Ethnopharmacology and Ethnobotany: Antimicrobial Potential of Medicinal Plants

NAILA GHAFOOR, MUHAMMAD UMAR IJAZ*, QURATULANN SATTAR, RABIA AZMAT, MEHRAB KHALIL, MARYAM JAMIL

Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad, Pakistan
*Corresponding author: umar.ijaz@uaf.edu.pk

SUMMARY

Ethnobotany and Ethnopharmacology have established an essential model for drug development, highlighting the medicinal potential of natural compounds derived from plants. Indigenous phytotherapy has historically been used to address many disorders and their symptoms using active phyto-compounds derived from ethnomedical flora. This chapter examines the historical and cultural importance of the antimicrobial potential of traditional plants in various disease management processes. Significant medicinal plants i.e., neem, garlic, turmeric, tea tree, and Echinacea purpurea have been discussed and they are extensively used in current and potential ethnopharmacological research for their antimicrobial therapeutic properties. Despite the effective collaboration between ethnopharmacology and contemporary medicine, there is a need for the development of research methodologies and the preservation of indigenous knowledge and plant diversity. Subsequent studies should concentrate on enhancing the medicinal efficacy and doses of native plants while safeguarding traditional bio-cultural heritage. Cooperative initiatives among medical researchers, traditional practitioners, and legislators are essential for the progression of phyto-therapeutic drugs exhibiting various curative effects including antimicrobial potential.

INTRODUCTION

Ethnobotany examines the interactions between humans and plants, with special emphasis on the use of plants for medical reasons by indigenous populations. These civilizations have established comprehensive pharmacopeias, often over centuries of empirical observation and experimentation (Tesfaye et al., 2020). Medicinal plants with antibacterial characteristics are integral to several traditional therapeutic systems, including Ayurveda, Traditional Chinese Medicine (TCM), and African Traditional Medicine (ATM) (Zhang et al., 2018).

Ethnopharmacology is the sub-branch of ethnobotany that encompasses several branches of science to understand and develop the traditional and cultural usage of plants in treating various diseases and disorders. The antimicrobial properties of medicinal plants have recently drawn much attention due to the emergence of resistant strains to conventional antibiotics (Murthy et al., 2020). This chapter details the rich past as well as current utilization of plants with microbial inhibitory potential as primary sources of alternative and complementary medicines (Getaneh and Girma, 2014).

Ethnobotanical and Ethnopharmacological Insights

The indigenous people of the Amazon, Africa and South Asia use decoctions, infusions and poultices from plants like ginger, eucalyptus, and aloe Vera for the management of infections and wounds (Umadev et al., 2013). Specifically, both the Ebers Papyrus from Egypt (descendant from approximately 1500 B.C.) and classical Indian Ayurvedic texts describe garlic, turmeric, and neem as means to cure diseases. Traditional healers are essential in the dissemination of ethnobotanical knowledge, safeguarding the perpetuation of this unique resource (Yang et al., 2016; Murthy et al., 2020).

1. Biological Screening: Methods such as bioassays facilitate the identification of plants with antibacterial characteristics (Parham et al., 2020).

2. Active chemicals: The isolation of bioactive chemicals, including alkaloids, flavonoids, and terpenoids, helps in understanding their modes of action (Damtew, 2022).

3. Phytochemical Synergy: Numerous therapeutic plants have synergistic effects, whereby a mixture of substances functions more effectively than separate components (Yuan et al., 2016).

MEDICINAL PLANTS WITH EXTENSIVE ANTIMICROBIAL POTENTIALS

Medicinal plants still play a significant role in healthcare systems for a large portion of the world population, especially in developing countries where they have been used for a long

How to Cite: Ghafoor N, MU Ijaz, Q Sattar, R Azmat, M Khalil, M Jamil, 2024. Ethnopharmacology and ethnobotany: Antimicrobial potential of medicinal plants. In: Ethnopharmacology and Ethnobotany of Medicinal Plants (Sindhu ZuD, B Aslam, MN Faisal & W Majeed, eds): FahumSci, Lahore, Pakistan, pp. 1-6. ISBN: 978-627-7745-10-3. https://doi.org/10.61748/EEMP.2024/01

time (Salar et al., 2023). Both industrialized and developing nations are increasingly recognizing the medicinal and financial benefits of these plants. They continue to provide new medicines for humanity. Some of the beneficial properties ascribed to plants have recognized to be flawed and medicinal plant treatment is based on the experimental findings of hundreds to thousands of years (Almabruk et al., 2018).

NEEM (*Azadirachta indica*)

Neem is a member of the Meliaceae family, which includes mahogany. The botanical name of the plant is Azadirachta indica A. Juss (Gupta et al., 2017). The Persian term for neem has undergone Latinization. The term "Azad" signifies "freedom," "Dirakht" refers to a "tree," and "i-Hind" indicates a connection to "Indian" origin. Therefore, it is often recognized as "the free tree of India." The neem tree is a remarkable species documented by the United Nations as the "Tree of the 21st Century." A. indica is a rapidly growing tropical evergreen tree predominantly located in India, Africa, and America (Bansode & Salalkar, 2015). It extends from the southern Indian region of Kerala to the Himalayan peaks (Kumar et al., 2018). The area encompasses regions within tropical and subtropical latitudes, varying from humid tropical to semi-arid environments, and spans elevations from sea level to 2,300 feet. The ethnopharmacological knowledge of medicinal plants is rapidly declining, particularly in industrialized nations, where the erosion of public information on these plants occurs at a faster rate than the developing countries (Lekha et al., 2018). The rapid decline of this knowledge necessitates urgent documentation and a comprehensive understanding of its botanico-historical foundations within ethno-allied areas (Anand et al., 2019). Various components of neem have been historically used in the treatment of human ailments since ancient times (Damtew, 2022)

Phytochemical Constituents

Medicinal plants contain specific organic compounds that produce distinct physiological effects on the human body. Plants synthesize two categories of metabolites, including primary and secondary metabolites (Liu et al., 2012). Primary metabolites are necessary for the normal metabolic processes of plants, including growth and development. Plants may produce secondary metabolites that serve minimal functional purposes (Eid et al., 2017). These occur in nearly all parts that make up the plant, including bark, leaves, stems, roots, flowers, fruits, and seeds. Bioactive molecules are classified as secondary metabolites. Bioactive compounds found in neem includes tannins, alkaloids, carbohydrates, terpenoids, steroids, as well as flavonoids are identified (Ghafoor et al., 2024; Bansode & Salalkar, 2015).

Anti-microbial Potency

Previous investigations examined the antimicrobial properties of extracts from the fruit seed, bark, and leaf of A indica against bacteria sourced through oral cavities. The outcomes indicated that leaf and bark clippings exhibited bactericidal activity against all tested bacteria. Additionally, antibacterial activity in fruit and seed clippings was observed only at higher doses (Lekha et al., 2018). A study evaluated the antibacterial efficacy of neem leaves as endodontic irritants compared to the standard irrigant, sodium hypochlorite. The results indicated that leaf extracts demonstrated zones of inhibition, suggesting antimicrobial qualities. Leaf extracts inhibited a greater number of zones compared to 3% sodium hypochlorite. Neem leaf, seed, and bark extracts exhibit antibacterial properties against various Gram-negative and Gram-positive pathogens, such as Mycobacterium tuberculosis, Vibrio cholerae, and Klebsiella pneumonia (Sujarwo et al., 2016). Neem bark extract (NBE) significantly inhibited HSV-1 entry into cells at doses ranging from 50 to 100 g ml-1. The NBE extract exhibits a direct anti-HSV-1 effect, as indicated by its inhibitory action when incubated with the virus instead of the codocytes, recommends that neem bark possesses this antimicrobial potency. Neem leaf extract exhibits virucidal properties against coxsackievirus B-4, as evidenced by virus inactivation and yield reduction assays, and it disrupts an early stage of the viral replication cycle (Tiwari et al., 2010).

GARLIC (*Allium sativum* L)

Allium sativum L. (Garlic) is a species that belongs to tuber obtaining spice and herb, recognized as one of the most in-demand botanicals, utilized in household practices and ethnomedicine for various diseases globally (Shende et al., 2014). Allium sativum L., commonly referred to as garlic, is a member of the Amaryllidaceae family. The bulb is primarily utilized for therapeutic purposes, featuring upward stems with flowers that can reach heights of up to 0.5 meters (Hemeg et al., 2020). The leaf lamina is robust, flattened, and linear measuring approximately 0.4–0.9 inches in length and featuring a sharp apex. The medical benefits of this substance are recorded in Sanskrit texts from approximately 4500 years ago and they were first noted in Chinese traditional medicine around 3500 years ago. Garlic is cultivated globally that is recognized to have over 300 varieties (Getaneh and Girma, 2014). Planting each clove in the soil is a technique for asexual propagation of this plant in cultivation.

Cloves are typically planted six weeks before the onset of freezing temperatures in the winter season. The bulbous plants exclusively generate roots and lack any above-surface stems. This plant is cultivated throughout the world due to its immense pharmacological properties (Karou et al., 2011). Previous studies (Table 1) have established an array of pharmacological attributes for this species, including, antihyperlipidemic, hypoglycemic, hepatoprotective, anti-inflammatory, antioxidant, anticancer, and antimicrobial activities (Banerjee, 2024). Compounds of organosulfur are associated with changes in their properties such as antioxidant and antimicrobial effects. Garlic-based compounds have been identified as potential immunee enhancers and effective immunostimulants.

Antimicrobial Potency

A. sativum has been recognized as a strong antimicrobial agent. Raw bulb garlic essential oil, which contains diallyl monosulfide, disulfide, trisulfide, and tetrasulfide, inhibited *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *E. coli.*

Table 1. Pharmacological potentials of *A. sativum*

Extracted proportions	Analyses via in vitro/in vivo models	Mechanism	Reference
Ethanol-based root extraction	Ethanol-based root extracts consisting of Staphylococcus aureus, E. Pseudomonas Bacillus cereus, Aspergillus versicolor, and Penicillium citrinum, P. expansum.	Enhance the development of bacteria suppression	Mueed et al., 2023
Extract of aged cloves of garlic	Burkholderia cepacia	Enhance the development of bacteria suppression	Hemeg et al., 2020
Ethanolic bulb extract	Bacillus subtilis, B. megaterium, B. sphaericus, , Penicillium oxalicum, Aspergillus flavus, Staphylococcus aureus, B. polymyxa, A. Rhizopus stolonifer, Scopulariopsis sp. and Mucor sp, E.coli, luchuensis,	Enhance the development of bacteria suppression	Castronovo et al., 2021 Banerjee, 2024
Ethanolic bulb extract	Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli	Enhance the development of bacteria suppression	Chandra et al., 2020

According to Sher et al. (2011), the antimicrobial potential of Allium depends on the allyl group in its chemical configuration. Due to allicin activity disrupting phospholipid bilayer production, watery bulb infusion is effective against Bacillus subtilis, Staphylococcus aureus, Klebsiella pneumoniae, Escherichia coli, and Candida albicans (Hamza et al., 2024). Garlic essential oil may inhibit Penicillium funiculosum by entering membranes, disturbing the cytoskeleton, and leaking cytoplasmic contents and biomolecules. Proteomic analyses have revealed that garlic oil may modulate the expression of various proteins involved in physiological metabolic pathways (Reen et al., 2018). Garlic methanol and aqueous clove formulations were tested against Candida albicans, Bacillus cereus, E. coli, Staphylococcus aureus, Listeria monocytogenes, Pseudomonas aeruginosa, and Rhodotorula mucilaginosa. Ultra-high-performance liquid chromatography with mass spectrometry and photodiode array detection identified and quantified pharmacologically active substances in garlic. That correlation study reported the antibacterial and antioxidant capabilities of this species (Soladoye et al., 2014).

TURMERIC (*Curcuma longa*)

Curcuma longa is a herbaceous perennial plant belonging to the Zingiberaceae family. Turmeric is originated from South Asia (Yahaya, 2020). Curcumin is the principal bioactive constituent of this plant, which has received great attention due to its numerous medicinal benefits within the framework of Ayurveda, TCM, and Siddha. Turmeric is historically used as an active constituent containing plant that has significant contributions to modern medicine (Odo et al., 2023).

Active Compounds in Turmeric

The medicinal properties of turmeric are mostly ascribed to its polyphenolic constituent, curcumin. Turmeric also comprises other beneficial components, including demethoxycurcumin, bisdemethoxycurcumin, and essential oils such as turmerone, atlantone, and zingiberene (Kasta, 2020).

Curcumin: the most extensively researched component, has significant anti-inflammatory, antioxidant, and antibacterial properties. It also affects several cellular signalling pathways, positioning it as a potential treatment for chronic disorders (Rahman et al., 2021).

Turmerone: This essential oil improves the absorption of curcumin and has neuroprotective characteristics and antimicrobial potetials (Momoh et al., 2022).

Demethoxycurcumin and Bisdemethoxycurcumin: These compounds enhance turmeric's medicinal efficacy by regulating immunological responses and diminishing oxidative stress (Sattar et al., 2024).

Antimicrobial Properties

Turmeric has been acknowledged for its potent antibacterial capabilities, mostly attributed to its active component curcumin. Various investigations have shown its efficacy against infections, including bacteria, fungi, and viruses (Kasta, 2020). Curcumin has antibacterial efficacy against prevalent pathogens like Streptococcus aureus, E. coli, and Pseudomonas aeruginosa, which are implicated in several illnesses. It disrupts bacterial cell membranes, reduces enzyme activity, inhibits biofilm formation that is effective in treating various bacterial diseases (Matowa et al., 2020). Additionally, the antioxidant properties of turmeric show effectiveness against pathogenic forms of fungi including Candida albicans and Aspergillus niger from skin and oral thrush treatment (Yahaya, 2020). Curcumin also inhibits viral replication including HSV and HCV and exhibits anti-bacterial as well as, anti-fungal activity. The antibacterial property of the turmeric is accredited not just to the curcumin but also to the other compounds like turmerones and zingiberene found in the essential oil of rhizome. Curcumin demonstrates excellent antibacterial activity; however, its low bioavailability remains a significant challenge. Research efforts have focused on enhancing its absorption for effective medicinal use (Momoh et al., 2022).

TEA TREE (*Melaleuca alternifolia*)

Tea tree is an evergreen species indigenous to Australia, mostly located in New South Wales and Queensland. It remains a fundamental aspect of traditional medicine utilized by indigenous Aboriginal cultures, who have harnessed its exceptional healing powers for generations. Indigenous peoples mostly used pulverized tea tree leaves as a treatment for dermal infections, lacerations, and injuries (Akhtar and Mirza, 2018). The leaves were steeped to produce infusions for alleviating sore throats and colds or used as poultices to reduce discomfort and inflammation. The Aboriginal techniques included both direct application and the heating of leaves to produce an antibacterial vapor. This vapor was used to disinfect wounds and address respiratory conditions. The exceptional antibacterial capabilities of this plant makes it an essential component of their herbal medicine cabinet, far before contemporary science started its investigation of its potential (Zeng et al., 2021).

Active Compounds

Tea tree oil's extensive therapeutic benefits stem from its complex chemical makeup, notably the inclusion of terpinene-4-ol and cineole. These substances have been thoroughly investigated for their antibacterial, anti-inflammatory, and antioxidant activities (Vaou et al., 2021). Terpinen-4-ol: This is the principal active ingredient in tea tree oil, accountable for a significant portion of its antibacterial effectiveness. Terpinen-4-ol has significant efficacy against various bacteria, fungi, and viruses, which makes it beneficial for infection treatment and wound healing enhancement. It has anti-inflammatory effects that alleviate redness, swelling, and irritation (Ali et al., 2023).

Cineole (Eucalyptol): Although found in lesser quantities than terpinen-4-ol, cineole enhances the medicinal attributes of tea tree oil, especially its efficacy in clearing respiratory passages and serving as a mild antiseptic. Excess cineole, nevertheless, may induce skin irritation, which is why premium tea tree oil is prepared with a regulated concentration. The amalgamation of various chemicals, including γ-terpinene and α-terpineol, enhances many therapeutic uses of tea tree essential oil (Puvača et al., 2021).

Antimicrobial Activity

Tea tree oil has exceptional antibacterial characteristics, rendering it efficient against many diseases (Paul and Roychoudhury, 2021). It has shown effectiveness against:

Bacteria: Tea tree oil is proficient in countering Staphylococcus aureus (including MRSA), E. coli, and Propionibacterium acnes, the bacteria linked to acne (Kumar et al., 2022).

Fungi: Tea tree oil exhibits strong antifungal properties against Candida albicans, Trichophyton species (causative agents of the athlete's foot), and Malassezia (linked to dandruff) (Akhtar and Mirza, 2018).

Viruses: Previous research indicates that tea tree oil has antiviral effects, demonstrating efficacy in diminishing the activity of the viruses that cause herpes simplex and influenza (Lam et al., 2015).

The capability of tea tree oil to permeate the skin and address infections makes it a effective for the treatment of several dermatological problems. Terpinen-4-ol has antibacterial capabilities that diminish acne-inducing microorganisms, while its anti-inflammatory activities alleviate redness and swelling (Ali et al., 2023). Tea tree oil expedites wound healing by inhibiting infection and facilitating skin regeneration. It assists in mitigating symptoms such as pruritus, desquamation, and irritation. Tea tree oil serves as an active component in several oral care products, such as mouthwashes and toothpaste, owing to its efficacy in diminishing detrimental oral microorganisms and enhancing gum health (Paul and Roychoudhury, 2021). It is often used in shampoos and conditioners to address dandruff, lice, and scalp irritation. Its antifungal qualities specifically target Malassezia, while its calming effect alleviates itching and flakiness owing to its remarkable antimicrobial potential (Akhtar and Mirza, 2018).

ECHINACEA (*Echinacea purpurea*)

Echinacea is a prominent plant in traditional medical practice, especially in North America, in which it has been extensively employed by indigenous populations for generations. Native American cultures, such as the Lakota and the Sioux, used echinacea to address various ailments, often using it as a treatment for infections, wounds, and snake bites (Sharma et al., 2020). The plant's roots and aerial parts were used to prepare poultices, infusions, and teas for the treatment of fever, colds, and other respiratory ailments. Upon seeing these methods, European immigrants swiftly included echinacea within their therapeutic repertoire. It gradually became popular in both traditional and herbal medical systems, especially in Europe and the United States (Abers et al., 2021).

Active compounds and anti-microbial potential

The therapeutic attributes of echinacea are mostly ascribed to its bioactive constituents, including alkamides, cichoric acid, and polysaccharides. Alkamides, the most extensively researched active chemicals, have shown the ability to alter the immune system's functioning by augmenting the function of macrophages as well as T-cells, which are pivotal in the body defense against infections. These chemicals enhance echinacea's well-known immunostimulatory properties (Sattar et al., 2024). Echinacea is extensively utilized as an immunostimulatory agent. It is often used as a prophylactic against colds, influenza, and other respiratory illnesses. Studies indicate that echinacea may diminish the duration and intensity of the common cold when administered at the onset of symptoms. It is frequently employed as a topical remedy for wounds, bites from insects, and skin infections owing to its antibacterial and anti-inflammatory properties (Nassr-Allah et al., 2009).

Some studies indicate that echinacea may additionally alleviate symptoms of autoimmune diseases, such as rheumatoid arthritis, and might encourage the healing of wounds (Wagner et al., 2009). In recent years, echinacea has gained attention in natural health circles as a go-to remedy for maintaining general wellness and preventing infections (Adnan et al., 2023). Echinacea should also be used with caution in individuals with autoimmune disorders, as its immune-stimulating effects could exacerbate symptoms (Sharma et al., 2020). With its extensive history in traditional medicine and its proven effects in modern scientific studies, echinacea continues to be a staple in natural medicine for its ability to boost the immune system, reduce inflammation, and support overall health (Oladosu et al., 2015)

CONCLUSION

In recent years, ethnobotanical and conventional uses of natural compounds, especially those derived from plants, have garnered significant attention due to their comprehensive effectiveness evaluations and general perception of safety for human intake. This is the most conventional approach in the search for new chemicals to cure different diseases. Neem, garlic, turmeric, and similar plants are multifaceted medicinal species; several phytochemicals have been extracted from diverse portions of these plants. Flowers, fruits, oils, leaves, roots, bark, twigs, and seeds have been utilized for medicinal and dietary purposes. These plants have reported diverse pharmacological properties including, antibacterial, antiviral, antifungal and activity. These medicinal plants have been employed in humans and animals to treat various infections caused by bacteria and other microorganisms. Further investigation into the described properties could potentially enhance the commercial use of the aforementioned medicinal plants regarding antimicrobial potentials on a broader scale.

REFERENCES

Abers M, S Schroeder, L Goelz, et al., 2021. Antimicrobial activity of the volatile substances from essential oils. BMC Complementary Medicine and Therapies, 21, pp.1-14. https://doi.org/10.1186/s12906-021-03285-3

Adnan M, M Patel & M Snoussi, 2023. Ethnobotany and Ethnopharmacology of Medicinal and Aromatic Plants: Steps Towards Drug Discovery. CRC Press. https://doi.org/10.1201/b22842

Akhtar N & B Mirza, 2018. Phytochemical analysis and comprehensive evaluation of antimicrobial and antioxidant properties of 61 medicinal plant species. Arabian Journal of Chemistry, 11:1223-35. https://doi.org/10.1016/j.arabjc.2015.01.013

Ali SR, S Kumari, SK Prasad et al., 2023. Drug Development Projects Guided by Ethnobotany and Ethnopharmacology Studies. Drug Discovery and Design Using Natural Products, pp.3-21. https://doi.org/10.1007/978-3-031-35205-8_1

Almabruk KH, LK Dinh & B Philmus, 2018. Self-resistance of natural product producers: past, present, and future focusing on self-resistant protein variants. ACS Chemical Biology 13:1426-37. https://doi.org/10.1021/acschembio.8b00173

Anand U, N Jacobo-Herrera A Altemimi, et al., 2019. A comprehensive review on medicinal plants as antimicrobial therapeutics: potential avenues of biocompatible drug discovery. Metabolites 9:258. https://doi.org/10.3390/metabo9110258

Banerjee S, 2024. Introduction to ethnobotany and traditional medicine. In Traditional Resources and Tools for Modern Drug Discovery: Ethnomedicine and Pharmacology (pp. 1-30). Singapore: Springer. https://doi.org/10.1007/978-981-97-4600-2_1

Bansode T, & B Salalkar, 2015. Phytochemical analysis of some selected Indian medicinal plants. International Journal of Pharmacy and Biological Sciences, 6(1): 550-556.

Castronovo LM., A Vassallo & A Mengoni, 2021. Medicinal plants and their bacterial microbiota: a review on antimicrobial compounds production for plant and human health. Pathogens 10:106. https://doi.org/10.3390/pathogens10020106

Chandra H, C Singh & P Kumari, 2020. Promising roles of alternative medicine and plant-based nanotechnology as remedies for urinary tract infections. Molecules 25:5593. https://doi.org/10.3390/molecules25235593

Damtew M, 2022. A review on chemical composition, medicinal value and other applications of Azadirachta indica. Agricultural and Biological Research 38:268-72.

Eid A, N Jaradat & N Elmarzugi, 2017. A Review of chemical constituents and traditional usage of Neem plant (*Azadirachta indica*). Palestinian Medical and Pharmaceutical Journal 2:75-81. https://doi.org/10.59049/2790-0231.1060

Getaneh S & Z Girma, 2014. An ethnobotanical study of medicinal plants in Debre Libanos Wereda, Central Ethiopia. African Journal of Plant Science 8:366-79. https://doi.org/10.5897/AJPS2013.1041

Ghafoor N, T Mehar, M Batool et al., 2024. Attenuative effects of poncirin against polyethylene microplastics-prompted hepatotoxicity in rats. Journal of King Saud University-Science 36:103475. https://doi.org/10.1016/j.jksus.2024.103475

Gupta SC, S Prasad, AK Tyagi et al. 2017. Neem (*Azadirachta indica*): An Indian traditional panacea with modern molecular basis. Phytomedicine 34:14-20. https://doi.org/10.1016/j.phymed.2017.07.001

Hamza A, M Raza, K Javed et al., 2024. Pharmacological potential of essential oils: exploring therapeutic perspectives. In: Complementary and Alternative Medicine: Essential oils (Zafar MA, RZ Abbas, M Imran, S Tahir & WQamar (eds): Unique Scientific Publishers, Faisalabad, Pakistan, pp:90-97. https://doi.org/10.47278/book.CAM/2024.168

Hemeg HA, IM Moussa & S Ibrahim, 2020. Antimicrobial effect of different herbal plant extracts against different microbial population. Saudi Journal of Biological Sciences 27:3221-7. https://doi.org/10.1016/j.sjbs.2020.08.015

Karou SD, T Tchacondo, D Tchibozo, et al., 2011. Ethnobotanical study of medicinal plants used in the management of diabetes mellitus and hypertension in the Central Region of Togo. Pharmaceutical Biology 49:1286-97. https://doi.org/10.3109/13880209.2011.621959

Kasta G, 2020. Antimicrobial activity of ethanol extract of rhizome turmeric (*Curcuma longa* L.) for growth of Escherichia coli, Staphylococcus aureus and Candida albicans. Asian Journal of Pharmaceutical Research and Development 8:5-8. https://doi.org/10.22270/ajprd.v8i3.712

Kumar R, S Sharma & L Devi, 2018. Investigation of total phenolic, flavonoid contents and antioxidant activity from extracts of *Azadirachta indica* of Bundelkhand region. International Journal of Life-Sciences Scientific Research 4:1925-33. https://doi.org/10.21276/ijlssr.2018.4.4.10

Kumar S, B Singh & R Singh et al., 2022. *Catharanthus roseus* (L.) G. Don: A review of its ethnobotany, phytochemistry, ethnopharmacology and toxicities. Journal of Ethnopharmacology 284:114647. https://doi.org/10.1016/j.jep.2021.114647

Lam W, Z Jiang, F Guan et al., 2015. PHY906 (KD018), an adjuvant based on a 1800-year-old Chinese medicine, enhanced the anti-tumor activity of Sorafenib by changing the tumor microenvironment. Scientific Reports 5:9384. https://doi.org/10.1038/srep09384

Lekha GS, S Aparna, N Kasirajan et al., 2018. Diagnosis and treatment of cancer-siddha perspective. Journal of Research in Siddha Medicine 1:3-14. https://doi.org/10.4103/2582-1954.328141

Liu SH & YC Cheng, 2012. Old formula, new Rx: the journey of PHY906 as cancer adjuvant therapy. Journal of Ethnopharmacology 140:614-23. https://doi.org/10.1016/j.jep.2012.01.047

Matowa PR, M Gundidza & L Gwanzura, 2020. A survey of ethnomedicinal plants used to treat cancer by traditional medicine practitioners in Zimbabwe. BMC Complementary Medicine and Therapies 20:1-13. https://doi.org/10.1186/s12906-020-03046-8

Momoh JO, AA Manuwa & YO Bankole, 2022. Phytochemical screening, atomic absorption spectroscopy, GC-MS and antibacterial activities of turmeric (Curcuma longa L.) rhizome extracts. Journal of Advances in Microbiology 22:116-31. https://doi.org/10.9734/jamb/2022/v22i930498

Mueed A, S Shibli & DA Al-Quwaie, 2023. Extraction, characterization of polyphenols from certain medicinal plants and evaluation of their antioxidant, antitumor, antidiabetic, antimicrobial properties, and potential use in human nutrition. Frontiers in Nutrition 10:1125106. https://doi.org/10.3389/fnut.2023.1125106

Murthy HA, T Desalegn & M Kassa, 2020. Synthesis of green copper nanoparticles using medicinal plant Hagenia abyssinica (Brace) JF. Gmel. leaf extract: Antimicrobial properties. Journal of Nanomaterials 2020:3924081. https://doi.org/10.1155/2020/3924081

Nassr-Allah AA, AM Aboul-Enein, KM Aboul-Enein et al., 2009. Anti-cancer and anti-oxidant activity of some Egyptian medicinal plants. Journal of Medicinal Plants Research 3:799-808.

Odo EO, JA Ikwuegbu & EI Obeagu, 2023. Analysis of the antibacterial effects of turmeric on particular bacteria. Medicine 102:e36492. https://doi.org/10.1097/MD.0000000000036492

Oladosu IA, SO Balogun & LIO Zhi-Qiang, 2015. Chemical constituents of Allophylus africanus. Chinese Journal of Natural Medicines 13:133-41. https://doi.org/10.1016/S1875-5364(15)60017-6

Parham S, AZ Kharazi & HR Bakhsheshi-Rad 2020. Antioxidant, antimicrobial and antiviral properties of herbal materials. Antioxidants 9:1309. https://doi.org/10.3390/antiox9121309

Paul A & A Roychoudhury, 2021. Go green to protect plants: repurposing the antimicrobial activity of biosynthesized silver nanoparticles to combat phytopathogens. Nanotechnology for Environmental Engineering 6:10. https://doi.org/10.1007/s41204-021-00103-6

Puvača N, J Milenković, TG Coghill et al., 2021. Antimicrobial activity of selected essential oils against selected pathogenic bacteria: In vitro study. Antibiotics 10:546. https://doi.org/10.3390/antibiotics10050546

Rahman ANAA, NIM Sarmin, NSNA Jamil et al., 2021. Anti-microbial properties of turmeric extracts against common oral pathogens as a potential therapeutic alternative in dentistry. In Enhancing Halal Sustainability: Selected Papers from the 4th International Halal Conference 2019, pp. 287-93. https://doi.org/10.1007/978-981-33-4854-7_25

Reen FJ, JA Gutiérrez-Barranquero, ML Parages, 2018. Coumarin: a novel player in microbial quorum sensing and biofilm formation inhibition. Applied Microbiology and Biotechnology 102:2063-73. https://doi.org/10.1007/s00253-018-8787-x

Salar MZ, MF Hayat, A Hamza, et al., 2023. Contribution of ethnopharmacology in ameliorating toxicity of vital organs. In: Complementary and Alternative Medicine: One Health Perspective (Sindhu ZuD, B Aslam, U Uslu & M Mohsin, eds): FahumSci, Lahore, Pakistan, pp: 172-179. https://doi.org/10.61748/CAM.2023/023

Sattar Q, A Tahir, A Rashid et al., 2024. Homeopathic first aid natural remedies for common ailments. In: Abbas RZ, Khan AMA, Qamar W, Arshad J and Mehnaz S (eds), Complementary and Alternative Medicine: Botanicals/Homeopathy/Herbal Medicine. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 265-72. https://doi.org/10.47278/book.CAM/2024.286

Sharma K, S Guleria, VK Razdan, et al., 2020. Synergistic antioxidant and antimicrobial activities of essential oils of some selected medicinal plants in combination and with synthetic compounds. Industrial Crops and Products 154:112569. https://doi.org/10.1016/j.indcrop.2020.112569

Shende JJ, BM Rajurkar, MN Mhaiskar et al., 2014. Ethnobotanical studies of Samudrapur Tahsil of Wardha district. Joural of Pharmacology Biological Sciences:16-23.

Sher Z, Z Khan & F Hussain, 2011. Ethnobotanical studies of some plants of Chagharzai valley, district Buner, Pakistan. Pakistan Journal of Botany 43:1445-52.

Soladoye MO, EC Chukwuma, OM Sulaiman, et al., 2014. Ethnobotanical survey of plants used in the traditional treatment of female infertility in Southwestern Nigeria. Ethnobotany Res Appl. 12:81

Sujarwo W, AP Keim & G Caneva, 2016. Ethnobotanical uses of neem (Azadirachta indica A.Juss.; Meliaceae) leaves in Bali (Indonesia) and the Indian subcontinent in relation with historical background and phytochemical properties. Journal of Ethnopharmacology 189:186-93. https://doi.org/10.1016/j.jep.2016.05.014

Tesfaye S, A Belete, E Engidawork et al., 2020. Ethnobotanical study of medicinal plants used by traditional healers to treat cancer-like symptoms in eleven districts, ethiopia. Evidence-Based Complementary and Alternative Medicine 2020:7683450. https://doi.org/10.1155/2020/7683450

Tiwari V, N Darmani N, B Yue, et al., 2010. In vitro antiviral activity of neem (*Azardirachta indica* L.) bark extract against herpes simplex virus type-1 infection. Phytotherapy Research 24:1132-40. https://doi.org/10.1002/ptr.3085

Umadevi M, KPS Kumar, D Bhowmik et al., 2013. Traditionally used anticancer herbs in India. Journal of Medicinal Plants Studies 1:56-74. https://doi.org/10.1007/978-1-4419-0020-3_3

Vaou N, E Stavropoulou, C Voidarou, et al., 2021. Towards advances in medicinal plant antimicrobial activity: A review study on challenges and future perspectives. Microorganisms 9:2041. https://doi.org/10.3390/microorganisms9102041

Wagner H & G lrich-Merzenich, 2009. Synergy research: Approaching a new generation of phytopharmaceuticals. Phytomedicine 16:97-110. https://doi.org/10.1016/j.phymed.2008.12.018

YAHAYA N, 2020. Antimicrobial and antioxidant activities in 'beluntas'(Pluchea indica), turmeric (Curcuma longa) and their mixtures. Sains Malaysiana 49:1293-302. https://doi.org/10.17576/jsm-2020-4906-07

Yang X, D Chen, L Chai et al., 2016. Case Report of poisoning caused by incorrect use of salvia. American Journal of Case Reports 17:580-3. https://doi.org/10.3390/agronomy13030835

Yuan H, Q Ma, L Ye et al., 2016. The traditional medicine and modern medicine from natural products. Molecules 21:559. https://doi.org/10.3390/molecules21050559

Zeng L, X Zhou, Y Liao et al., 2021. Roles of specialized metabolites in biological function and environmental adaptability of tea plant (Camellia sinensis) as a metabolite studying model. Journal of advanced research 34:159-71. https://doi.org/10.1016/j.jare.2020.11.004

Zhang Y, Asass H, Van Acker, J Wille et al., 2018. Coumarin Reduces Virulence and Biofilm Formation in Pseudomonas aeruginosa by Affecting Quorum Sensing, Type III Secretion and C-Di-GMP Levels. Front. Microbiology 9:1952. https://doi.org/10.3389/fmicb.2018.01952 https://doi.org/10.3389/fmicb.2018.01952