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Research Article

# Phytochemical Investigation And Antibacterial Activity Of Dried Lime Citrus Aurantifulia

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**Abstract:** To continue the efforts of screening natural products to obtain more active drugs and safer to use, this study established to screening the phytochemical compounds on dried lime *Citrus aurantifulia and* evaluate the antibacterial activity of its water extract on several bacteria species. Via GC-MS analysis, the most phytochemicals were found in water extract of *C. aurantifulia*, dl-Limonene (34.05%), alpha. -Terpineol (13.45%), Terpinene gamma (4.56%), Alpha.-terpinolene (4.56%), Pinene beta (3.88%), endo-Borneol (3.26%), beta.-Bisabolene (3.31%). The Kirby-Bauer disk diffusion susceptibility test was utilized to determine the antibacterial activity of the extract at various concentration (200, 100, 50, 25, 12.5, and 6.25 mg/ml)., it's found to inhibited the bacterial growth as dose depending manner, where the inhibition zone were (25, 25, 19, 25, 26 and 23mm) against *E. faecalis, St. aureus, B. cereus, E.coli, K. pneumoniae* and *P. aeruginosa*, respectively. In conclusion, the dried lime has a high potential to be used as antibacterial drug in many fields.

**Keywords:** Dried lime, phytochemicals, GC-MS analysis, antibacterial activity

## How to Cite:

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## INTRODUCTION

Presently, scientists have been searching for alternative treatment or drugs to fighting pathogens in response to the rise in antibiotic resistance. Furthermore, in recent years there has occurred a decrease in the detection of novel antibacterial drugs (Tüfekci et al., 2020). Various traditional medicinal plants would be the finest alternative source of quality and crucial herbal formulations for the treatment and protection from a variety of diseases in addition, plant-derived treatments are considered the safest and most acceptable among people (Satabathy et al., 2020). Plants are extraordinarily rich in bioactive natural compounds (Al Kateeb, 2022). A large number of secondary metabolites (SMs) are formed in higher plants generated by primary metabolites support plant defense against pests, phytopathogens, insects, herbivores, as well as other challenges (Jain et al., 2019). The physiological and developmental condition of the plant influences the formation of all these pharmaceutically important chemicals, which produce in trace degrees (Twaij and Hasan 2022).

Citrus peels, which provide almost all of citrus "residue," contain an abundance of potential purposes and contain numerous important compounds, includes flavonoids, limonoids, alkaloids, essential oils, and pectin. Citrus fruits provide an enormous variety of industrial byproducts. (Kazeem et al., 2020; Xiao et al., 2021). C aurantifolia is member the Rutaceae family, which involves 900 species and 150 genera (Mohammed, 2016). C aurantifolia is a popular raw material for cosmetics, food flavouring, beverage flavor enhancers, and traditional medicine (Swandiny et al., 2021). A number of studies have shown the C. aurantifolia includes biological activities such as an insecticidal, larvicidal, and repellent properties (Galovičová et al., 2022), antimicrobial, antioxidant, and anticancer activities (Julaeha et al., 2022) antimicrobial, analgesic, astringent, antiviral, antifungal, diuretic, anti-cholesterol, appetite stimulant, and treatment of constipation. The wide range of biological functions shown via C. aurantifolia is clarified by the presence of secondary metabolites (Shchérazade et al., 2021).

Lime Basra, noomi Basra, or dry black lime are the names given to this commodity in Iraq. These are also known as Black Lemons, Omani Lemons in Iran (originating in Oman), and Loomi in various Arab nations throughout the region. The fruit is used in almost every tropical home, primarily to flavour food, but also to make drinks and for a range of therapeutic purposes. C aurantifolia is recognized for its aroma and taste and for the health advantages resulting with the bioactive compounds contained in the plant. (Boulos, 1998). Due to each section in plant contains unique bioactive ingredients and biochemical processes, further research into these chemicals is required. Detailed knowledge of the constituents of the dry black lime fruit will lead to a better and specifically diverted application and also to know its purity only be obtained by means of carefully performed GC/MS experiments. Our study aims to analyze phytochemical compounds in the dried lime with GC-MS analysis and investigation their antibacterial activity against several pathogenic bacteria that show high resistance to the antibiotics that are found in the pharmacies.

## MATERIAL AND METHODS

### Plant Extraction

The dried lime was obtained from the market in Al Muthanna city, powdered by electric blender then 50 g was taken and mixed with distilled water in a ratio 1:6 (plant: water) and boiled until ¼ the solution stay. After that, the solution was filtered by filter paper then dried under room temperature until full dryness (Handa et al., 2007).

**Gas Chromatography-Mass Spectrometry (GC-MS) Analysis**All chemical constants in dried lime were determined via GC-MS. The condition used for the analysis shown in the following Table 1.


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**Table 1.** The conditions of GC-MS used to analysis of plant extract

| | |
|---|---|
| Device | Shimadzu GCMS QP 2010 ULTRA |
| Column | RXI-5MS Capillary column (30m; 0.25 mm; 0.25 µm). |
| Carrier gas | Helium (1 ml/min flow) |
| Column furnace temperature | 40°C |
| Injection temperature | 2 |
| Pressure: | 100 kPa |
| Injection mode | Split |
| Split ratio | 25 |
| Injection volume | 1ul |
| Oven temperature program | 3 min at 40°C, 40°C to 240°C in 4°C/min increment, 240 °C, 240 °C 10min/Total 63 min. |
| Interface temperature | 250°C |
| Ion source temperature | 200°C |

## Antibacterial activity method

The bacterial isolates used in this study were obtained from the Department of Life Sciences at the College of Science, Al-Muthanna University. Bacterial species were purified using specialized *Enterococcus. faecalis*, *Staph. aureus*, *Bacillus cereus*, *Escherichia. coli*, *Klebsiella pneumoniae* and *P. aeruginosa*. Kirby-Bauer disk diffusion susceptibility test was used to evaluate the antibacterial activity of dried lime *C. aurantifula* extracts in different concentrations (200, 100, 50, 25, 12.5and 6.25 mg/ml). The overnight bacterial culture adjusts to 0.5 McFarland standard in 0.9% sterilized normal saline. By sterile cotton swab the inoculum spread on Muller Hinton agar medium. By using A small filter disk, at 6mm diameter saturated with100 µl of each concentration of plant extracts, also place on that plate. Then normal saline filled on disc as a negative control and using for control. After 24 h. of incubation of all plates at 37°C, the microbial gro wth inhibition zones (I.Z.) were measured. All experiments were carried out in duplicate (Humphries et al., 2021).

## RESULTS AND DISCUSSION

The current study investigated the phytochemical compounds of dried lime water extract and its antibacterial activity against six of bacterial species. Table 2 and Figure 1 showed the compounds that were found in lime extraction. The yield of hot water extraction of dried lime was (1 gm). GC-MS analse compound according to retention time and the result of GC-MS illustrated the presence of 49 compound occurred in many groups like monoterpenes and sesquiterpenoids but the largest amount was dl-Limonene (34.05%), alpha. -Terpineol (13.45%), Terpinene gamma (4.56%), Alpha. terpinolene (4.56%), Pinene beta (3.88%), endo-Borneol (3.26%), beta. -Bisabolene (3.31%). These compounds known to give the special flavor of the lime also using in perfumes industry and medicine as local antiseptic according to (Ranganna *et al.*, 1983; Boulos, 1998). Our results agree with (Mohammed et al., 2024) work, where they study the essential oils of lime and found the above mention compounds. Also, (Olatunya & Akintayo., 2017) found limonene, Terpineol and Alpha and beta pinene in the dried lime.

**Table 2.** Phytochemical compounds of *Citrus aurantifula water extract*

| Peak | R. time | Area% | Name |
|---|---|---|---|
| 1 | 9.532 | 2.63 | Pinene alpha |
| 3 | 10.073 | 1.17 | Camphene |
| 4 | 11.193 | 3.88 | Pinene beta |
| 5. | 11.871 | 0.80 | beta.-Myrcene |
| 6 | 12.321 | 0.27 | Phellandrene alpha |
| 7. | 12.822 | 2.25 | alpha.-Terpinene |
| 8 | 13.162 | 4.98 | Benzene, 1-methyl-2-(1-methylethyl)- (CAS) |
| 9 | 13.424 | 34.05 | dl-Limonene |
| 10 | 14.153 | 0.18 | 1,3,6-Octatriene, 3,7-dimethyl-, (E)- (CAS) |
| 11 | 14.546 | 4.56 | Terpinene gamma |
| 12 . | 15.714 | 4.56 | Alpha.-terpinolene |
| 13 | 16.204 | 0.75 | Linalool |
| 14 | 16.696 | 2.59 | Fenchol alpha |
| 15 | 17.031 | 0.20 | Bornyl bromide |
| 16 | 17.519 | 0.91 | Terpin-3-en-1-ol |
| 17 - | 17.916 | 0.98 | Cyclohexanol, 1-methyl-4-(1-methylethenyl) |
| 18 | 18.366 | 0.34 | BICYCLO[2.2.1]HEPTAN-2-OL, 1,7,7-TRIMETHYL |
| 19 | 18.568 | 0.59 | Bicyclo[2.2.1]heptane, 2-chloro-1,7,7-trimethyl-, (1R-endo |
| 20 | 18.738 | 3.26 | endo-Borneol |
| 21 | 19.175 | 1.39 | 3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R) |
| 22. | 19.778 | 13.45 | alpha.-Terpineol |
| 23 | 19.975 | 1.64 | Terpineol gamma |
| 24 | 20.261 | 0.38 | Decanal (CAS) |
| 25 | 20.762 | 0.20 | Octanal, 7-methoxy-3,7-dimethy1- |
| 26 | 21.128 | 0.29 | Citronellol |
| 27 | 21.660 | 0. 20 | Carvone |
| 28 | 22.081 | 0.29 | Geraniol |
| 29 | 23.827 | 0.23 | Carvacrol |
| 30 | 25.960 | 0.19 | NERYL ACETATE |
| 31 | 26.614 | 0.39 | Geranyl acetate |
| 32. | 26.942 | 0.35 | BETA. ELEMENE |
| 33 | 27.448 | 0.17 | Lauric aldehyde |
| 34 | 27.879 | 1.01 | TRANS(.BETA.)-CARYOPHYLLENE |
| 35 | 28.394 | 1.45 | Bicyclo[3.1.1]hept-2-ene, 2,6-dimethyl-6-(4-methyl-3-pentenyl)- |
| 36 | 29.008 | 0.22 | alpha.-Humulene (CAS) |
| 37 | 30.549 | 0.25 | TRANS-.ALPHA.-BISABOLENE |
| 38. | 30.757 | 3.31 | beta.-Bisabolene |
| 39 | 30.987 | 0.17 | Spathulenol |
| 40 | 32.721 | 0.28 | Caryophyllene alcohol |
| 41 | 32.888 | 0.50 | Sabinene |
| 42 | 33.344 | 1.90 | ALPHA.-PINENE, (-)- |
| 43 | 34.482 | 0.36 | 1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta., |
| 44 | 34.580 | 0.19 | Eudesmol |
| 45 | 35.658 | 0.41 | Neoisolongifolane, hydroxy- |
| 46. | 36.116 | 0.74 | alpha.-Bisabolol |
| 47 | 40.731 | 0.28 | 1,3,4,6,7,8-HEXAHYDRO-4,6,6,7,8,8-HEXAMETHYLCYCLOPENTA(G)-2-BENZOPYRAN OR GALAXOLI |
| 48 | 42.527 | 0.27 | Hexadecanoic acid, methyl ester (CAS) |
| 49 | 51.312 | 0.19 | Pentacosane |
| | | 100.00 | |


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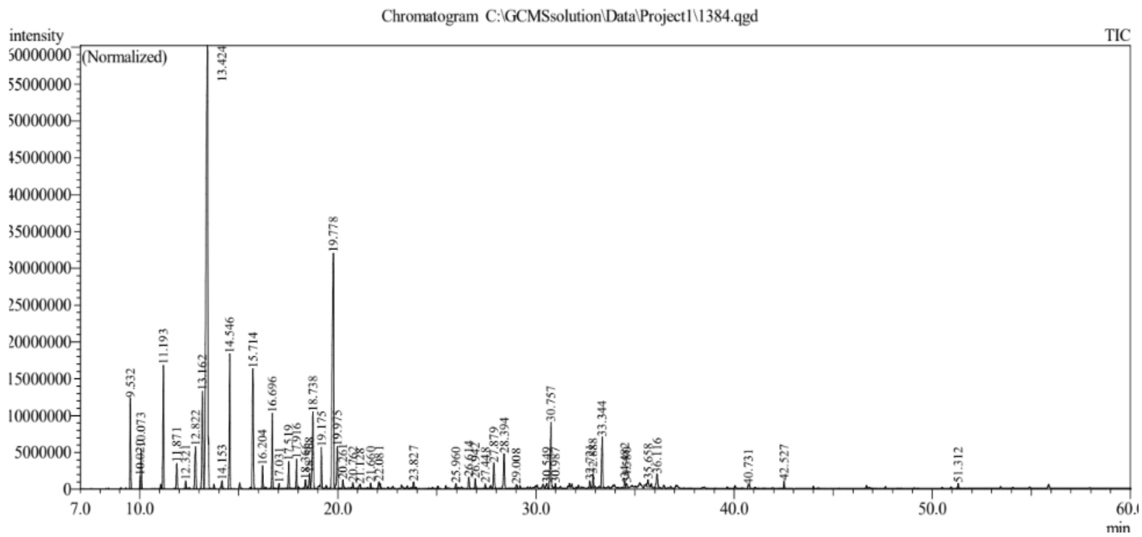


**Figure 1.** GC-MS chromatograms of *Citrus aurantifula extract*

**Table 3.** The antibacterial activity of dried lime water extract against several bacteria (by mm)

| Bacteria | Extract concentration mg/ml | | | | | |
|---|---|---|---|---|---|---|
| | 200 | 100 | 50 | 25 | 12.5 | 6.25 |
| *E. faecalis* | 25 | 21 | 19 | 19 | 16 | 12 |
| *S. aureus* | 25 | 23 | 18 | 16 | 12 | 8 |
| *B. cereus* | 19 | 19 | 14 | 13 | 9 | 9 |
| *E. coli* | 25 | 23 | 23 | 20 | 16 | 11 |
| *K. pneumoniae* | 26 | 25 | 19 | 18 | 12 | 7 |
| *P. aeruginosa* | 23 | 18 | 15 | 10 | 0 | 0 |

The results of antibacterial activity of dried lime shown in Table 3, the inhibition zone against K. pneumoniae was between 26 and 7 mm depending on concentrations. Also, the inhibition zones were 25 mm against each of E. faecalis, St. aureus, E. coli and it was 23 mm against P. aeruginosa while it was 19 mm against B. cereus. The antibacterial activity of the lime extract return to its different phytochemicals, these compounds have ability to disrupting the bacterial cell membranes, inhibiting the essential enzyme and destroying the resistance mechanisms of the bacterial cells (Guo et al., 2021). Our results agreed with (Al Farraj et al., 2018), where they found high antibacterial activity of different extractions of dried lime including water extract against several bacteria. Also, in other study by (Olatunya et al., 2024) they work on fresh lime and dried lime and found the same high antibacterial activity against different bacterial species. The highly antibacterial activity of lime extract against these pathogenic bacteria return to the high amount of phytochemicals in it like limonene, alpha and beta pinene, also the presence of alpha, beta and gamma terpineol as illustrated in Figure 1 and Table 2 (Al-Jabri and Hossain., 2014). This antibacterial activity gives way to the possibility of treating the diseases caused by infection with these pathogenic bacteria. Where S. aureus has been found to be resistant to many of the available antibiotics via many mechanisms (Guo et al., 2020). While by using lime extract all the concentrations possess antibacterial effect on this bacterium. The same applies to the other bacteria used in this study. As most types of bacteria have started to resist the conventional antibiotics used to eliminate them, which requires finding new agents to get rid of these pathogenic and deadly bacteria (Bayode et al., 2021; Murray et al., 2019). Limonene is a monoterpenoid compound make the major compound in the essential oils of citrus family, it's found to destruct the bacterial cell integrity by effecting the cell membrane permeability leading to cell death (Han et al., 2019). Furthermore, Limonene is found to significantly inhibit both gram positive and negative bacteria as well as fungi (Hsouna et al., 2011). Alpha pinene also showed high antibacterial activity and one of the suggested mechanisms was generating promoters for heat shock in the targeted bacteria (Melkina et al., 2021). Additionally, in further study terpineol and its isomeric showed antibacterial activity via destroying cell membrane and cell wall of the bacterial cells (Huang et al., 2021).

## CONCLUSION

In the present study several phytochemical compounds were be determined in the water extract of dried lime. Also, the extract showed high antibacterial activity on many bacterial species. this activity thought to be related to the presence of many phytochemicals' compounds in the dried lime water extract. Further studies will be established to screen the antioxidant, anti-inflammatory and anticancer activity of dried lime.


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### Personal Interest

The authors proclaim no conflicts of interest

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### Ethical Approval

Non-applicable.

## REFERENCES


Al Kateeb, A. I., Tüfekci, E. F., Baloğlu, M. C., Zengin, G., Yıldıztugay, E., & Altunoğlu, Y.Ç. (2022). Antibacterial Effects of Phlomoides molucelloides (Bunge) Salmaki. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 25(Ek Sayı 2), 402-410. https://doi.org/10.18016/ksutarimdoga.v25i73358.1077985

Alfarraj, D., Al Khulaifi, M. M., & Moubayed, N. M. (2018). Correlation of phenolic content and antibacterial activity of dried lime extracts against human pathogens. Biomedical Research, 29(16), 3239-3242. DOI: 10.4066/biomedicalresearch.29-18-828

Al-Jabri, N. N., & Hossain, M. A. (2014). Comparative chemical composition and antimicrobial activity study of essential oils from two imported lemon fruits samples against pathogenic bacteria. Beni-Suef University Journal of Basic and Applied Sciences, 3(4), 247-253. https://doi.org/10.1016/j.bjbas.2014.10.011

Bayode, M. T., Olalemi, A. O., & Oladejo, B. O. (2021). Multiple antibiotic resistant index and detection of qnrS and qnrB genes in bacterial consortium of urine samples from clinical settings. European Journal of Biological Research, 11(1), 45-56. http://dx.doi.org/10.5281/zenodo.4304311

Boulos, L. (1983). Medicinal plants of North Africa. Medicinal plants of North Africa.

Galovičová, L., Borotová, P., Vukovic, N. L., Vukic, M., Kunová, S., Hanus, P., and, Kačániová, M. (2022). The potential use of Citrus aurantifolia L. essential oils for decay control, quality preservation of agricultural products, and anti-insect activity. Agronomy, 12(3), 735. https://doi.org/10.3390/agronomy12030735

Guo, F., Chen, Q., Liang, Q., Zhang, M., Chen, W., Chen, H., and Chen, W. (2021).Antimicrobial activity and proposed action mechanism of linalool against Pseudomonas fluorescens. Frontiers in Microbiology, 12,562094. https://doi.org/10.3389/fmicb.2021.562094

Guo, Y., Song, G., Sun, M., Wang, J., & Wang, Y. (2020). Prevalence and therapies of antibiotic-resistance in Staphylococcus aureus. Frontiers in cellular and infection microbiology, 10, 107. https://doi.org/10.3389/fcimb.2020.00107

Han, Y., Sun, Z., & Chen, W. (2019). Antimicrobial susceptibility and antibacterial mechanism of limonene against Listeria monocytogenes. Molecules, 25(1), 33. https://doi.org/10.3390/molecules25010033

Handa, S. S., Khanuja, S. P. S., Longo, G., Rakesh, D. D. (2008). Extraction Technologies for Medicinal and Aromatic Plants, (1stedn), no. 66. Italy: United Nations Industrial Development Organization and the International Centre for Science and High Technology, 747-752. environment@ics.trieste.it

Hsouna, A. B., Trigui, M., Mansour, R. B., Jarraya, R. M., Damak, M., & Jaoua, S. (2011). Chemical composition, cytotoxicity effect and antimicrobial activity of Ceratonia siliqua essential oil with preservative effects against Listeria inoculated in minced beef meat. International journal of food microbiology, 148(1), 66-72. https://doi.org/10.1016/j.ijfoodmicro.2011.04.028

Huang, J., Yang, L., Zou, Y., Luo, S., Wang, X., Liang, Y., Du, Y., Feng, R., & Wei, Q. (2021). Antibacterial activity and mechanism of three isomeric terpineols of Cinnamomum longepaniculatum leaf oil. Folia microbiologica, 66(1), 59–67. https://doi.org/10.1007/s42452-024-05813-5

Humphries, R., Bobenchik, A. M., Hindler, J. A., & Schuetz, A. N. (2021). Overview of changes to the clinical and laboratory standards institute performance standards for antimicrobial susceptibility testing, M100. Journal of clinical microbiology, 59(12), 10-1128. https://doi.org/10.1128/jcm.00213-21

Jain, C., Khatana, S., & Vijayvergia, R. (2019). Bioactivity of secondary metabolites of various plants: a review. International of Journal Pharmaceutical Sciences and Research, 10(2), 494-504. http://dx.doi.org/10.13040/IJPSR.0975-8232.10(2).494-04 .

Julaeha, E., Nurzaman, M., Wahyudi, T., Nurjanah, S., Permadi, N., & Anshori, J. A. (2022). The development of the antibacterial microcapsules of citrus essential oil for the cosmetotextile application: a review. Molecules, 27(22), 8090. https://doi.org/10.3390/molecules27228090

Kazeem, M. I., Bankole, H. A., Oladokun, T. I., Bello, A. O., & Maliki, M. A. (2020). Citrus aurantifolia (Christm.) Swingle (lime) fruit extract inhibits the activities of polyol pathway enzymes. E Food, 1(4), 310-315. https://doi.org/10.2991/efood.k.200824.001

Melkina, O. E., Plyuta, V. A., Khmel, I. A., & Zavilgelsky, G. B. (2021). The mode of action of cyclic monoterpenes (−)-limonene and (+)-α-pinene on bacterial cells. Biomolecules, 11(6), 806. https://doi.org/10.3390/biom11060806

Mohammed, I. O., Alrasheid, A. A., & Hussein Ayoub, S. M. (2024). GC-MS Analysis and Study of the Antimicrobial Activity of Citrus paradisi, Citrus aurantifolia, and Citrus sinensis Peel Essential Oils as Hand Sanitizer. International Journal of Microbiology, 2024. 10.1155/2024/4957712

Mohammed, R. M. O., & Ayoub, S. M. H. (2016). Study of phytochemical screening and antimicrobial activity of citrus aurantifolia seed extracts. American Journal of Analytical Chemistry, 7(03), 254. 10.4236/ajac.2016.73022.

Murray, C. J., Ikuta, K. S., Sharara, F., Swetschinski, L., Aguilar, G. R., Gray, A., and Tasak, N. (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. The lancet, 399(10325), 629-655.:https://doi.org/10.1016/S0140-6736(21)02724-0

Olatunya, A. M., & Akintayo, E. T. (2017). Evaluation of the effect of drying on the chemical composition and antioxidant activity of the essential oil of peels from three species of citrus group. International Food Research Journal, 24(5), 1991-1997.

Olatunya, A. M., Olatunya, O. S., Hassan, G. F., Adeyemi, L. A., Oyelami, O. A., & Akintayo, E. T. (2024). Antimicrobial activities of essential oils from three species of citrus fruits against six infectious tropical bacteria: implications for the care and control of common bacterial tropical diseases in developing countries. Discover Applied Sciences, 6(4), 209. https://doi.org/10.1007/s42452-024-05813-5

Ranganna, S., Govindarajan, V. S., Ramana, K. V. R., & Kefford, J. F. (1983). Citrus fruits—varieties, chemistry, technology, and quality evaluation. Part II. Chemistry, technology, and quality evaluation. A. Chemistry. Critical Reviews in Food Science & Nutrition, 18(4), 313-386. https://doi.org/10.1080/10408398309527366

Satapathy, K. B., Mishra, P. K., & Jena, G. S. J. P. (2020). Micro-botany of plants used in rituals in Jajpur district of Odisha. International Journal of Botany Studies, 5(4), 1-8. http://www.botanyjournals.com

Shchérazade, O. S. F., Pétronille, A. Z., Joseph, F. K. Y., & Georges, A. (2021). Study of the Analgesic Effect of the Aqueous Extract of the Leaves of Citrus aurantifolia (Rutaceae) in Mice. GSC Biological and pharmaceutical Sciences, 14(3), 207-214. https://doi.org/10.30574/gscbps.2021.14.3.0072

Swandiny, G. F., Nafisa, S., Gangga, E., & Fauzi, M. (2021). Standardization of 70% ethanol extract and 96% lime leaves as antioxidants with DPPH and FRAP. Journal of Pharmacognosy and Phytochemistry, 10(4), 47-52. https://dx.doi.org/10.22271/phyto

Tüfekci, E. F., Alkateeb, A., Akar, S., Çorum, O., Altunoğlu, Y. Ç., Baloğlu, M. C., and Çöplü, N. (2020). Antimicrobial and anti-quorum sensing activities of giant fennel (Ferula elaeochytris Korovin) from the Hatay region. Eurasian Journal of Veterinary Sciences, 36(3). https://hdl.handle.net/20.500.12395/46213

Twaij, B. M., & Hasan, M. N. (2022). Bioactive secondary metabolites from plant sources: types, synthesis, and their therapeutic uses. International Journal of Plant Biology, 13(1), 4-14. https://doi.org/10.3390/ijpb13010003

Xiao, L., Ye, F., Zhou, Y., & Zhao, G. (2021). Utilization of pomelo peels to manufacture value-added products: A review. Food Chemistry, 351, 129247. https://doi.org/10.1016/j.foodchem.2021.129247





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