, flavonoids, sterols, simple phenolic compounds, proteins, enzymes, lipids, oils, carbs, etc. Natural resources still serve as the foundation of the primary healthcare system and are the source of synthetic and conventional herbal medication. Scientists have been researching plants for their potential use in managing chronic wounds and treating certain infectious diseases due to the presence of numerous life-sustaining components in plants [2].

There is considerable research on medicinal plants in India, and India is considered the hub of medicinal plants. Many plants are used as medicine for specific illnesses, and some can also be utilized in the culinary arts. Furthermore, the demand for traditional medicinal plants is growing; in India, the market for medicinal plants is growing at a rate of 20% per year [3]. There is a demand for medicinal plants, and more studies are being conducted worldwide. *Murrya koenigii*, often known as the curry plant, is a herbal medicine utilized for healing and culinary purposes. The *Murraya koenigii* or Bergera koenigii is a tropical to sub-tropical tree in the Rutaceae (the rue family), including rue, citrus, and satinwood. It is native to Asia. M. koenigii is additionally known as sweet neem, even though it belongs to a different family than neem, Azadirachta indica, in the Meliaceae family [4]. According to [5] only two Murraya species, *M. koenigii* and *M. paniculate,* are found in India. The present study aims to evaluate the phytochemical GC-MS analysis and potential antimicrobial activity of Murraya koeinigii.

Methodology

Plant Collection and Processing

Fresh leaves of *Murraya* were collected from Tulasi Nursery, Hyderabad, in January. The collected leaves were shade-dried and pulverized into a fine powder using an electric blender. The powdered samples were stored in airtight containers until further use.

Extract Preparation

A total of 500 g of air-dried powdered leaves of *Murraya* were macerated with 2.5 L of methanol by cold maceration at room temperature for 48 hours with intermittent shaking. The extract was filtered, and the filtrate was concentrated at 40 °C under reduced pressure using a rotary evaporator to obtain the crude dry extract.

Phytochemical Analysis

Qualitative phytochemical screening of the methanolic extract was performed following the method described by [6]. The following tests were conducted:

- **Test for Tannins:** To 2 ml of extract, 2 ml of distilled water and a few drops of ferric chloride solution were added. A blue-black or greenish colour indicated the presence of tannins.
- **Test for Saponins:** 3 ml of extract was mixed with 3 ml of distilled water and shaken vigorously. Formation of persistent foam upon heating indicated the presence of saponins.
- **Test for Flavonoids:** To 1 ml of extract, 1 ml of 10% lead acetate solution was added. No colour change was observed, indicating absence of flavonoids.
- **Test for Alkaloids:** 3 ml of extract was mixed with 3 ml of 1% HCl in a hot water bath. The solution was divided into two test tubes; 1 ml of Mayer's reagent was added to one. Formation of a buff-coloured precipitate confirmed the presence of alkaloids.
- **Test for Terpenoids:** 2 ml of extract was dissolved in 2 ml of chloroform and evaporated to dryness. Concentrated H_2SO_4 (2 ml) was added, and the mixture was heated for 2 minutes. No characteristic colour change was observed, indicating absence of terpenoids.
- **Test for Steroids:**

- *Salkowski's Test:* 2 ml of extract was dissolved in 2 ml of chloroform, followed by addition of 2 ml concentrated H_2SO_4. Formation of a red colour in the chloroform layer indicated the presence of steroids.
- *Liebermann's Test:* (details can be added if performed).

- **Test for Phenols:** 1 g of extract was dissolved in 5 ml of distilled water and treated with 5% ferric chloride solution. Formation of a dark green colour confirmed the presence of phenolic compounds.
- **Test for Anthraquinones:** 2ml of Murraya Koenigii extract was taken in a test tube, and 4ml of concentrated sulphuric acid was added to the test tube, boiled and shaken well, and then 3ml of chloroform was added to the test tube. The chloroform layer was separated, and a pipette containing diluted ammonia was taken out to another test. The appearance of a pink-red/ violet colour at the lower phase indicates the presence of anthraquinones.

II. GC-MS Analysis

The *Murray* extracts were analyzed using GC-MS (SHIMADZU, Japan) equipped with an Optima 5 ms capillary column (30 m × 0.25 mm, 0.25 µm film thickness), following the method described by Azra & Bhavani (2022).

- **Oven program:** Initial temperature 60°C, increased at 10°C/min to 160°C, then to 250°C, with a 2-minute hold at each increment.
- **Injection parameters:** Splitless injection volume of 1.0 µL, split ratio 1:1, injector temperature 200°C.
- **MS conditions:** Ion source at 230°C, interface temperature 250°C, solvent delay 4.5 min, scan range 50–700 amu. Multiplier voltage 1859, electron ionization (EI) mode at 70 eV.
- **Compound identification:** Based on retention time, fragmentation patterns, and spectral data compared with the Wiley and NIST libraries (Azra & Bhavani, 2022).

III. Antimicrobial Test

3.1 Preparation of Active Bacterial Cultures

A single colony of pure bacterial culture was inoculated into 50 mL of nutrient broth in a 150 mL conical flask and incubated for 8–12 hours at 37°C.

3.2 Preparation of Sample Concentrations

- **Powdered samples:** Dissolved in 1 mL of an appropriate solvent (water/methanol/DMSO, etc.), then aliquoted into different concentrations for MIC assay.
- **Liquid samples:** Used directly or diluted with water/solvent as required.

3.3 Antibacterial Assay

The pour plate method was used.

- 1% of active bacterial culture was mixed into autoclaved agar medium just before solidification and poured into plates.
- Test organisms: *Staphylococcus sp.* (Gram-positive) and *Escherichia coli* (Gram-negative).
- Wells were made using a sterile borer, and 100 µL of each sample was loaded. Plates were incubated at 37°C for 18–24 hours.

3.4 Antifungal Assay

- **Test organisms:** *Fusarium sp.* and *Macrophomina phaseolina*.
- **Media:** Potato Dextrose Agar (PDA) with antibiotics (Streptomycin/Chloramphenicol) to prevent bacterial contamination.
- **Procedure:** Plates were poured and allowed to solidify. Fungal plugs (5 mm) were placed at the center, and wells (5 mm) were created around them using a sterile cork borer.
- Each well was loaded with 100 µL of samples; one well contained antifungal standard chemicals as control.
- **Incubation:** Plates were incubated at 25°C for 96 hours, and results were recorded.

IV. Results

4.1 Phytochemical Analysis: Phytochemical analysis of Murraya's leaf extract shows saponins, alkaloids, terpenoids, steroids, phenols, and anthraquinones, and compounds like tannins and flavonoids are absent.

Test	Results
Tannins	Absent
Saponins	Present
Flavonoids	Absent
Alkaloids	Present
Terpenoids	Present
Steroids	Present
Phenols	Present
Anthraquinones	Present

4.2 GC-MS Analysis

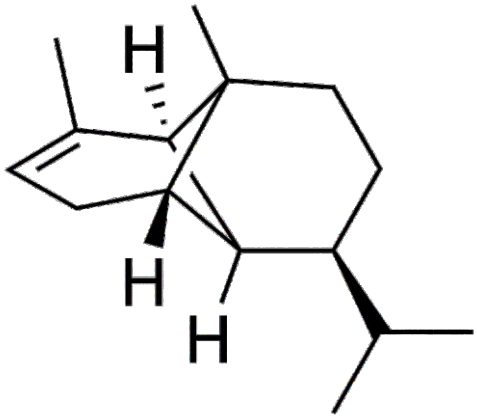
Based on GC-MS analysis results, it comprises numerous compounds. From the lists of GC-MS analysis, 15 compounds have been selected, which are mentioned in the table below.

S.No	Name	R.Time	Aera	Mol. F	Mol. Wt	Compound
1	Ethyl Acetate	1.451	0.18	$C_4H_8O_2$	88	Ester
2	1-Nitro-2 propane	1.770	0.01	$C_3H_5NO_3$	103	Alkanes
3	Beta-pinene	5.206	0.12	$C_{10}H_{16}$	136	Monoterpene
4	Isoborynyl Acetate	9.845	0.05	$C_{12}H_{20}O_2$	196	Aromatic compound
5	Alpha-Cubebene	10.698	0.19	$C_{15}H_{24}$	204	Sesquiterpenoids
6	Copaene	11.053	0.74	$C_{15}H_{24}$	204	Sesquiterpenes
7	Caryophllene	12.365	0.85	$C_{15}H_{24}$	204	Sesquiterpenes
8	Germacrene D	12.975	0.29	$C_{15}H_{24}$	204	Terpenes
9	Spathulenol	14.030	0.29	$C_{15}H_{24}O$	220	Sesquiterpenoids
10	Isoaromadendrene epoxide	14.156	0.64	$C_{15}H_{24}O$	220	Sesquiterpenoids
11	Diethyl phthalate	14.431	0.11	$C_{12}H_{14}O_4$	222	Ester
12	9-Eicosyne	19.740	0.85	$C_{15}H_{24}$	204	Alkynes
13	Tetradecanoic Acid	21.091	1.85	$C_{14}H_{28}O_2$	228	Fatty acid
14	Campesterol	31.406	1.26	$C_{28}H_{48}O$	400	Steroid
15	Gamma-Sitosterol	32.112	2.10	$C_{29}H_{50}O$	414	Steroid

4.3 GC-MS -Nature of Compounds

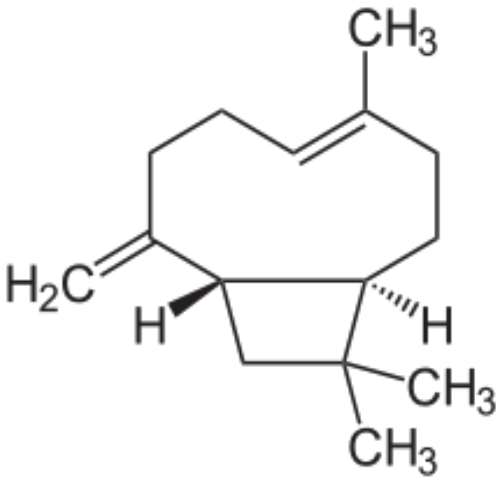
Compound Name	Retention Time (min)	Area %	Nature of the Compound
9,10-Secocholesta-5,7,10(19)-triene-1,3-diol, 25-[(trimethylsilyl)oxy]	0.086	20.2	This is a derivative of silylated sterol. Sterols are well-known for their possible antioxidant and anti-inflammatory properties [7]
Pyrazine, tetrakis(1-methylethyl)	29.955	8.35	One class of heterocyclic aromatic organic compounds is pyrazine. Some pyrazines have been investigated for their possible biological activities, such as antioxidant qualities, while others are used as flavouring agents [8]
Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylether-	12.649	8.01	Some naphthalene derivatives have been investigated for their potential in traditional medicine, and they can display a variety of biological activities [9]
Pyridine-4-aldehyd, N-ethoxycarbonylhydrazon	2.42	6.4	In medicinal chemistry, pyridine derivatives are frequently used scaffolds with a variety of biological activities, such as anti-inflammatory and anti-cancer effects [10]
IR,3Z,9s-4,11,11-Trimethyl-8-methylenebicyclo[7.2.0]undec-3-ene	11.603	4.13	This substance belongs to a broad class of natural products called terpenes, which have a variety of bioactivities, including antibacterial, antioxidant, and anti-inflammatory properties [11]
2-Methyl-pyrrolidine-2-carboxylic acid	9.12	3.71	Many alkaloids contain compounds that contain pyrrolidines, which are frequently linked to pharmacological effects [12]
Eudesma-4(14),11-diene	12.065	3.48	This hydrocarbon is a sesquiterpene. A significant class of substances derived from plants, sesquiterpenes are known to have cytotoxic, antimicrobial, and anti-inflammatory effects [13]
Eudesma-4(14),11-diene	12.53	1.97	This is a sesquiterpene hydrocarbon, a class of compounds known for their antimicrobial, anti-inflammatory, and cytotoxic effects [14]
1.E-11.Z-13-Octadecatriene	23.044	2.65	This kind of hydrocarbon can play a number of functions in biological systems, such as membrane structure and cell signalling [15]
Bicyclo[2.2.1]heptane, 7,7-dimethyl-2-methylene-	6.025	2.52	Terpene is the name given to this bicyclic compound. Terpenes have a range of biological activities, such as antioxidant and antimicrobial qualities [16]
Butane, 2,3-dichloro-, (R@,S@)-	1.095	2.17	This hydrocarbon is chlorinated. The potential of certain chlorinated organic compounds as solvents or in chemical synthesis has been investigated [17]
Cyclohexasiloxane, dodecamethyl-	9.34	2.12	Siloxanes are substances based on silicon that are extensively used in industry. In general, little is known about their bioactive qualities [18]
gamma.-Sitosterol	32.112	2.1	A phytosterol that has been researched for its anti-inflammatory and cholesterol-lowering qualities [19]
Tetradecanoic acid	21.091	1.85	This saturated fatty acid, which is present in a lot of plant and animal fats, is also referred to as myristic acid. It has some anti-inflammatory qualities and has been researched for its function in cellular signalling [20]
Pyrazine, tetrakis(1-methylethyl)-	30.384	1.81	It has been demonstrated that this pyrazine compound possesses antioxidant qualities and may have biological activities [21]
Bicyclo[3.1.1]hept-2-ene, 2,6-dimethyl-6-(4-methyl-3-pentenyl)-	11.82	1.47	This monoterpene has a number of biological activities, such as antibacterial and anti-inflammatory qualities [22]
alpha.-Tocopherol-.beta.-D-mannoside	31.145	1.44	This is a derivative of the well-known antioxidant tocopherol, also known as vitamin E [23]
Campesterol	31.406	1.26	A phytosterol has demonstrated anti-inflammatory and cholesterol-lowering qualities [24]
Cyclooctasiloxane, hexadecamethyl-	16.165	1.02	a siloxane compound that is usually employed in industrial settings. In general, bioactive properties lack sufficient documentation [25]
Caryophyllene-(11)	12.365	0.85	Commonly present in essential oils, this sesquiterpene has been researched for possible anti-inflammatory, antimicrobial, and pain-relieving properties [26]

Terpenoids are chemicals present in the essential oils of various plants that have been shown to benefit human and animal health. Sesquiterpenes, one of the most abundant terpenes, are a group of natural compounds with a wide range of beneficial industrial qualities. Copaene (COP) is a sesquiterpene derived from numerous plants [27]. Copaene, or α-Copaene, is the chemical term for an oily liquid hydrocarbon found in many essential oil-producing plants.



Copaene

The sesquiterpene (E)—caryophyllene is a significant plant volatile oil found in high concentrations in various spice and culinary plants [7]. Caryophyllene is a sesquiterpene found in a variety of plant essential oils. Caryophyllene is thought to have anti-inflammatory, antibacterial, antioxidant, anticarcinogenic, and local anesthetic properties [12]. Campesterol is an anabolic steroid precursor of boldenone. Boldenone undecylenate is a common anabolic steroid used in veterinary medicine to help cattle grow, but it is also one of the most dangerously addictive anabolic steroids in sports.



Antimicrobial Activity

After incubation, bacterial plates were examined for zones of inhibition. Antibacterial activity was evaluated by determining the minimum inhibitory concentration (MIC). For this assay, wells were loaded with 25 µL, 50 µL, 75 µL, and 100 µL of each sample, diluted with water or an appropriate solvent to maintain a final volume of 100 µL per well. The MIC values were expressed as 25, 50, 75, and 100 µL, corresponding to the respective dilutions of the test samples, as sample concentrations varied across different extracts.

Antibacterial Activity and Zone of Inhibition

Gram-positive bacteria - Staphylococcus sp. – 13mm
Gram Negative bacteria – E.Coli - 14mm

Minimum Inhibitory concentration (mm)

Sample	*Staphylococcus sp.*	*E.Coli*
25 µl	06	08
50 µl	08	08
75 µl	10	10
100 µl	12	12
	25 **µl**	25 **µl**

The fungal plates were observed after incubation time, and the following results were noted.

Antifungal activity and Hypahe intention

Fusarium sp: 2mm
Macrophomina sp: 6mm

Minimum inhibitory concentration (MIC) assay of the given samples

The samples checked for antifungal activity were assayed for their minimum inhibitory concentrations (MIC) by loading 25 µl, 50 µl, 75 µl, and 100 µl of samples diluted with water/solvent to make up the volume to 100 µl in each plate well, respectively. The MIC was designated as 25, 50, 75, and 100, which should be referred to for respective dilutions based on sample concentrations, as different samples have different concentrations.

Minimum inhibitory concentration

Sample	Macrophomina sp	Fusarium sp	Total
25 µl	-	-	
50 µl	3mm	-	50
75 µl	4mm	3mm	75
100 µl	6mm	5mm	100

From the findings, it can be said that the methanolic extract of curry leaves has antimicrobial activity on various organisms.

Discussion

Murraya koenigii is traditionally used as a stimulant for the management of diabetes, and the leaves are eaten to treat diarrhea and dysentery. Many fatty acids, steroids, and different terpenoid components are seen. According to GC-MS analysis of the leaf extract, highly volatile oil molecules like Copaene, Spathulenol, and Germacrene D are generated from sesquiterpenoid component terpenes. Terpenes are a natural product that includes chemicals with the formula $(C_5H_8)n$. These unsaturated hydrocarbons, made up of over 30,000 chemicals, are produced mainly by plants, particularly conifers. Monoterpenes (C_{10}), sesquiterpenes (C_{15}), and diterpenes (C_{20}) are the three types of terpenes (C_{20}). Moreover, it also includes steroids, esters, fatty acids and aromatic compounds.

The leaf powder extract was subjected to antimicrobial activity, and the results were investigated. The findings of this study demonstrate that curry leaf methanolic and ethanolic extracts have antibacterial effects on a variety of microorganisms. This discovery paves the way for additional investigation and studies to pinpoint the active ingredients responsible for the biological activity of plants. More studies are required on different strains that have the potential to be used as medicine for other ailments. However, further investigation with purified fractions is required to predict the exact mechanism of action.

Conclusion

This study focused on phytochemical and GC-MS compounds rich in compounds like steroids, fatty acids, and terpenes. I want to proceed with the pharmacological study on plants and work on some compounds obtained through GC-MS analysis based on these studies. More research will be done on the curry leaf's antibacterial component and how the extracts can be used for clinical and other applications.

References

1. Arizmendi, N., Alam, S. B., Azyat, K., Makeiff, D., Befus, A. D., & Kulka, M. (2022). The complexity of sesquiterpene chemistry dictates its pleiotropic biologic effects on inflammation. *Molecules*, *27*(8), 2450. https://doi.org/10.3390/molecules27082450

2. Azra, B. H., & Bhavani, D. N. L. (2022, January). *Chamaecostus Cuspidatus (Nees & Mart.) Ethanolic Extract: GC-MS Analysis & Characterization by FTIR and UV*. https://ijsdr.org/papers/IJSDR2201012

3. Balakrishnan, et al. "Medicinal Profile, Phytochemistry, and Pharmacological Activities of Murraya Koenigii and Its Primary Bioactive Compounds." *Antioxidants*, vol. 9, no. 2, 2020, p. 101. *Crossref*, https://doi.org/10.3390/antiox9020101.

4. Batiha, G. E., Olatunde, A., El-Mleeh, A., Hetta, H. F., Al-Rejaie, S., Alghamdi, S., Zahoor, M., Beshbishy, A. M., Murata, T., Zaragoza-Bastida, A., & Rivero-Perez, N. (2020). Bioactive Compounds, Pharmacological Actions, and Pharmacokinetics of Wormwood (Artemisia absinthium). *Antibiotics*, *9*(6), 353. https://doi.org/10.3390/antibiotics9060353

5. Bosly, H. A. E. (2022). Larvicidal and adulticidal activity of essential oils from plants of the Lamiaceae family against the West Nile virus vector, Culex pipiens (Diptera: Culicidae). *Saudi Journal of Biological Sciences*, *29*(8), 103350. https://doi.org/10.1016/j.sjbs.2022.103350

6. Cho, Y. S., Park, J., Choi, B., Moon, J., & Yi, J. (2001). A novel catalyst preparation and kinetic study on the dechlorination of chlorinated hydrocarbons. In *Studies in Surface Science and Catalysis* (pp. 559–564). https://doi.org/10.1016/s0167-2991(01)82012-7

7. Choudhary, D., Garg, S., Kaur, M., Sohal, H. S., Malhi, D. S., Kaur, L., Verma, M., Sharma, A., & Mutreja, V. (2022). Advances in the Synthesis and Bio-Applications of Pyrazine Derivatives: A Review. *Polycyclic Aromatic Compounds*, *43*(5), 4512–4578. https://doi.org/10.1080/10406638.2022.2092873

8. Dinakaran, S., Bose, V. S. C., Vishwanathan, C., Saranya, K., & Manivasagan, V. (2021). *Comparative analysis of the antibacterial activity of Psidium guajava & Murraya koenigii*. https://ijrti.org/papers/IJRTI2110011.pdf

9. Duhem, N., Danhier, F., & Préat, V. (2014). Vitamin E-based nanomedicines for anti-cancer drug delivery. *Journal of Controlled Release*, *182*, 33–44. https://doi.org/10.1016/j.jconrel.2014.03.009

10. Fidyt, K., Fiedorowicz, A., Strządała, L., & Szumny, A. (2016). β-caryophyllene and β-caryophyllene oxide—natural compounds of anticancer and analgesic properties. *Cancer Medicine*, *5*(10), 3007–3017. https://doi.org/10.1002/cam4.816

11. Ge, J., Liu, Z., Zhong, Z., Wang, L., Zhuo, X., Li, J., Jiang, X., Ye, X., Xie, T., & Bai, R. (2022). Natural terpenoids with anti-inflammatory activities: Potential leads for anti-inflammatory drug discovery. *Bioorganic Chemistry*, *124*, 105817. https://doi.org/10.1016/j.bioorg.2022.105817

12. Gertsch, J., Leonti, M., Raduner, S., Racz, I., Chen, J. Z., Xie, X. Q., Altmann, K. H., Karsak, M., & Zimmer, A. (2008). Beta-caryophyllene is a dietary cannabinoid. *Proceedings of the National Academy of Sciences*, *105*(26), 9099–9104. https://doi.org/10.1073/pnas.0803601105

13. Han, Z., Fina, A., & Camino, G. (2014). Organosilicon compounds as polymer fire retardants. In *Elsevier eBooks* (pp. 389–418). https://doi.org/10.1016/b978-0-444-53808-6.00012-3

14. Handral, H. K., Pandith, A., & Shruthi, S. (2012). A Review On Murraya Koenigii: A Multipotential Medicinal Plant. *Asian Journal of Pharmaceutical and Clinical Research*, *5*, 5–14. https://www.researchgate.net/profile/Anup-Pandith/publication/235758652

15. Kiralan, M., Ketenoglu, O., & Kiralan, S. S. (2021). Trans fatty acids—Occurrence, technical aspects, and worldwide regulations. In *Studies in natural products chemistry* (pp. 313–343). https://doi.org/10.1016/b978-0-12-819489-8.00018-1

16. Legault, J., & Pichette, A. (2007). Potentiating effect of β-caryophyllene on anticancer activity of α-humulene, isocaryophyllene & paclitaxel. *Journal of Pharmacy & Pharmacology*, *59*(12), 1643–1647. https://doi.org/10.1211/jpp.59.12.0005

17. Makar, S., Saha, T., & Singh, S. K. (2018). Naphthalene, a versatile platform in medicinal chemistry: Sky-high perspective. *European Journal of Medicinal Chemistry*, *161*, 252–276. https://doi.org/10.1016/j.ejmech.2018.10.018

18. Mohamed, E.A., Ismail, N.S.M., Hagras, M. *et al.* Medicinal attributes of the pyridine scaffold as anticancer targeting agents. *Futur J Pharm Sci* **7**, 24 (2021). https://doi.org/10.1186/s43094-020-00165-4

19. Mojsiewicz-Pieńkowska, K., Jamrógiewicz, M., Szymkowska, K., & Krenczkowska, D. (2016). Direct Human Contact with Siloxanes (Silicones) – Safety or Risk Part 1. Characteristics of Siloxanes (Silicones). *Frontiers in Pharmacology*, *7*. https://doi.org/10.3389/fphar.2016.00132

20. Moreira, R., Pereira, D. M., Valentão, P., & Andrade, P. B. (2018). Pyrrolizidine alkaloids: chemistry, pharmacology, toxicology and food safety. *International Journal of Molecular Sciences*, *19*(6), 1668. https://doi.org/10.3390/ijms19061668

21. Mortzfeld, F. B., Hashem, C., Vranková, K., Winkler, M., & Rudroff, F. (2020). Pyrazines: Synthesis and Industrial Application of these Valuable Flavor and Fragrance Compounds. *Biotechnology Journal*, *15*(11). https://doi.org/10.1002/biot.202000064

22. Naz, S., Alam, S., Ahmed, W., Khan, S. M., Qayyum, A., Sabir, M., Naz, A., Iqbal, A., Bibi, Y., Nisa, S., Khalifa, A. S., Gharib, A. F., & Askary, A. E. (2021). Therapeutic Potential of Selected Medicinal Plant Extracts against Multi-Drug Resistant Salmonella enterica serovar Typhi. *Saudi Journal of Biological Sciences*, *29*(2), 941–954. https://doi.org/10.1016/j.sjbs.2021.10.008

23. Prasad, M., Jayaraman, S., Eladl, M. A., El-Sherbiny, M., Abdelrahman, M. a. E., Veeraraghavan, V. P., Vengadassalapathy, S., Umapathy, V. R., Hussain, S. F. J., Krishnamoorthy, K., Sekar, D., Palanisamy, C. P., Mohan, S. K., & Rajagopal, P. (2022). A Comprehensive Review on Therapeutic Perspectives of Phytosterols in Insulin Resistance: A Mechanistic Approach. *Molecules*, *27*(5), 1595. https://doi.org/10.3390/molecules27051595

24. Shahzad, N., Khan, W., Md, S., Ali, A., Saluja, S. S., Sharma, S., Al-Allaf, F. A., Abduljaleel, Z., Ibrahim, I. A. A., Abdel-Wahab, A. F., Afify, M. A., & Al-Ghamdi, S. S. (2017). Phytosterols as a natural anticancer agent: Current status and future perspective. *Biomedicine & Pharmacotherapy*, *88*, 786–794. https://doi.org/10.1016/j.biopha.2017.01.068

25. Srivastava, P. (2014). *Phytochemical screening - an overview | ScienceDirect Topics*. Https://Www.Sciencedirect.Com. https://www.sciencedirect.com/topics/medicine-and-dentistry/phytochemical-screening

26. Stillwell, W. (2016). Membrane proteins. In *Elsevier eBooks* (pp. 89–110). https://doi.org/10.1016/b978-0-444-63772-7.00006-3

27. Türkez, H., Çelik, K., & Toğar, B. (2013). Effects of Copaene, a Tricyclic Sesquiterpene, on Human Lymphocyte Cells in vitro. *Cytotechnology*, *66*(4), 597–603. https://doi.org/10.1007/s10616-013-9611-1