Metabolites Profiling and Biological Activities of Volatile Compounds of Ruellia tuberosa L. Leaves by GC-MS

by Susilo Muhamad Farhan

Submission date: 26-Mar-2023 08:27PM (UTC+0700)
Submission ID: 2046790821
File name: 690-698_JPTCP_manuscript.pdf (715.26K)
Word count: 4912
Character count: 26843

Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.47750/jptcp.2023.30.03.071

Metabolites Profiling and Biological Activities of Volatile Compounds of *Ruellia tuberosa* L. Leaves by GC-MS

Susilo[1*], Muhamad Farhan[2]

[1,2]Departement of Biology Education, Universitas Muhammadiyah Prof. DR. Hamka, Jl. Tanah Merdeka, Kp. Rambutan, Jakarta Timur, Indonesia 13830

***Corresponding author:** Susilo, Departement of Biology Education, Universitas Muhammadiyah Prof. DR. Hamka, Jl. Tanah Merdeka, Kp. Rambutan, Jakarta Timur, Indonesia 13830, Email: susilo@uhamka.ac.id

Submitted: 15 November 2022; Accepted: 10 December 2022; Published: 15 January 2023

ABSTRACT

Ruellia tuberosa L. is a common plant that traditionally has pharmacological potential. The leaves are believed to help accelerate wound healing. However, exploring the biochemical profile in it is still limited. This study aimed to establish phytoconstituent profiles on the leaves of *R. tuberosa* L. Therefore, a Gas Chromatography-Mass Spectrometer Analysis (GC-MS) was based. This study revealed 18 polar and non-polar compounds, with five compounds having known biological activity. Squalene dominates in the leaves of *R. tuberosa* L., with the highest content of 15.41%, a source of essential anti-oxidants. The study also revealed the presence of new compounds that have not been identified for activity, such as Salvialane, Tridecanoic acid, 12-oxo-, Phenazine, 2-methoxy-, Cyclododecanone, 2-methylene- and others. We conclude that *Ruellia tuberosa* L. is an essential herbal candidate that can be used for drug development.

Keywords: *bioactive compounds; GC-MS analysis; medicinal plants; Ruellia tuberosa L.; phytochemicals*

INTRODUCTION

Ruellia tuberosa L., or "cracker plant," is a species of the Acanthaceae that grows a lot in hot and tropical to subtropical climates (1,2). R. Tuberosa L. is a shrub plant with a height of 30-45 cm (3). R. Tuberosa L. grows at altitudes above 150 meters above sea level, rapidly growing in moist and shady areas (4). This plant is native to Central America and is popular in India as an ornamental plant (5).

R. tuberosa L. has been reported to have benefits as a medicinal plant, and in pharmacology, it contains antimicrobials, anti-oxidants, antipyretics, antidiabetics, and anti-cancer (6,7), anti-inflammatory (8), antinociceptive (9,10), antibacterial (11). The herbal decoction of *R. tuberosa* L. is also used as a substitute for ipecac in the medical world. It treats various diseases such as bladder, diabetes, diarrhea, typhoid, chronic jaundice, cholera, headache, and fever (8,12). *R. tuberosa* L. contains active phytochemicals such as flavonoids, phenolics, glycosides (13,14), steroids, triterpenoids, alkaloids (9), and tannins (15). Ethanol extract from *R. tuberosa* L. contains flavonoids that have the potential to be anti-inflammatory (16).

Previous research revealed the presence of flavonoids, glycosides, phenols, and saponins in *R. tuberosa* L plants with HPTLC (17). Furthermore, the LC-HRMS method can identify 12 compounds containing *R. tuberosa* L. (15). However, no work has been done on the phytoconstituents of this plant with GC-MS. Therefore, our goal is to perform quantitative and qualitative screening of phytoconstituents on the leaves of *R. tuberosa* L.

MATERIAL AND METHOD

Plant material

The naturally grown fresh plant *R. tuberosa* L. was collected from the Tapos region, Depok, Indonesia (6°24'53.8"S 106°53'16.6"E) in a plastic bag in mid-August 2022. It was identified by the Life Sciences Research Organization, BRIN (National Research and Innovation Agency) Indonesia. The identification results were deposited at the Herbarium Bogoriensis with specimen voucher No. LHU46085.

Extract preparation

Healthy leaves are selected and washed with running tap water. The leaves are cut (± 4 cm) and dried at 40 oC using the oven for 72 hours. Then, the dried leaves are mashed with an electric grinder until they become a fine powder. After the previous procedure, 50 g of leaf powder was transferred to 500 mL of ethanol to be macerated for five days in an impermeable room (18,19). Finally, the extract is filtered with Whatman No.1 paper and placed in a glass bottle for subsequent analysis.

GC-MS Analysis

GC-MS analysis was performed using Gas Chromatography (Agilent 7890) equipped with a 5975 Mass Selective Detector and Chemstation data system (20,21). A total of 5 µL of R. Tuberosa L. leaf extract was filtered by hammering a syringe filter and inserted into column HP-5 by split method (8:1). The initial column temperature was set at 50 oC was raised every 3 oC/min to 150 oC and held for 1 minute, then increased by 20 oC/min to 180 oC and held for 26 minutes.

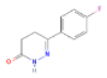
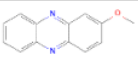
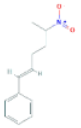
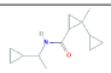
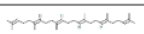
Data analysis

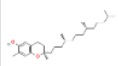
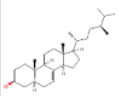
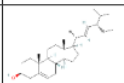
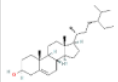
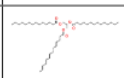
Qualitative data analysis was performed with Agilent MassHunter Qualitative Analysis Software. Identification of compounds in the spectrum is carried out based on retention time and the extent of peak integrals. Unknown mass fragments and mass spectra compared to NIST Chemistry WebBook (https://webbook.nist.gov/chemistry/) PubChem (https://pubchem.ncbi.nlm.nih.gov/), and SpectraBase (https://spectrabase.com/). The similarity of compounds matching > 70% is listed based on a literature search. After that, the name, molecular mass, and structure of the phytocomponent are determined to determine further their bioactivity potential based on relevant sources (22).

RESULTS

Developing herbal formulations from natural ingredients has become an exciting research topic. The extraction process, instrument selection, and analysis are fundamental to the performance of potential compound discovery (23,24). This study was designed to identify the metabolites profiling in R. Tuberosa L. leaf by Gas Chromatography-Mass Spectroscopy (GC-MS). In this study, GC-MS could detect 18 phytoconstituents, consisting of pyridazinones, acyclic diterpenoids, phenazines and derivatives, diphenylmethanes, carbonyl, fatty acids, pyrrolopyrazines, tertiary alcohols, cyclopropane carboxylic acids and derivatives, triterpenoids, tocopherols, ergosterol and derivatives, stigmastanes and derivatives, triacylglycerols with details of each compound listed in (Table 1). Squalene is the compound with the most content of 15.41%.

TABLE 1: Fitocompound present in leaves of R. Tuberosa L. using GS-MS analysis

No.	RT	Metabolites Compound	% of area	M.F.	M.W. g/mol	Chemical structure	Library	Class of compound
1.	27.210	2,6,10-trimethyl, 14-ethylene-14-pentadecne	4,51	C20H38	278.516		PubChem	Unknown
2.	27.679	Salvialane	3,14	-	-	-	-	-
3.	28.713	Pyridazin-3 (2H)-one, 4,5-dihydro-6-(4-fluorophenyl) –	5,01	C10H9FN2O	192.19		PubChem	Pyridazinones
4.	29.486	(2e)-3,7,11,15-tetramethyl-2-hexadecen-1-ol	11,47	C20H40O	296,50		PubChem	Prenol Lipids: Acyclic diterpenoids
5.	30.313	Phenazine, 2-methoxy-	5,77	C13H10N2O	210.23		PubChem	Phenazines and derivatives
6.	30.527	Acetamide, n-(3,3-diphenylpropyl) –	1,28	C17H19NO	253.34		PubChem	Diphenylmethanes
7.	30.713	Cyclododecanone, 2-methylene-	4,01	C13H22O	194.31		PubChem	Organooxygen: Carbonyl
8.	31.113	Tridecanoic acid, 12-oxo-	3,44	C13H24O3	228.33		PubChem	Fatty Acyls: Fatty acids and conjugates
9.	31.603	(5-Nitrohex-1-enyl) benzene	8,16	C12H15NO2	205.25		PubChem	Pyrrolopyrazines
10.	32.113	9-Methyltricyclo [4.2.1.1 (2,5)] deca-3,7-diene-9, 10-diol	1,97	C11H14O2	178.23		PubChem	Tertiary alcohols
11.	32.568	Cyclopropane carboxamide, 2-cyclopropyl-2-methyl-N-(1-cyclopropyethyl) –	4,18	C13H21NO	207.31		PubChem	Cyclopropane carboxylic acids and derivatives
12.	32.713	Trispiro [(3,4-diazatetracyclo [5.5.1.0 (2,6). 0 (8,12)] trideca-3,10-diene)-5,9,13-tricyclopropane	1,86	C17H20N2	252.36		PubChem	-
13.	32.851	Squalene	15,41	C30H50	410.7		PubChem	Prenol lipids : Triterpenoids

14.	35.940	Vitamin E	6,13	C29H50O2	430.71		PubChem	Prenol lipids: Tocopherols
15.	37.526	7-Ergostenol	1,31	C30H50O2	442.7		PubChem	Steroids: Ergosterol and derivatives
16.	37.953	Stigmasterol	2,71	C29H48O	412.70		PubChem	Steroids: Stigmastanes and derivatives
17.	38.939	Stigmast-5-en-3-ol	1,97	C29H50O	414.71		PubChem	Steroids: Stigmastanes and derivatives
18.	49.965	2,3-bis (tetradecanoyloxy) propyl myristate	15,04	C45H86O6	723.2		PubChem	Glycerolipids: Triradylcglycerols

Squalene is the most compound in the leaves of R. Tuberosa L., with as much content (15.41 %) coming from the class of prenol lipids, with subclass triterpenoids. Squalene is composed of six isoprene units. Squalene includes compounds that are widely spread in various plants, such as apricot, broccoli, coconut, and corn. Squalene, which belongs to the kingdom of organic compounds, is found in plants and deep-sea shark liver oil. In contrast to the least amount of compound named 2,6,10-trimethyl, 14-ethylene-14-pentadecne with as much content (1.22%) has never been reported. The identity of the compound is not yet known for sure.

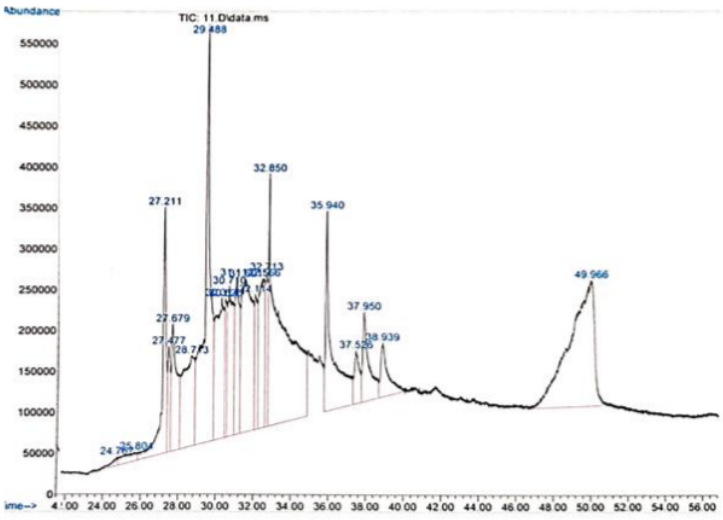


FIGURE 1: Chromatogram of total ions GC-MS from the leaves of R. Tuberosa L.

DISCUSSION

In this study, the dissolution used was ethanol (C2H6O) which can remove fat components (25). Ethanol belongs to the class of straight-chain primary alcohols (26), which are often used in various studies and are used in industries such as the manufacture of medicines, plastics, and cosmetics (27), food and beverage additives (28), and the chemical industry (29). Ethanol is also a major component in the fermentation of food, beverages, and fruit products at large and small levels (30,31). Through ethanol extract, GCMS analysis found 18 compounds identified from the leaves of R. Tuberosa L, which belong to the class of unique compounds. Only five compounds whose biological activity has been reported in the study (Table 2), and 13 have not been reported (Table 3). This study also found a phytosterol group in the steroid class, a beneficial compound for living beings.

TABLE 2: Biological activity of the Active compound on the identified R. Tuberosa L.

No.	Metabolites of Compound	Biology Activity
1.	(2e)-3,7,11,15-tetramethyl-2-hexadecen-1-ol	Antimicrobial, antifungal, antibacterial, antiparasitic, antimutagenic (32), anti-oxidant (33), anti-inflammatory (34)
2.	Squalene	Anti-oxidant (35), anti-tumor, anti-cancer, hypolipidemic action in blood and liver (36), & reduces cardiovascular disease (37)
3.	Vitamin E	Anti-oxidant (38,39), Anti-inflammatory (40), antibacterial (41)
4.	Stigmasterol	Antiinflammatory (42,43), antidiabetic (44), antitumor (45), anticancer, & anti-allergic (46)
5.	Stigmast-5-en-3-ol	Anti-cancer (47), anti-diabetic, anti-hyperlipidemic and anti-tumor (48)

TABLE 3: The biological Activity of the active Compound on R. Tuberosa L. has not been identified.

No.	Metabolite of Compound	Biology Activity
1.	2,6,10-trimethyl, 14-ethylene-14-pentadecne	Unknown
2.	Salvialane	Unknown
3.	Phenazine, 2-methoxy-	Unknown
4.	Acetamide, n-(3,3- diphenylpropyl) –	Unknown
5.	Cyclododecanone, 2-methylene-	Unknown
6.	Tridecanoic acid, 12-oxo-	Unknown
7.	-Nitrohex-1-enyl) benzene	Unknown
8.	Methyltricyclo [4.2.1.1 (2,5)] deca-3,7-diene-9, 10-diol	Unknown
9.	cyclopropane carboxamide, 2- cyclopropyl-2-methyl-N-(1-cyclopropyethyl) –	Unknown
10.	Trispiro [(3,4-diazatetracyclo [5.5.1.0 (2,6). 0 (8,12)] trideca-3,10-diene)-5,9,13-tricyclopropane	Unknown
11.	7-Ergostenol	Unknown
12.	2,3-bis (tetradecanoyloxy) propyl myristate	Unknown
13.	Pyridazin-3 (2H)-one, 4,5-dihydro-6-(4-fluorophenyl) –	Unknown

Stigmasterol (C29H48O) is a phytosterol or plant lipid that has a chemical structure similar to cholesterol (49) and is most commonly found in food (50). To be precise, stigmasterol belongs to the subclass of stigmastanes. Stigmasterol helps prevent anti-inflammatory (42,43), anti-tumor (45), anti-cancer, & anti-allergic (51), anti-diabetic (44) by lowering cholesterol in the blood (52). Even in animal studies, stigmasterol can produce ovalbumin by reducing oxidative stress and can inhibit the expression of vascular cell adhesion molecules (53). Stigmasterol has also been found in the leaves of R. Tuberosa L., which shows benefits (1).

Stigmast-5-en-3-ol and 7-ergostenol are phytosterol group compounds found in the leaves of R. Tuberosa L. Stigmast-5-en-3-ol belongs to stigmasterol derivatives which are also in the

stigmastanes subclass. In contrast to 7-ergostenol, which is precisely derived from the subclass ergosterol. Although the leaves of R. Tuberosa L. contain only a tiny amount of phytosterols, the presence of these compounds is very beneficial for humans.

Compounds as most compounds (15.41%) include unsaturated triterpenoid compounds (54) found in plant oils that are often used for the manufacture of medicines (22,55,56), dietary supplements (57), industrial cosmetics (54,58). Squalene can protect the skin from UV rays, increase skin flexibility, moisturize human skin, and increase the absorption of other substances in the human body (59,60). Squalene also has pharmacological properties, such as preventing cholesterol and cardiovascular diseases, and has anti-oxidant, anti-tumor, and anti-cancer effects, such as ovaries, breasts, and lungs (58). Several studies have proven that Squalene contains hypolipidemic action in the blood and liver in spinach plants (61,62).

Vitamin E (C29H50O2) is tocopherol, a lipid product of plant and animal origin, and is specifically included in lipophilic anti-oxidants used in food packaging, cosmetics, and the biomedical field (63). Vitamin E is useful for preventing anti-oxidants (39), anti-inflammatory (40), and antibacterial (41). Vitamin E in animals such as fish serves to protect biological membranes and lipoproteins against oxidation (64), such as studies in O. niloticus (65), Micropterus salmoides (66), Salmo caspius (67). Through this study, many compounds still have not been reported for biological activity. These compounds should be further researched so that people from various parts of the world know the essential benefits of each compound and can maximize the utilization of R. Tuberosa L. leaves in life.

CONCLUSION

GC-MS analysis carried out using ethanol extract found 18 compounds in the leaves of R. Tuberosa L. from various classes of compounds. The dominant compound is Squalene which is very beneficial as an anti-oxidant. Phytosterols are also found in the leaves of R. Tuberosa L. but in small amounts. Only five compounds whose biological activity has been reported. This suggests that the leaves of R. Tuberosa L still require further research regarding the biological activity of each compound contained.

ACKNOWLEDGMENTS

The author would like to thank the ELSA Botanical Identification Services (Herbarium Bogoriense) and the National Research and Innovation Agency (BRIN), Indonesia.

Competing Interests

The authors declare that they have no competing interests.

Funding

No funding for this research.

REFERENCES

1. Samy MN, Sugimoto S, Matsunami K, Otsuka H, Kamel MS. Chemical Constituents and Biological Activities of Genus Ruellia. Int J Pharmacogn. 2015;2(6):270–9.
2. Wiranto B, Husnin, Susilo. Diversity of terrestrial ferns (Pteridophytes) in Ciliwung Telaga Warna Puncak Bogor tea estate in West Java. J Phys Conf Ser. 2021;755(1):1–6.
3. Rasdianah Aziz I, Restu Puji Raharjeng A, Susilo, Nasution J. Ethnobotany of traditional wedding: A comparison of plants used by Bugis, Palembang, Sundanese and Karo ethnic in Indonesia. J Phys Conf Ser. 2019;1175(1).
4. Akbar B, Susilo, Nissa RA, Ritonga RF, Lestari S, Astuti Y, et al. Antifertility Effect of the Ethanol Extract of Centella asiatica L. Urban Against the White Rat (Rattus norvegicus L.) in the Early Post-Implantation. J Phys Conf Ser. 2018;1114(1).
5. Nurmawati D, Sudiarti D, Hasbiyati H. Identification of Medicinal Plant Potential of Kasiyan Village Puger District. Bioeduscience. 2022;6(1):31–40.
6. Risnawati R, Meitiyani, Susilo. The effect of adding Kepok Banana peels (Musa paradisiaca) to powder media on the growth of white oyster mushrooms (Pleurotus ostreatus). J Phys Conf Ser. 2021;755(1).
7. Ramses, Fenny Agustina, R. Pramuanggit Panggih Nugroho. Antibacterial Potential of Bidara Laut (Ximenia americana) Plant Against Vibrio alginolyticus and V. parahaemolyticus Bacteria. Bioeduscience. 2021;5(1):15–23.

8. Trinh PTN, Giang BL, Tuan NT, Hang HTT, Thuy NT Le, Tuan NN, et al. Alfa Glucosidase Inhibitory, Anti Inflammatory Activities and A New Furanocoumarin Derivative of Ruellia Tuberosa. Nat Prod Res. 2019;0(0):1–8.
9. Alam MA, Subhan N, Awal MA, Alam MS, Sarder M, Nahar L, et al. Antinociceptive and Anti-Inflammatory Properties of Ruellia Tuberosa. Pharm Biol. 2009;47(3):209–14.
10. Hastiana Y, Siroj RA, Irma. Development of Electronic Magazine Teaching Materials for Key Determination and Cladograms in Ethnobotany and Phytochemical Studies. Bioeduscience. 2021;5(2):131–6.
11. Seerangaraj V, Sathiyavimal S, Shankar SN, Nandagopal JGT, Balashanmugam P, Al-Misned FA, et al. Cytotoxic Effects of Silver Nanoparticles on Ruellia Tuberosa: Photocatalytic Degradation Properties against Crystal Violet and Coomassie Brilliant Blue. J Environ Chem Eng. 2021;9(2):105088.
12. Roosdiana A, Permata FS, Fitriani RI, Umam K, Safitri A. Ruellia Tuberosa L . Extract Improves Histopathology and Lowers Malondialdehyde Levels and TNF Alpha Expression in the Kidney of Streptozotocin-Induced Diabetic Rats. Vet Med Int. 2020;1–7.
13. Simamora CJK, Rumambi ES, Pratiwi TW, Ningrum AM, Embau TZM. The Opportunity of Spent Bleaching Earth (Bentonite) and Silica Solubilizing Bacteria as Silica Source for Induction of Secondary Metabolites Production in Plants. Bioeduscience. 2021;5(2):148–53.
14. Suhendi A, Maulana AS. Inhibition Activity of Leaves , Flower and Root Extracts of Ruellia Tuberosa L on α -Glucosidase Enzymes. J Nutraceuticals Herb Med. 2020;3(2):21–8.
15. Safitri A, Fatchiyah F, Sari DRT, Roosdiana A. Phytochemical Screening, in Vitro Anti-Oxidant Activity, and In Silico Anti-Diabetic Activity of Aqueous Extracts of Ruellia Tuberosa L. J Appl Pharm Sci. 2020;10(03):101–8.
16. Hernawati D, Dwisandi RF, Nuryadin E. Potential of Bioactive Compounds of Arenga Vinegar as Traditional Medicine Through Reverse Docking Techniques. Bioeduscience. 2021;5(2):142–7.
17. Manikandan A, Doss DVA. Evaluation of Biochemical Contents, Nutritional Value, Trace Elements, SDS-PAGE and HPTLC Profiling in the Leaves of Ruellia tuberosa L. and Dipteracanthus patulus (Jacq.) A. J Chem Pharm Res. 2010;2(3):295–303.
18. Nabila N, Susilo S. A Comparative Metabolite Analysis of Pandanus Amaryllifolius Leaves from Different Growth Stages using GC-MS and Their Biological. Eur Chem Bull. 2022;11(12):22–38.
19. Balachandar R, Karmegam N, Subbaiya R. Extraction, separation and characterization of bioactive compounds produced by streptomyces isolated from vermicast soil. Res J Pharm Technol. 2018;11(10):4569–74.
20. Özbek O, Saglam B, Usta NC, Budak Y. GC–MS Analysis and Anti–Microbial Activity of Prunella Vulgaris L. Extracts. J Indian Chem Soc. 2022;99(6):100460.
21. Ochola JB, Mutero CM, Marubu RM, Haller BF, Hassanali A, Lwande W. Mosquitoes Larvicidal Activity of Ocimum kilimandscharicum Oil Formulation under Laboratory and Field-Simulated Conditions. Insects. 2022;13(2):1–15.
22. Jose BE, Selvam PP. Identification of Phytochemical Constituents in the Leaf Extracts of Azima tetracantha Lam using Gas Chromatography-Mass Spectrometry (GC-MS) analysis and Antioxidant Activity. Asian J Res Chem. 2018;11(6):857.
23. Palupi D, Desi Aryani R, Lestari S. Variations in Morphology and Anatomy of Breadfruit (Artocarpus altilis) Based on Differences in Altitude. Bioeduscience. 2021;5(2):122–30.
24. Priya S, Nethaji S, Sindhuja B. GC-MS analysis of some bioactive constituents of diospyros Virginiana. Res J Pharm Technol. 2014;7(4):429–32.
25. Jeong M, Lee S, Cho S. Effect of Three Defatting Solvents on the Techno-Functional Properties of an Edible Insect (Gryllus bimaculatus) Protein Concentrate. Molecules. 2021;26:1–9.
26. Mokkath JH. Impact of Adsorption of Straight Chain Alcohol Molecules on the Optical Properties of Calcite (10.4) Surface. nanomaterials. 2022;1–11.
27. Shihabudeen PK, Notash MY, Sardroodi JJ, Roy Chaudhuri A. Nitrogen incorporated zinc oxide thin film for efficient ethanol detection. Sensors Actuators B Chem. 2022;358:1–10.
28. Bhavani R, Bhuvaneswari E, Rajeshkumar S. Antibacterial and antioxidant activity of ethanolic extract of ceiba pentandra leaves and its phytochemicals analysis using GC-MS. Res J Pharm Technol. 2016;9(11):1922–6.
29. Benemir Erkan S, Bugra Coban H, Turhan I. Evaluation of the inhibitory effect of 5-hydroxymethylfurfural (HMF) on ethanol fermentation by using immobilized Saccharomyces cerevisiae in stirred-tank bioreactor and mathematical modeling. Fuel. 2022;317:1–7.
30. He S, Cui Y, Dong R, Chang J, Cai H, Liu H, et al. Global transcriptomic analysis of ethanol tolerance response in Salmonella Enteritidis. Curr Res Food Sci. 2022;5:798–806.
31. Aravind R, Bindu AR, Bindu K, Alexeyena V. GC-MS analysis of the bark essential oil of cinnamomum malabatrum (burman. f) blume. Res J Pharm Technol. 2014;7(7):754–9.
32. Chan CA, Ho LY, Sit NW. Larvicidal Activity and Phytochemical Profiling of Sweet Basil (

Ocimum basilicum L .) Leaf Extract against Asian Tiger Mosquito (Aedes albopictus). Horticulture. 2022;8:1–14.
33. Hossain MA, Al-toubi WAS, Weli AM, Al-riyami QA, Al-sabahi JN. Identification and characterization of chemical compounds in different crude extracts from leaves of Omani neem. J Taibah Univ Sci. 2018;7(4):181–8.
34. Lawal B, Sani S, Onikanni AS, Ibrahim YO, R. Agboola A, Lukman HY, et al. Biomedicine & Pharmacotherapy Preclinical anti-inflammatory and antioxidant effects of Azanza garckeana in STZ-induced glycemic-impaired rats , and pharmacoinformatics of it major phytoconstituents. Biomed Pharmacother. 2022;152:1–15.
35. Huang Z, Lin Y, Fang J. Biological and Pharmacological Activities of Squalene and Related Compounds: Potential Uses in Cosmetic Dermatology. molecules. 2009;10:540–54.
36. Shin DH, Heo HJ, Lee YJ, Kim HK. Amaranth squalene reduces serum and liver lipid levels in rats fed a cholesterol diet. Br J off Biomed Sci. 2016;(June):11–4.
37. Ketenoglu O, Ozkan KS, Yorulmaz A, Tekin A. Molecular distillation of olive pomace oil ─ Multiobjective optimization for tocopherol and squalene. LWT - Food Sci Technol. 2018;91:198–202.
38. Fata G La, Weber P, Mohajeri MH. Effects of Vitamin E on Cognitive Performance during Ageing and in Alzheimer's Disease. Nutrients. 2014;(6):5453–72.
39. Richard EL, Laughlin GA, Kritz-silverstein D, Reas ET, Barrett-connor E, Mcevoy LK. Dietary Patterns and Cognitive Function among Older Community-Dwelling Adults. Nutrients. 2018;(10):1–15.
40. Barros S, Ribeiro APD, Steven O, Loewy ZG. Anti-Inflammatory E ff ects of Vitamin E in Response to Candida albicans. microorganisms. 2020;8:1–13.
41. Campoccia D, Visai L, Reno F, Cangini I, Rizzi M, Poggi A, et al. Bacterial adhesion to poly- (D , L) lactic acid blended with vitamin E : Toward gentle anti-infective biomaterials. Soc Biomater. 2014;1447–58.
42. Avarro A, Heras BD Las, Villar A. Anti-Inflammatory and Immunomodulating Properties of a Sterol Fraction from Sideritis foetens C LEM . Biol Pharm Bull. 2001;24(5):470–3.
43. Afroz M, Zihad SMNK, Uddin SJ, Rouf R, Rahman MS, Islam MT, et al. A systematic review on antioxidant and antiinflammatory activity of Sesame (Sesamum indicum L .) oil and further confirmation of antiinflammatory activity by chemical profiling and molecular docking. Phyther Res. 2019;(June):1–24.
44. Wang J, Huang M, Yang J, Ma X, Zheng S, Deng S, et al. Anti-diabetic activity of stigmasterol from soybean oil by targeting the GLUT4 glucose transporter. Food Nutr Res. 2017;61(1).
45. Gao Z, Maloney DJ, Dedkova LM, Hecht SM. Inhibitors of DNA polymerase β: Activity and mechanism. Bioorganic Med Chem. 2008;16(8):4331–40.
46. Wijayanti DR, Dewi AP. Extraction and Identification Potent Antibacterial Bioactive Compound of Streptomyces sp. MB 106 from Euphorbia sp. Rhizosphere. Bioeduscience. 2022;6(1):84–8.
47. Fernando IPS, Sanjeewa KKA, Ann Y, Ko C, Lee S, Lee WW, et al. Apoptotic and antiproliferative e ff ects of Stigmast-5-en-3-ol from Dendronephthya gigantea on human leukemia HL-60 and human breast cancer MCF-7 cells. Toxicol Vitr. 2018;52:297–305.
48. Iyer D, Patil UK. Efficacy of Stigmast-5-en-3 β -ol Isolated from Salvadora persica L . as Antihyperlipidemic and Anti-tumor agent : Evidence from animal studies. Asian Pacific J Trop Dis. 2012;2:S849–55.
49. Khan MA, Khan MJ. Nano-gold displayed anti-inflammatory property via NF-kB pathways by suppressing COX-2 activity. Artif Cells, Nanomedicine, Biotechnol. 2018;46(S1):S1149–58.
50. Susilo, Setyaningsih M. Analysis of genetic diversity and genome relationships of four eggplant species (Solanum melongena L) using RAPD markers. J Phys Conf Ser. 2018;948(1):0–6.
51. Moreau RA, Whitaker BD, Hicks KB. Phytosterols, phytostanols, and their conjugates in foods : structural diversity, quantitative analysis, and health-promoting uses. Prog Lipid Res. 2002;41:457–500.
52. Prasad M, Jayaraman S, Eladl MA, El-Sherbiny M, Abdelrahman MAE, Veeraraghavan VP, et al. A Comprehensive Review on Therapeutic Perspectives of Phytosterols in Insulin Resistance: A Mechanistic Approach. Molecules. 2022;27(5):1–17.
53. Antwi AO, Obiri DD, Osafo N. Stigmasterol Modulates Allergic Airway Inflammation in Guinea Pig Model of Ovalbumin-Induced Asthma. Mediators Inflamm. 2017;2017:1–12.
54. Tominaga M, Miyazaki K, Hataya S, Mitsui Y, Kuroda S, Kondo A, et al. Enhanced squalene production by modulation of pathways consuming squalene and its precursor. J Biosci Bioeng. 2022;134(1):1–6.
55. Pandian RS, Noora AT. GC-MS analysis of phytochemical compounds present in the leaves of Citrus medica. L. Res J Pharm Technol. 2019;12(4):1823–6.
56. Krishnaveni M, Krishna Kumari G, Ragina Banu C, Kalaivani M. Phytochemical analysis of Terminalia catappa stem using GC-MS/MS. Res J Pharm Technol. 2015;8(9):1281–3.

57. Vanoye L, Guicheret B, Rivera-Cárcamo C, Castro Contreras R, de Bellefon C, Meille V, et al. Process intensification of the catalytic hydrogenation of squalene using a Pd/CNT catalyst combining nanoparticles and single atoms in a continuous flow reactor. Chem Eng J. 2022;441(March).
58. Hu Y, Suo J, Jiang G, Shen J, Cheng H, Lou H, et al. The effect of ethylene on squalene and β-sitosterol biosynthesis and its key gene network analysis in Torreya grandis nuts during post-ripening process. Food Chem. 2022;368(May 2021):130819.
59. Cowan EA, Tran H, Gray N, Perez JJ, Watson C, Blount BC, et al. A gas chromatography-mass spectrometry method for quantifying squalane and squalene in aerosol emissions of electronic cigarette, or vaping, products. Talanta. 2022;238(P1):122985.
60. Azmi L, Gupta SS, Shukla I, Kant P, Sidhu OP, Rao C V. Effect of squalene in surgically induced gastro-oesophageal reflux disease on rats. Res J Pharmacol Pharmacodyn. 2017;9(1):1.
61. Lozano-grande MA, Gorinstein S, Espitia-rangel E, Davila-Ortiz G, Martinez-Ayala AL. Plant Sources , Extraction Methods , and Uses of Squalene. Int J Agron. 2018;1–14.
62. Zahi MR, Liang H, Khan A, Yuan Q. Identification of Essential Oil Components in Chinese Endemic Plant Achnatherum inebrians. Asian J Res Chem. 2014;7(6):576–9.
63. Gamna F, Cochis A, Scalia AC, Vitale A, Ferraris S, Rimondini L, et al. The use of vitamin E as an anti-adhesive coating for cells and bacteria for temporary bone implants. Surf Coat Technol. 2022;444:128694.
64. Lu Y, Liang XP, Jin M, Sun P, Ma HN, Yuan Y, et al. Effects of dietary vitamin E on the growth performance, antioxidant status and innate immune response in juvenile yellow catfish (Pelteobagrus fulvidraco). Aquaculture. 2016;464:609–17.
65. Wu F, Jiang M, Wen H, Liu W, Tian J, Yang C geng, et al. Dietary vitamin E effects on growth, fillet textural parameters, and antioxidant capacity of genetically improved farmed tilapia (GIFT), Oreochromis niloticus. Aquac Int. 2017;25(2):991–1003.
66. Li S, Lian X, Chen N, Wang M, Sang C. Effects of dietary vitamin E level on growth performance, feed utilization, antioxidant capacity and nonspecific immunity of largemouth bass, Micropterus salmoides. Aquac Nutr. 2018;24(6):1679–88.
67. Saheli M, Rajabi Islami H, Mohseni M, Soltani M. Effects of dietary vitamin E on growth performance, body composition, antioxidant capacity, and some immune responses in Caspian trout (Salmo caspius). Aquac Reports. 2021;21:100857.

J Popul Ther Clin Pharmacol Vol 30(3):e690–e698; 15 January 2023.

Metabolites Profiling and Biological Activities of Volatile Compounds of Ruellia tuberosa L. Leaves by GC-MS

ORIGINALITY REPORT

16%	13%	11%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	journals.plos.org Internet Source	2%
2	Rizwan Ahmad, Aljawharah Alqathama, Mohammed Aldholmi, Muhammad Riaz et al. "Gas Chromatography-Mass Spectrometry (GC-MS) Metabolites Profiling and Biological Activities of Various Capsicum annum cultivars", Plants, 2022 Publication	1%
3	Sofidiya, Margaret O., Calistus O. Orisaremi, Ikeoluwa Sansaliyu, and Toyin O. Adetunde. "Gastroprotective and antioxidant potentials of ethanolic stem bark extract of Margaritaria discoidea (Euphorbiaceae) in rats", Journal of Ethnopharmacology, 2015. Publication	1%
4	www.knowitall.com Internet Source	1%
5	academicjournals.org Internet Source	1%

6	Anna Safitri, Anna Roosdiana, Nia Kurnianingsih, Fatchiyah Fatchiyah, Eldina Mayasari, Rina Rachmawati. "Microencapsulation of Ruellia tuberosa L. Aqueous Root Extracts Using Chitosan-Sodium Tripolyphosphate and Their In Vitro Biological Activities", Scientifica, 2022 Publication	1 %
7	researcharchive.lincoln.ac.nz Internet Source	1 %
8	assets.researchsquare.com Internet Source	1 %
9	journals.ums.ac.id Internet Source	1 %
10	pubchem.ncbi.nlm.nih.gov Internet Source	1 %
11	scholarhub.ui.ac.id Internet Source	1 %
12	www.ejmanager.com Internet Source	1 %
13	www.researchgate.net Internet Source	1 %
14	Submitted to Higher Education Commission Pakistan Student Paper	1 %

15	Enjalbert, F.. "Effects of peripartum biotin supplementation of dairy cows on milk production and milk composition with emphasis on fatty acids profile", Livestock Science, 200804 Publication	<1 %
16	www.nrfhh.com Internet Source	<1 %
17	research.vu.nl Internet Source	<1 %
18	www.tandfonline.com Internet Source	<1 %
19	Malairaj Sathuvan, Anadhan Vignesh, Ramar Thangam, Perumal Palani, Ramasamy Rengasamy, Kandasamy Murugesan. "In Vitro Antioxidant and Anticancer potential of Bark of Costus pictus D.DON", Asian Pacific Journal of Tropical Biomedicine, 2012 Publication	<1 %
20	lpi.oregonstate.edu Internet Source	<1 %
21	"Emerging Issues in Fish Larvae Research", Springer Science and Business Media LLC, 2018 Publication	<1 %
22	innovareacademics.in Internet Source	

		<1 %
23	japsonline.com Internet Source	<1 %
24	www.hindawi.com Internet Source	<1 %
25	Tao Zhang, Yufan Zhou, Xinyu Li, Ying Chen, Dan Zheng, Xinxin Li, Pengcheng Xu. "Catalytic decomposition sensing mechanism of mesoporous gamma alumina for freon R134a detection", Sensors and Actuators B: Chemical, 2023 Publication	<1 %
26	Vetter, W.. "Determination of Q1, an unknown organochlorine contaminant, in human milk, Antarctic air, and further environmental samples", Environmental Pollution, 200012 Publication	<1 %
27	Abdul Qadir, Nausheen Khan, Shehla Nasar Mir Najib Ullah, Asad Ali, Dipak Kumar Gupta, Sauban Ahmed Khan. "GC–MS analysis of phytoconstituents present in methanolic extract of Actinidia deliciosa L. fruits and its antioxidant activity", Journal of the Indian Chemical Society, 2022 Publication	<1 %

Exclude quotes	On	Exclude matches	< 3 words
Exclude bibliography	On		