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Review

CURBING ANTI-MICROBIAL RESISTANCE OF SYNTHETIC MEDICINAL AGENTS USING HERBAL DRUG ALTERNATIVES: CURRENT TRENDS AND FUTURE INSIGHTS

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ABSTRACT

Anti-microbial resistance represents a critical global health threat, undermining the effectiveness of conventional antibiotics and posing challenges in the treatment of infectious diseases. The increasing resistance to synthetic anti-microbial agents underscores the urgent need to explore alternative therapeutic approaches, particularly through natural and herbal remedies. Unlike synthetic drugs, which are often associated with harmful side effects and toxicity, medicinal plants offer a promising, safer alternative due to their rich array of bioactive compounds. These plant-derived substances have demonstrated significant anti-microbial activity against a variety of pathogens. Traditionally, medicinal plants have been used to treat a wide range of diseases and conditions, but their potential must be validated and standardized through scientific research to ensure both efficacy and safety. The anti-microbial properties of medicinal plants stem from their diverse phytochemical constituents, including alkaloids, flavonoids, terpenoids, and phenolic compounds, which exhibit broad-spectrum activity against bacteria, fungi, and viruses. This review explores the anti-microbial potential of these plant-based compounds, emphasizing their broad-spectrum efficacy in combating resistant pathogens. It also highlights the importance of further research to optimize the use of medicinal plants in modern healthcare, offering a viable strategy to mitigate the growing threat of anti-microbial resistance and provide safer alternatives to conventional antibiotics.

KEYWORDS: Micro-organism, phytoconstituents, medicinal uses, herbal nanoparticles, *in-silico* studies

1. Introduction

Plants and herbs have been recognized to offer therapeutic benefits since ancient times. Traditionally, people have been using medicinal plants and their natural components to cure a varied array of ailments including infectious diseases. The established herbal medicine practice and current scientific studies provide verification of the effectiveness of medicinal plants in curbing anti-microbial resistance.

Medicinal plants have been employed in healthcare from the time when life began on earth. Medicinal plants are the very first and the safest source of treatment and management for numerous morbidities, principally for chronic diseases. Plants are considered to be the essential source of therapeutic constituents including flavonoids, glycosides, alkaloids, saponins, tannins, tri-terpenoids, coumarins, lignins, organic acids, essential oils etc. These all exhibits a significant role in treating mild fever to the deadliest cancer [1]. Natural components are also significantly used in traditional medicines (TMs), traditional Chinese medicine (TCM), ayurveda, neuropathy, homoeopathy, and Unani system of medicine. These systems have developed into well-structured medical systems [2]. Investigations are continuously conducted globally not only in support of the effectiveness but to uncover the hidden therapeutic potential of the medicinal plants. Moreover, natural medicines have remained popular in this modern era owing to safety and cost-effectiveness.

1.1. Traditional uses of medicinal plants

Plants and natural extracts have been utilized for their therapeutic efficacy in different traditional systems of medicine. These extracts and raw herbs have shown promising analgesic, anti-inflammatory, anti-diabetic, anti-microbial, antioxidant, and anti-cancer activities. They are successfully employed to treat both acute and chronic ailments. Constituents present in plants and other natural sources including animals, microorganisms, marine, insects, and minerals or their analogues have made a remarkable contribution to the efficacious natural origin medicines in current era [3-6].

1.2. Anti-microbial properties of medicinal plants

Infectious diseases have existed since antiquity and are still found challenging to be treated. In the present era, new diseases are emerging owing to mutation in existing microorganisms, environmental changes, animal-human cycles, urbanization, and many others. The emerging and already identified diseases are posing significant threats to the global health and economies therefore, developing the need of potent novel antimicrobial agents to curb the pathetic situation [7]. These pathologies usually occur due to the infections caused by the five major types of causative organisms including viruses (influenza, hepatitis, dengue, corona, measles, rubella, polio, mumps etc.), bacteria (*Salmonella*, *Escherichia coli*, *Streptococcus pneumonia*, Shigella, *Staphylococcus aureus*, *Helicobacter pylori*, *Vibrio cholera* etc.), fungi (*Candida albicans*, *Histoplasma capsulatum*), protozoa (plasmodium spp., *Giardia lamblia*, Leishmania), and worms (hook worm, round worm, flat worm etc.) [8]. The anti-microbial potential of medicinal plants is extensively investigated and not only documented but even utilized broadly in traditional medicine systems. Medicinal plants such as *Azadirachta indica* (Neem), *Ocimum basilicum* (basil), *Matricaria chamomilla* (chamomile), *Eucalyptus globules* (eucalyptus), *Glycyrrhiza glabra* (licorice), *Cinchona* spp. (quinine), *Casia angustifolia* (senna), *Aloe barbadensis* (Aloe), *Vaccinium* spp. (cranberry), *Camellia sinensis* (green tree), *Punica granatum* (pomegranate). However, researchers are continuously putting strenuous efforts in exploring the anti-microbial potential of the other plants as well [9]. This review explores the pharmacognostic properties of selected medicinal plants with their promising antimicrobial activities against pathogenic organisms.

2. Materials and methods

This comprehensive review is comprised of ten years literature survey covering investigations from January 2014 to December 2023. The data was extracted by searching through the web engines of PubMed, Google Scholar, Research Gate, Science Direct, Elsevier, chapters from books, National Institute of Health (NIH) website, PubChem., Drug.com, Medscape.com, WebMD.com, Rxlist.com. The keywords were medicinal plants, anti-microbial agents, anti-microbial resistance, anti-fungal, anti-viral, anti-bacterial, indications, mechanism of antimicrobial action, pharmacological actions, adverse effects, pharmacognostic features, phytochemistry, phytochemical constituents, extracts, toxicity, and doses along with the names of the medicinal plants including *Apium graveolens* Linn.., *Hypericum perforatum* Linn., *Moringa oleifera* Linn., *Thymus vulgaris* Linn., *Zingiber officinale* roscoe., *Azadirachta indica* Linn., *Allium sativum* Linn., *Curcuma longa* Linn., *Hibiscus sabdariffa L.*, *Tanacetum parthenium, Apocynum cannabinum, Echinacea purpurea, Rosemarinus officinalis* Linn., *Humulus lupulus* Linn., *Pistacia lentiscus* Linn., *Agrimonia pilosa* Ledeb., *Aniba rosaeodora* ducke., *Commiphora myrrha, Cichorium intybus* L., *Momordica charantia* L., *Eruca vesicaria sativa* and *Andrographis paniculata.* The original research articles, review, systematic reviews and meta-analysis dealing with the pharmacognostic, phytochemical and anti-microbial activity of the above-mentioned medicinal plants were incorporated [10].

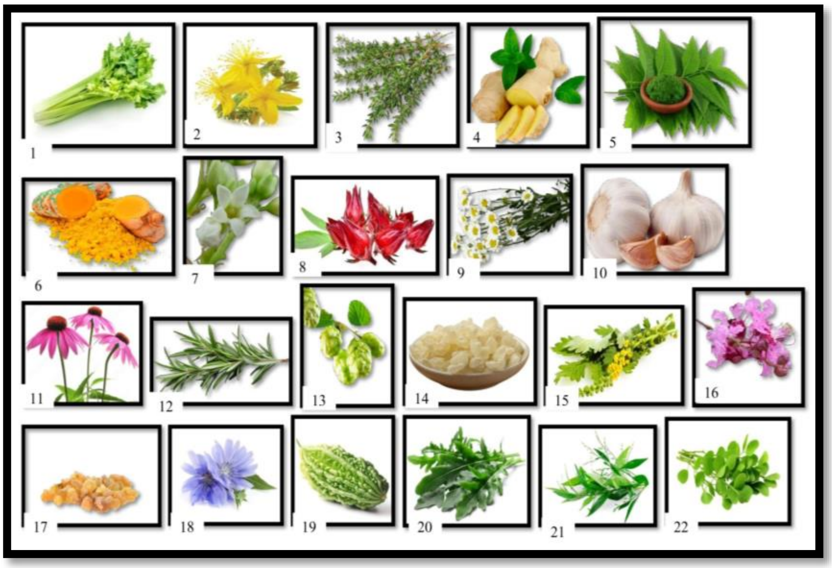

Fig. 1. Photographs of the twenty two medicinal plants. *1: Apium graveolens* L., *2: Hypericum perforatum* L., *3: Thymus vulgaris* L., *4: Zingiber officinale* Roscoe., *5: Azadirachta indica* Adrien-Henri de Jussieu, *6: Curcuma longa* L., *7: Apocynum cannabinum* L. *8: Hibiscus sabdariffa* L., *9: Tanacetum parthenium* L., *10: Allium sativum* L., *11: Echinacea purpurea* L., *12: Rosemarinus officinalis* L., *13: Humulus lupulus* L. *14: Pistacia lentiscus* L. *15: Agrimonia pilosa* Ledeb. *16: Aniba rosaeodora* Ducke. *17: Commiphora myrrha* Nees. *18: Cichorium intybus* L. *19: Momordica charantia* L. *20: Eruca vesicaria* subsp. sativa Mill. *21: Andrographis peniculata* Burm. F. *22. Moringa oleifera* Lam.

3. Results

3.1. Pharmacognostic Properties of Medicinal Plants

The medicinal plants were selected after thorough review of the literature owing to their significant anti-microbial activity. The photographs of the 22 medicinal plants discussed in this review article are given in Fig. 1.

The details of each medicinal plant are provided separately as follow:

3.1.1. *Apium graveolens* L.

A. *graveolens* L. is native to Europe, Western Asia, and Northern Africa. It is a miraculous herb, with a variety of medicinal characteristics. It is grown under moderate to mildly harsh conditions in different locations of Pakistan. Leafy stems are used to cure bronchitis and seeds are utilized in liver-spleen disorders. Side effects associated with *A. graveolens* are allergies and dermatitis [11].

3.1.2. *Hypericum perforatum* L.

St. John's Wort is a perennial herb with unique yellow flowers that grows natively throughout North America, Europe, Asia, Russia, India, and China. It is well-known to have anti-depressant properties. Recent studies suggest that this herb can treat a variety of other ailments from mild cuts and burns to serious cancer and other inflammatory disorders. It has anti-bacterial and anti-viral potential against disease causing micro-organisms showcasing the broad-spectrum efficacy. Photosensitivity, elevated serotonin levels, anxiety, insomnia, headaches, dry mouth, dizziness, gastrointestinal problems, and sexual dysfunction are among the frequent side effects [12, 13].

3.1.3. *Moringa oleifera* Lam.

Moringa oleifera Lam. is native to Africa and Asia. It is commonly known as the drumstick tree and is grown all over the world for both nutritional and therapeutic purposes. It has been utilised for many years in both conventional and alternative medical practices [14]. Moringa is well known for its ability to strengthen immunity and good health. There are no reported adverse effects to appear from its use. Different dosage forms of *Moringa oleifera* are available globally. Scientific literature reveales the strong anti-bacterial activities of phytochemical constituents present in the plant [15].

3.1.4. *Thymus vulgaris* L.

Thymus vulgaris L. is an evergreen perennial herb indigenous to southwestern Europe and southeastern Italy. It belongs to the *Lamiaceae* family of angiosperm plants having about 400 different species of aromatic herbs. The volatile oils present in the plant include thymol, carvacrol, p-cymene, γ-terpinene, and linalool. Taking excessive amounts of thyme, particularly in the form of thyme oil, could result in headaches, dizziness, upset stomachs, and contact dermatitis [16].

3.1.5. *Zingiber officinale* Roscoe.

Zingiber officinale (ginger) is a member of the *Zingiberaceae* family and indigenous to Southeast Asia. Ginger is rich in active compounds like α-Zingiberene, (E,E)-α-farnesene, geranial, β-sesquiphellandrene, and ar-curcumene [17]. Adverse consequences may be observed upon excessive intake of ginger rhizome in form of burping, diarrhea, heartburn, and generalized stomach discomfort [18].

3.1.6. *Azadirachta indica* L.

Azadirachta indica Linn. (neem) belongs to *Meliaceae* family. It is native to Indian sub-continent, tropical and subtropical regions. It is distinguished by its significant anti-microbial attributes due to presence of phytochemicals like steroids, tannins, alkaloids, triterpenes, flavonoids, and anthraquinone glycosides [19]. It has been widely used in traditional systems of medicine worldwide for the treatment and prevention of various diseases. Adverse effects related to the use of *Azadirachta indica* include vomiting, diarrhea, drowsiness, seizures, loss of consciousness, coma, and death [20].

3.1.7. *Allium sativum* L.

Garlic (*Allium sativum* L.) is a bulbous plant native to Central Asia. It has a pungent smell due to its high sulfur content. This perennial plant is used to treat various diseases, particularly bacterial infections. The side effects associated with garlic includes bad breath, heartburn, gas, and diarrhea [21].

3.1.8. *Curcuma longa* L.

Curcuma longa Linn. (turmeric), belongs to a family *Zingiberaceae*. It is native to Asian countries [22]. It possesses anti-inflammatory, anti-oxidant, and anti-microbial properties. Stomach upset, nausea, dizziness, and diarrhea are some of the adverse effects associated with turmeric [23].

3.1.9. *Hibiscus sabdariffa* L.

Hibiscus sabdariffa L. *(*a perennial plant) grows all over the world as it is easy to grow. The plant is well known for its scarlet flowers and calyces as it is the main source of medicinal compounds. Organic acids, phenolic acids, flavonoids, anthocyanins, and dietary fiber are linked to the therapeutic efficacy of *H. sabdariffa*. It is considered safe if taken according to prescription. Adverse effect associated with irrational use of *H. sabdariffa* includes spermatogenesis, kidney and liver function disturbances [24].

3.1.10. *Tanacetum parthenium* L.

Tanacetum parthenium (Feverfew) is herbaceous plant that belongs to the *Asteraceae* family. Native to South-eastern Europe, central Asia, and west Himalayas, feverfew is recognized for its distinctive yellow and white daisy-like flowers and aromatic leaves. Traditionally, it has been utilized for its medicinal properties, particularly in the management of migraines and other health conditions. Side effects are nausea, digestive problems, and bloating [25, 26].

3.1.11. *Apocynum cannabinum* L.

Apocynum cannabinum (Indian hemp) is a perennial herbaceous plant native to North America. It belongs to the *Apocynaceae* family. Indian hemp is characterized by slender stems, opposite leaves, and clusters of small, bell-shaped flowers. Despite its toxicity, some traditional herbal medicine practitioners have explored its narrow spectrum medicinal properties, to be given only on prescription. This herb is considered to have a significant toxicity profile. It is unsafe to take by mouth and can cause irritation in the throat, stomach, and intestines. It may also cause bradycardia and hypertension [27, 28].

3.1.12. *Echinacea purpurea* L.

Echinacea purpurea (purple coneflower) is a perennial plant native to North America. It is recognized both for its ornamental beauty and traditional medicinal uses. This flowering plant has a distinctive appearance with pink to purple daisy-like flowers featuring a cone-shaped central disc. The side effects include stomach pain, constipation, diarrhea, heartburn, vomiting, and rash [29-31].

3.1.13. *Rosemarinus officinalis* L.

Rosemarinus officinalis (Rosemary) is an evergreen, aromatic shrub with height up to two meters long. This perennial shrub is indigenous to Europe, Africa, Western Asia, and in the Mediterranean. Rosemary essential oil is commonly utilized in aromatherapy for relieving headache and tension, boost mental activity, reduce stress levels, and support respiratory health [32, 33]. Side effects associated with higher doses or if consumed in essential oil form include dermatitis, infertility, and miscarriage (rare), vomiting, coma, spasm, pulmonary edema. Toxicity is not known but liver and kidney damage (rare) are reported [34].

3.1.14. *Humulus lupulus* L.

Humulus lupulus (*Cannabaceae*) is known predominantly to be a raw material with substantial health-promoting qualities. It is native to Europe and Western Asia. It is primarily used to relieve anxiety [35]. Hops have been used in cosmetic and pharmaceutical industries, especially for their antimicrobial and antiviral effect. Side effects were only observed when taken in concentrated form. Sleepiness and slow breathing are two common side effects [36].

3.1.15. *Pistacia lentiscus* L.

P. lentiscus L. (*Anacardiaceae*) is indigenous to Mediterranean coastal region. It serves as an antioxidant, antifungal, antibacterial, and anti-inflammatory agent. It contains resins as chemical constituents. They are translucent, white or pale-yellow, turning more yellowish and opaquer on aging. The resin is effective in treating gastric ulcers, especially *H. pylori*. It primarily contains volatile oils particularly α-pinene and myrcene, mastic oil, triterpenoids, phytosterols, polyphenols. High consumption of *P. lentiscus* can cause allergic contact dermatitis headache, upset stomach, and dizziness [37, 38].

3.1.16. *Agrimonia pilosa* Ledeb.

Agrimonia pilosa (*Rosaceae*) is indigenous to Eastern Europe, Northern Asia and Indochina. It is used to treat diarrhoea, stomach ulcers, gastritis, and other illnesses. *A. pilosa* Ledeb. contains flavonoids, triterpenoids, and isocoumarin. The pharmacological effects of *A. pilosa* include anti-oxidant, anti-bacterial, anti-cancer, anti-inflammatory, and anti-tumour activity. Beyond many benefits with optimum safety window, stomach irritation and liver damage are the potential adverse effects [39, 40].

3.1.17. *Aniba rosaeodora* Ducke.

Aniba rosaeodora (*Lauraceae*) is native to Amazon and Guyana. It has yellow-brown bark, reaches a height of 30 metres. Rosewood oil is a colourless to pale yellow liquid with a woody floral scent. Its primary ingredient is the monoterpene alcohol, linalool. Although only the trunk wood is collected, the entire aromatic tree is used. Various species of the plant has been utilized for ornamental and decorative purposes, but on the other hand this medical plant is effectively used to manage epileptic episodes as well. Adverse effects are not reported except allergy [41].

3.2.8. *Commiphora myrrha* Nees

Commiphora myrrha (*Burseraceae*) contains oleo gum resins. *C. myrrha* Nees represents a genus comprised of approximately 150 trees and shrub species found mostly in Africa, India, Yemen, and the southern zones of Saudi Arabia [42]. The oleo gum resins are the best sources of the fragrance. It has strong analgesic action and is extensively used in the treatment of wounds, management of pain, inflammation of the joints, parasitic infections, obesity, and gastro-intestinal diseases. Skin rash, diarrhea, kidney problem, heart rate fluctuation, blood sugar imbalance are some documented adverse effects [42].

3.2.9. *Cichorium intybus* L.

Cichorium intybus L. (Chicory), a perennial herb of the *Asteraceae* family within the *Cichorium* genus, is cultivated worldwide. Chicory is used as a raw material for inulin-commercially utilized as a powerful prebiotic. It has some mild side effects like abdominal pain, flatulence, bloating and other digestive problem [43].

3.3.0. *Momordica charantia* L.

Momordica charantia L. (bitter melon) is native to tropical and subtropical regions, notably in Asia, India, China, and Brazil. It holds traditional significance as a medicinal plant. Scientific investigations have unveiled a broad array of biologically active compounds supporting its therapeutic efficacy. The diverse applications of *Momordica charantia* make it principal in both traditional medicinal practices and contemporary scientific exploration. Hypoglycemia, fatigue, black stool, fever are the associated adverse effects [44].

3.3.1. *Eruca vesicaria* subsp. sativa Mill.

Eruca vesicaria sativa (Arugula) is an annual herb in the *Brassicaceae* family. It is native to North Africa and the Middle East and southern Europe. The young leaves are rich in calcium, iron, and vitamins A, C, and K. The side effects include contact urticaria and anaphylactic shock [45].

3.3.2. *Andrographis paniculata* Burm. F.

Andrographis paniculata (Green chirata) is a medicinal plant renowned for its therapeutic properties. It is native to south Asia and is conventionally used in various traditional medicine systems, including ayurveda and chinese, for its potential health benefits. Green chirata is recognized for its purported immuno-stimulant, anti-inflammatory, anti-bacterial, and hepato-protective properties. Side effects with the prolonged, unprescribed use of this medicinal plant are disorders affecting the gastrointestinal system, issues related to the skin and subcutaneous tissue, and instances of anaphylaxis [46].

4. Discussion

4.1. Development and anti-microbial potential of herbal nanoparticles

The field of herbal nanoparticles has also advanced significantly, enhancing the medicinal effects of plant extracts. Combining plant extracts with metals such as silver, gold, copper, and copper oxide boosts therapeutic efficacy. Sustainable green synthesis methods for these nanoparticles improve their bioavailability and stability therefore offering a promising alternative to traditional herbal remedies [47, 48]. Neupane *et al.* [49] performed an eco-friendly synthesis of *Moringa oleifera* nanoparticles (MONPs), which showed significant antibacterial activity against Gram-negative but even more higher effectiveness towards Gram-positive bacteria as compared to amoxicillin standard compound. Docking studies further unfolded that most compounds had better binding with 1jij, while luteolin had similar binding to standard ligand 1kzn. The study also confirmed that silver nanoparticles of *Moringa oleifera* containing flavonoids and polyphenols strongly inhibit DNA gyrase and tyrosyl-tRNA synthetase.

Abdellah and co-workers documented the antibacterial activity of curcumin from *Curcuma longa*. The biocompatible silver nanoparticles of curcuma have been found to improve both their effectiveness and stability many folds [50]. Another study conducted by Fierascu *et al.* [51] explored the effects of *Echinacea purpurea* extracts, obtained through traditional and microwave-assisted methods. The antibacterial properties of these newly synthesized silver nanoparticles were found effective against *Candida albicans* and *Escherichia coli*.

4.2. *In-silico* prediction of the anti-microbial activities of plant-derived compounds

Computational studies and molecular docking are crucial for understanding how plant-derived compounds interact with biological targets to reveal their therapeutic potential. These techniques help to clarify the mechanisms through which complex plant drugs affect protein interactions and biological processes, often overcoming bacterial resistance more effectively than synthetic drugs. They play a vital role in drug discovery by elucidating pharmacokinetics, pharmacodynamics, optimizing drug effects, and predicting interactions and toxicities. Sarwar *et al.* very recently explored the potential of cinnamon compounds targeting virulent proteins of *Helicobacter pylori* (virB4, virB8, and virB9). The molecular docking studies identified cinnamyl acetate and benzyl benzoate as promising inhibitors for *H. pylori* [52]. Likewise, it has been have reported that an ethanolic extract of *Hypericum perforatum* demonstrated superior anti-microbial activity against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* compared to many antibiotics. In another investigation, 6-gingerol extracted from *Zingiber officinale* was evaluated for its antibacterial properties by computational docking [53]. It was revealed that 6-gingerol strongly binds to the target and inhibits quorum sensing (QS) receptors, signifying its potential as an anti-virulent agent in combination with traditional antibiotics for severe infections. Lahiri *et al.* also studied the effects of a *Curcuma longa* (turmeric) extract mixture-curcumin-I and erythromycin on biofilm-forming *Staphylococcus aureus* and *Pseudomonas aeruginosa* [54]. It was found that mixtures of phyto-compounds were more effective than single compounds due to synergistic effects. Turmeric extract proved to be a cost-effective alternative to commercial curcumin-I for treating biofilm-forming bacterial infections. Seddoqi and co-researcher identified 19 compounds in *Pistacia lentiscus* L. leaf extract, with catechin gallate and epigallocatechin gallate as major active components. The extract showed high levels of polyphenols and flavonoids that are held responsible for the potent antioxidant and promising antibacterial activity against both Gram-positive and Gram-negative bacteria [55].

4.3. Current & future prospects of medicinal plants

Past investigations discovered the presence of essential oils, flavonoids, alkaloids, tannins, resins and glycosides constituents in different herbs. In the present study, the structures of the chemical constituents of the studied plants having anti-microbial activity are shown in Fig. 2.

The inclination in the utilization of herbs and medicinal plants is fundamentally owed to the treatment failures using conventional medicines probably due to anti-microbial resistance. This is observed critically in infectious diseases due to escalating issue of anti-microbial resistance. Infections that were once treatable with antibiotics have become untreatable or more difficult to manage, leading to extended hospital stays, higher health-care costs, and elevated mortality rates. There are many reasons for the failure of the synthetic anti-microbial agents as even the broad-spectrum antibiotics are losing their strong killing properties, subsequently hanging at the edge of effectiveness. Various mechanisms are known to revert the inhibitory effect of these potent drugs. Microorganisms have undergone some adaptations, like efflux pump for propelling out the intracellular drug or modify porin channels which help in drug penetration, consequential in reduced accumulation or impermeability of antibiotics. Another significant way is to produce specific enzymes responsible for destruction of antimicrobial agent rendering them ineffective. Production of beta lactamase and carbapenems are grave threats for many potent drugs: penicillin derivatives, amoxicillin, ampicillin, piperacillin, cephalosporins, doripenam, imipenam, meropenam, ertapenam etc. The therapeutic response, however, may be restored by combining β-lactam antibiotics with β-lactamase enzyme inhibitors such as clavulanic acid, sulbactam and tazobactam. Other resistance procedures may include the target site modification and mutations (RNA polymerase and DNA gyrase) causing alteration of binding affinity and ultimately making them inert against the administered chemicals, mainly rifamycins and quinolones. Susceptible populations include elderly, infants, and compromised immune systems individuals. Many modern and synthetic chemicals have their roots in the old medicinal plants which have been utilized for ages in a variety of civilizations for their healing abilities. Medicinal plants are a rich source of bio-active constituents, particularly secondary metabolites like flavonoids, phenols, terpenoids, and alkaloids, showing potential activity against infectious pathogens. Fig. 3 represents the common chemical constituents present in majority of medicinal plants with possible mechanism of anti-microbial action [56-58]

Natural anti-microbial agents are not as commonly and frequently used as the synthetic anti-microbial moieties, therefore the resistance against the phytochemicals is found to be negligible. Microorganisms are becoming adapted to routine antibiotics owing to extensive exposure and obviously exert resistance through structural modification and environmental adaptations. Thus, natural anti-microbial compounds offer promising alternatives or adjuncts to conventional antibiotics. Additionally, the adverse effects related to the antibiotics are much higher than the herbal medicines accompanied with higher clinical safety. Nowadays, the efficacy, safety, and mechanisms of action are subjects of ongoing research, aiming to harness their therapeutic potential while addressing the global challenge of anti-microbial resistance. Integrating these natural agents into healthcare practices requires careful evaluation and standardization to ensure consistent utilization in clinical settings. Despite the promising potential of herbal medicines, further scientific evidence through rigorous clinical trials and molecular investigations is necessary to determine their safety, efficacy, and potential to complement or enhance existing antibiotic therapies in the fight against resistant infections to validate the traditional claims. It is substantial to understand the need for the policy and regulatory framework to fully support the careful and authentic utilization of medicinal plants in the modern epoch. Integration of the latest findings with the traditional information is deemed to be necessary in order to cope with the evolving issues of anti-microbial resistance, the need for novel therapeutic agents, and the possibilities of natural therapies [59-61].

The pharmacognostic details of the reviewed medicinal plants having anti-microbial potential are provided in Table 1.

These phytochemical ingredients exhibited good to excellent anti-microbial activity against Gram-positive and Gram-negative bacteria and fungi as shown in Table 2.

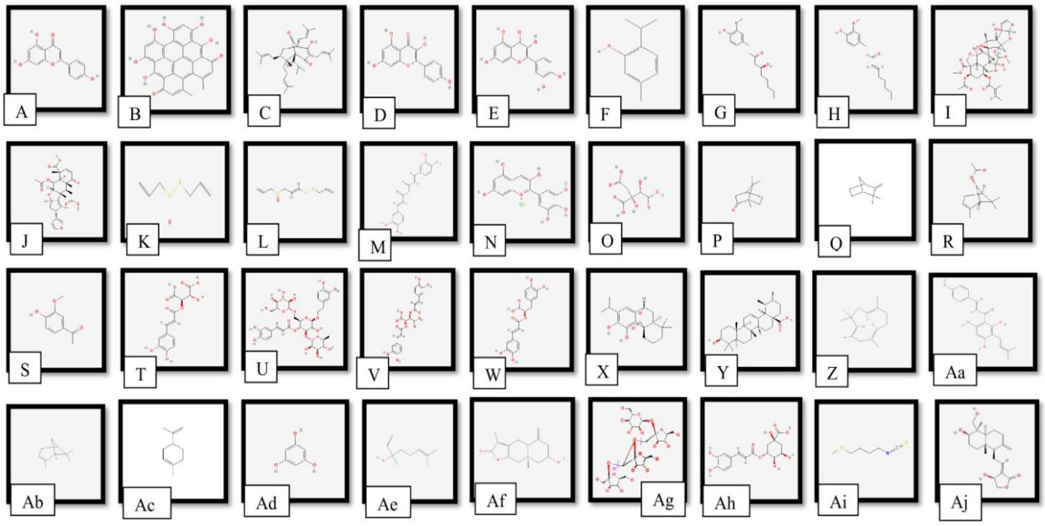

Fig.2. Phytochemical constituents structures responsible for anti-microbial activity: A - apigenin, B - hypericin, C - hyperforin, D - kaempferol, E - quercetin, F - thymol, G - gingerol, H - hoagols, I - azadirachtin, J - nimbin, K - allicin, L - ajoene, M - curcumin, N - delphinidin, O - hibiscus acid, P - camphor, Q - camphene, R - trans-chrysanthenyl acetate, S - apocynin, T - caftaric acid, U - echinacoside, V - chicoric acid, W - rosemarinic acid, X - carnosol, Y - ursolic acid, Z - humulene, Aa - xanthohumol, Ab - alpha pinene, Ac - limonene, Ad - phloroglucinol, Ae - linalool, Af - commiferin, Ag - inulin, Ah - chlorogenic acid, Ai - erucin, Aj – andrographolide..

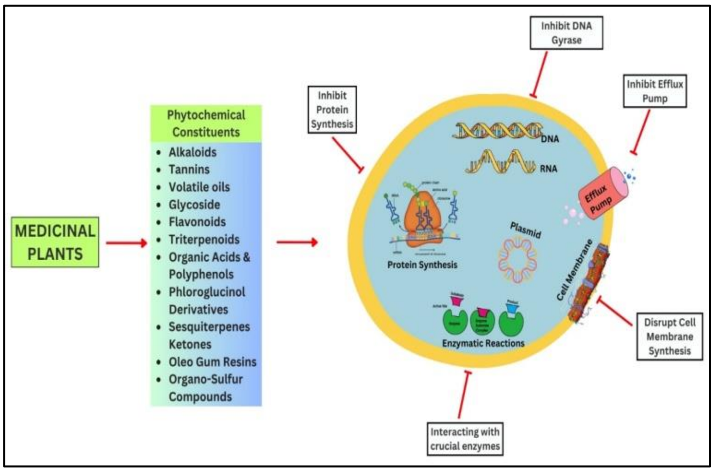

Fig. 3. Medicinal plants containing phytoconstituents including alkaloids, tannins, volatile oils, glycosides, flavonoids, triterpenoids, organic acids, polyphenols, phloroglucinol derivatives, sesquiterpenes ketones, oleo gum resins, organo-sulfur compounds with possible mechanisms of anti-microbial action including inhibition of protein synthesis, DNA gyrase, efflux pump, cell membrane synthesis and interaction with crucial enzymes.

Table 1. Pharmacognostic details of selected medicinal plants with anti-microbial activity.

S. No	Scientific name	Common name	Family	Part used	Pharmacological effects	Indications	Dosage form	Dose	Ref.
1	*Apium graveolens Linn.*	Celery/ smallage, Ajmoda, ajwain	Apiacaeae/ Umbiliferaceae	Leaf stalk, seeds, roots	Anti-cancer, anti-obesity, anti-hepatotoxic, anti-hypertensive, anti-oxidant, anti-microbial, anti-inflammatory.	Bone defects, gout, arthritis, ulcers, urinary tract infections (UTI), hypertension, flatulence, headache, malnutrition, bronchitis, hyperglycemia and hyperlipidemia, cancers	Fresh herb and seed powder	1-1.5 g of celery seed powder or extracts.	[62-66]
2	*Hypericum perforatum Linn.*	St.John Wort/Klamath weed, Tipton weed, goat weed, Enola weed/ chase-devil / Rosin-rose	Hypericaceae/ Clusiaceae/ Guttiferae	Flower, leaves, stem	Anti-depressant (by inhibition of monoamine oxidases), anti-bacterial, anti-viral, anti-inflammatory, anti-oxidant, and neuroprotective	*Insomnia, depression, somatic symptom disorder, generalized anxiety disorders, obsessive-compulsive disorder, and other diseases*	Hypericin standardized extract (0.3 %, 0.2 %) Hyperforin standardized extract (5 %) Crude extracts	300 mg capsules/extract with 0.3 % hypericin content taken 3 times per day with meals 250 mg extract with 0.2 % hypericin content taken 2 times daily. 300 mg capsules with 5 % hyperforin content taken 3 times daily Crude: 2-4 g orally every day to once in three days	[67-72]
3	*Moringa oleifera*	Moringa/Drums tick tree/Suhanjana	Moringaceae	Leaves, pods/ fruits	Hepato-protective, cardio-protective, anti-bacterial, anti-carcinogenic, anti-inflammatory, and anti-oxidant	Depression, Attention deficit hyperactivity disorder (ADHD), obsessive-compulsive disorder, premenstrual syndrome, psoriasis	Leaves Powder, extracts, seeds, pods	6-10 g of leaf powder	[14, 15, 73-76].
4	*Thymus vulgaris linn*	Thyme	Lamiaceae (Labiate)	Flowers, leaves	Anti-oxidant, anti-inflammatory, anti-cancer, and anti-microbial.	Cough, patchy hair loss (alopeciaareata), dementia.	Capsules, drops, tablets		[16].
5	*Zingiber officinale Roscoe*	Ginger, adrak, sonth	Zingiberaceae	Rhizome	Anti-convulsant, analgesic, anti-inflammatory, anti-ulcer, immunomodulatory	Throat infections, inflammation, asthma, dyspepsia, constipation, loss of appetite, palpitation, indigestion constipation, arthritis, colds, nausea, migraines, hypertension	Capsules, tablets, powder 0.5-3 g by mouth daily		[17, 18, 77].
6	*Azadirachta indica Linn*	Neem, margosa, Indian lilac, Limbo, Nim, Nimba, Medusa and Vempu	Meliaceae	Leaves, flowers, seeds, fruits, roots, and bark	Hypolipidemic, anti-fertility, microbicidal, anti-diabetic, anti-inflammatory, hepatoprotective, anti-pyretic, hypoglycemic, insecticidal, nematocidal, anti-ulcer, anti-oxidant, neuroprotective, cardio-protective, and anti-leishmaniasis	Headache, pyrexia, ulcer, respiratory disorders, diabetes, cancer, leprosy, dengue, malaria, chickenpox, and dermal complications	Powder, capsule, tablet		[78, 79]

7	*Allium sativum linn.*	Garlic, rason	Liliaceae	Leaves, flowers, and cloves	Anti-bacterial, anti-fungal, anti-viral, anti-parasitic, hypotensive for intraocular pressure, hypotensive, anti-atherosclerotic, anti-thrombotic or anti-aggregatory, hypolipidemic, hypoglycemic, immune-modulator, anti-cancer, anti-diabetic, anti-inflammatory, neuroprotective	Infections, cardiovascular diseases, diabetes, high cholesterol, hypertension	Oil, powder, tablet, capsule		[21, 80]
8	*Curcuma longa Linn*	Turmeric, haldi, amba haldi, kurkum	Zingiberaceae	Rhizome	Anti-inflammatory, anti-oxidant, anti-neoplastic, anti-coagulant, anti-diabetic, cardio-protective, anti-ulcer, hypotensive, neuro-protective, anti-venin, hypo-cholesterolemic, and anti-viral	Fever, gastritis, dysentery, infections, chest congestion, cough, hyper-cholesterolemia, hypertension, rheumatoid arthritis, jaundice, liver and gallbladder problems, urinary tract infections, skin diseases, diabetic wounds, and menstrual discomfort	Tablets, capsule		[22, 23, 81]
9	*Hibiscus sabdariffa L.*	Roselle, red sorrel	Malvaceae	Calyces, seeds, oils, stems, and flowers	Anti-oxidant, anti-hypertensive, anti-diabetic, hepatoprotective, nephron-protective, anti-lipidemic, anti-microbial, anti-cancer, anti-parasitic, anti-obesity, diuretic, immunomodulatory	Hypertension, pulmonary hypertension, atherosclerosis, high cholesterol	Tea, extracts, powder	TEA: up to 720 mL daily for up to 6 weeks	[82-85]
10	*Tanacetum parthenium* L .	Feverfew	Asteraceae	Leaf, seed (oil)	Anti-microbial, anti-rheumatic, anti-inflammatory	Inflammation, women's ailments, migraine, headache, psoriasis, toothache, insect bites, asthma rheumatism, and stomach-ache		Extract 50-100 mg PO daily Fresh leaf 2.5 leaves PO daily Freeze-dried leaf 50-150 mg PO qD-BID	[25]
11	*Apocynumca nnabinum L.*	Indian hemp, dogbane	Apocynacea		Anti-inflammatory, anti-oxidant	Diabetes, arthritis, asthma, bowel disease, ulcer, heart related diseases, and atherosclerosis	Tincture		[27]
12	*Echinacea purpurea L*	Purple cauliflower	Asteraceae	Leaf, flower	Anti-inflammatory, anti-bacterial, anti-oxidant and lymphocyte activities	Typhoid fever, respiratory infections, prevents development of benign prostate hyperplasia	Capsule		[29, 31]

13	*Rosemarinus officinalis L. / Salvia officinalis L.*	Rosemary/dew of the sea	lamiaceae or labiatae	Leaves, flower, stems, roots	Anti-viral, anti-bacterial, anti-fungal, anti-tumor, hepato-protective anti-oxidant, anti-rheumatic, anti-nocioceptive and anti-thrombotic	Neuropathic pain, headache, depression, anxiety, inflammation, dysmennorrhoea, muscle spasms, hyperglycemia and hypercholesterolemia, acne vulgaris, alopecia areata (stimulates circulation to hair follicles), dandruff and greasy hair	Leaf powder/essential oils/mother tinctures in homeopathic medicine	Powder: 1-2 g/day as tea: 1-3 cups/d (steep 1-2g in 150 mL water) Extract: 2-4 mL PO TID (1:1 in 45% alcohol) Essential Oil: doses up to 0.1-1 mL (6-10% essential oil), massage scalp for 2 minutes.	[32, 33, 86, 87]
14	*Humulus lupulus Linn.*	Hops	Cannabaceae	dried, flowering parts	Anti-inflammatory effects, anti-microbial, anti-oxidant, anti-proliferative, glucose metabolism and hormonal effects regulating, lipid effects and sedative/hypnotic effects.	Leprosy, bad smell of feet, liver diseases, constipation, sleeping disorders and for purification of blood	Capsules, powder	1-2 g	[35, 36, 88]
15	*Pistacia lentiscus* Linn.	Chios mastic gum	Anacardiaceae	Resin	Anti-microbial, anti-oxidant, anti-inflammatory, hypolipidemic, and anti-cancer	Dental caries, cardiovascular disease, systemic inflammatory disorders, cancer, inflammatory bowel diseases	Capsule, powder		[38, 89]
16	*Agrimonia pilosa Ledeb.*	Rosacea	Rosacea	Leaves, seeds, flower	Anti-inflammatory, anti-diabetic, anti-tumor, anti-acetylcholinesterase, anti-oxidant, anti-bacterial, and anti-parasitic	Gastritis, gastric ulcer, diarrhea, lung inflammation, liver diseases cholecystitis, cholestasis, intestinal or bladder atony, pyelonephritis, bleeding disorders, skin defects, inflammatory conditions of the oral mucosa, tumors, trichomoniasis, vaginitis, diarrhea, and dysentery.	Capsules	1.5 – 4 g of the drug to be drunk twice or three times a day	[39, 40, 90]
17	*Aniba Rosaeodora ducke*	Rosewood	Lauraceae	Bark, leaves	Anti-bacterial, anti-fungal, anti-protozoal, anti-oxidant, trypanocidal, sedative, anxiolytic, and anti-convulsant	Bacterial infections, fungal infections, epilepsy, anxiety,	Oil		[41, 91]
18	*Commiphora myrrha*	Myrrh	Burseraceae	Resin	Expectorant, emmenagogue, carminative, anthelmintic, astringent, antiseptic, anti-microbial, anti-inflammatory, anti-oxidant, analgesic, neuroprotective, anti-diabetic, anti-cancer, and anti-parasitic	Inflammatory illnesses (sinusitis, pharyngitis, gingivitis, and pyorrhea), wounds, mouth ulcers, pains, fractures, stomach problems, and microbiological infections	Capsule	600-1200 mg daily	[42, 92, 93]

19	*Cichorium intybus. L*	Chicory/ coffee weed / blue sailor	Asteraceae	Roots, leaves	Anti-oxidant, hepato-protective, anti-inflammatory, anti-diabetic, anti-microbial, and tumor-inhibitory	Tumor, Inflammation	Capsule		[94, 95]
20	*Momordica charantia L*	Bitter Melon	Cucurbitaceous	Leaves,seeds	Anti-microbial, anti-oxidant, nutraceutical, and anti-inflammatory	Gastric ulcers and conditions like rheumatism, cancer	Tablet	50-100 mL qD OR 900 mg of fruit TID	[96]
21	*Eruca vesicaria sativa*	Arugula/ salad rocket	Brassicaceae	seeds, leaves	Anti-microbial, anti-oxidant, anti-proliferative, anti-emetic, and anti-ulcer	Cancer, cardio-vascular diseases, testicular dysfunction, diabetes mellitus, nephroprotective	Capsules	400 mcg/day	[97, 98]
22	*Andrographis peniculata*	Green chiretta/ king of bitter	Acanthaceae	Leaves, seeds	Anti-inflammatory, hepatoprotective, hypotensive and hypoglycemic, anti-bacterial	Urine regulation, for reducing heat and fever, inflammation	Tablet		[99-100]

Table 2. Anti-microbial spectrum of the underlying medicinal plants.

S. No.	Medıcınal herb	Antı-mıcrobıal constıtuent	Antı-mıcrobıal spectrum	Ref.
1	*Apium graveolens* Linn.	Volatile oils, flavone glycosides (apigenin)	*Bacillus aerogenes, B. coagulans, B. megatarium, B. subtilis, Lactobacillus lichmani, Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli,Kleibsellapheumoniae, Pseudomonas aeruginosa, Salmonella typhi, Shigella, Aspergillus niger, A. flavus, Candida albicans, Cryptococcus neoformans, Trichophyton rubrum*	[64, 67, 101]
2	*Hypericum perforatum* Linn.	Essential oils, hypericin, hyperforin	*Penicillium expansum, Penicillium citrinum, Penicillium crustosum, S. aureus ATCC, S. epidermidis ATCC 12228.*	[103-104]
3	*Moringa oleifera* Linn.	Alkaloids, tannins, flavonoids (quercetin and kaempferol), saponins, and triterpenoids	*Corynebacterium pseudotuberculosis, Corynebacteriumulcerans,Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Citrobacter spp., Pseudomonas vulgaris, and Pseudomonas aeruginosa, leishmania donovani, Haemonchuscontortus.*	[76, 105]
4	*Thymus vulgaris* Linn.	Volatile oils (thymol, P-cymene, γ- terpinene, linalool)	*Klebsiella pneumoniae, Pseudomonas aeruginosa and Staphylococcus saprophyticus*	[106]
5	*Zingiber officinale* Roscoe.	Phenolic compounds, primarily gingerols and shogaols	*Pseudomonas aruginosa, Escherichia coli, Staphylococcus aureus, Vibrio cholerae, Klebsiella spp. and Salmonella spp*	[17, 78]
6	*Azadirachta indica* Linn.	Alkaloids, flavonoid glycosides, phenolic compounds, steroids, triterpenoids, carotenoids, and tetra-triterpenoids azadirachtin and nimbin	*Staphylococcus aureus, Pseudomonas aeruginosa,E-coli,*	[78,79, 107]
7	*Allium sativum* Linn.	Allicin, ajoene, and allyl sulphides	*Bacillus cereus, Escherichia coli, Enterobacter cloacae, Klebsiella pneumoniae, Micrococcus flavus, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi, Salmonella typhimurium, and Staphylococcus aureus*	[108-111]
8	*Curcuma longa* Linn.	Curcumin	*Gram-positive and Gram-negative bacterial strains: Staphylococcus aureus and Escherichia coli, Helicobacter pylori, Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus mutants,Enterococcus faecalis, Salmonella typhimurium, Bacillus subtilis, Bacillus cereus, Bacillus coagulans and Mycobacterium tuberculosis, Candida species*	[22, 112-114]
9	*Hibiscus sabdariffa* Linn.	Alkaloids, tannin, phenols, glycosides, terpenoids, saponins, coumarins, anthocyanins (delphinidin-3-	*Staphylococcus aureus ATCC 25923, Staphylococcus epidermidis ATCC 49461, and Bacillus cereus ATCC 10876, Escherichia coli ATCC 25922, Salmonella enteric ATCC 5174, Klebsiella pneumonia ATCC 27736, Proteus vulgaris ATCC*	[24, 85, 86]

		sambubioside and cyanidin-3-sambubioside), hibiscus acid, volatile oils	*49132, and Pseudomonas aeruginosa ATCC 27853;Streptococcus mutans, Staphylococcus aureus and Enterococcus faecalis; E. coli, Salmonella typhimurium, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Vibrio cholerae*	
10	*Tanacetum parthenium* Linn.	Essential oils, camphor, chrysanthenyl acetate, camphene,chrysanthenone, borneol, and bornyl acetate	*Gram-positive and Gram-negative bacteria, fungi*	[26]
11	*Apocynum cannabinum* Linn.	Apocynin oxime ester of undecanoic acid, fatty acid	*S. aureus MTCC 96, K. Planticola MTCC 530, Micrococcus luteus MTCC 2470, Staphylococcus aureus MLS-16 MTCC 2940, Escherichia coli MTCC 739, Bacillus subtilis MTCC 121, Klebsiella planticola MTCC 530, Pseudomonas aeruginosa MTCC 2453, Candida albicans MTCC 3017, C. albicans MTCC 3958, C. albicans MTCC 227* and *I. hanoiensis MTCC 4755, C. albicans MTCC 854, C. albicans MTCC 183, C. albicans MTCC 3018, C. albicans MTCC 1637, C. Glabrata MTCC 3019, C. krusei MTCC 3020*	[27, 28]
12	*Echinacea purpurea* Linn.	Flavonoids, polyphenolic compounds, caftaric acid, echinacoside, and chicoric acid	*E. coli, P. aeruginosa, S. aureus, B. cereus, B. amyloliquefaciens, L. monocytogenes, S. enteritis, E. faecalis, P. aeruginosa, C. albicans, S. cerevisiae*, and *Penicillium sp., Asp. niger ATCC 1015, Asp. flavus, Rhizopus sp., F. moniliforme ATCC 38932*, and *Mucor sp., C. albicans NBIMCC 74* and *S. cerevisiae*	[29]
13	*Rosemarinus officinalis* Linn.	Essential oil, ursolic acid, rosmarinic acid, rosmaridiphenol, carnosol, epirosmanol, carnosic acid, rosmanol, isorosmanol,	*P.aeruginosa and E. coli, Bacillus cereus, Bacillus subtilis and S. aureus, Aspergillus flavus, Candida albicans, C. krusei, C. glabrata, C. parapsilosis, C. tropicalis C. dubliniensis, C. lipolytica*	[34, 115-117]
14	*Humulus lupulus* Linn.	sesquiterpene ketones (humulene, isohumulone, lupulene, lupulone), xanthohumol, bitter acids	*S. aureus, S. mutans, Penicillium* and *Aspergillus species, Lactobacillus, Streptococcus, Staphylococcus, Micrococcus*, and *Bacillus, Brucella, Helicobacter pylori.*	[35, 36, 118]
15	*Pistacia lentiscus* Linn	Essential oils, terpene & terpenoids (α-pinene, terpinene, caryophyllene, limonene, and myrcene), oils of mastic resin, flavonoids, phenolic acids	*H. pylori, S. aureus, L. plantarum, Pseudomonas spp., S. enteritides, Streptococcus spp., Enterococcus faecalis, Porphyromonasgingivalis, Fusobacterium nucleatum, Actinomyces spp., Tannerella forsythia, Candida albicans* and *C. glabrata, Klebsiella pneumonia* and *Pseudomonas aeruginosa, A. niger* and *A. flavus, B. cereus, L. monocytogens, S. arizona, S. aureus, E. coli, S. typhimurium, K. pneumoniae.*	[37, 38, 119-121]
16	*Agrimonia pilosa* Ledeb.	Flavanoids, phloroglucinol derivatives (agrimol C, agrimol F, agrimol G, and agrimophol)	*Staphylococcus aureus, Bacillus cereus*, and *Gardnerella species*	[39, 90]
17	*Aniba rosaeodora* ducke.	Essential oil (linalool,α-terpinolene, linalool cis-oxide	*Aeromonas caviae, Enterococcus faecalis, Klebsiella pneumonia, Providenciastuartii*	[41].
18	*Commiphora myrrha*	Oleo-gum-resin, furanosesquiterpenes (furano-sesquiterpenoids, 2-methoxyfuranodiene and 2-acetoxyfuranodiene), commiferin	*Staphylococcus aureus, Bacillus cereus, Bacillus subtilis, Escherichia coli, Klebsiella pneumoniae, Fusobacterium nucleatum, Paenibacilluspasadenensis NBRC 161214, Micrococcus yunnanensis YIM 65004, Pseudomonas azotoformans NBRC 12693, Rhodococcusqingshengii, Staphylococcus capitis JCM 2420, Staphylococcus epidermidis NBRC 100911, Deinococcusradiodurans R1*	[122]
19	*Cichorium intybus* Linn.	Inulin, sesquiterpene lactones, chlorogenic acid, organic acids (quinolinic, succinic, oxalic and chiquimic acids), chicoric acid	*S. aureus* and *methicillin-resistant S. aureus, P. aeruginosa*, and *E. coli, Salmonella spp.,Streptococcus mutans, Streptococcus sanguinis, Actinomyces naeslundii, Fusobacterium, nucleatum* and *Prevotella Intermedia, Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus* and *Fusarium solani, B. subtilis, S. sanguinis, A. naeslundii, F. nucleatum* and *P. Intermedia, C. albicans, C. lipolytica, C. krusei* and *F. solani,*	[43, 123]
20	*Momordica charantia* Linn.	Saponins and steroids (triterpenes), triterpenoids, quercetin, flavones	*Klebsiella pneumoniae* and *Proteus mirabilis, Staphylococcus aureus, Staphylococcus epidermidis, Candida albicans, Escherichia coli, Salmonella typhi*	[124] [125]
21	*Eruca vesicaria* sativa	Glucosinolate isothiocyanate, alkaloids, and their derivaties, flavonoid, phenols, tannins, erucin	*Escherichia coli HAS, Staphylococcus aureus HAS, Klebsiella pneumonia, Pseudomonas aeruginosa*	[98, 126]
22	*Andrographis paniculata*	Lactones (andrographolide), diterpenes, flavonoids, quinic acid, xanthones, noriridoids	*Bacillus cereus, Bacillus thuringiensis, Staphylococcus aureus*, and *Enterobacter faecalis, Shigella flagella, Salmonella typhimurium, Klebsiella pneumonia, Escherichia coli, Pseudomonas aeruginosa*, and *Vibrio parahaemolyticus, Aspergillus niger, Trichophyton mentagrophytes, Candida albicans, Candida tropical*	[127, 128]

5. Conclusions

Medicinal plants are effectively being explored for their therapeutic efficacy and safety after the development of resistance against most of the antibiotics. Medicinal plants possess significant activity against bacteria, viruses and fungi. The diverse constituents present in these plants have variable modes of action against pathogens. Rigorous research, scientific testing and validation are required to fully harness the anti-microbial potential, safety and broad-spectrum activity of these plants. Traditional knowledge, scientific data, standardization and quality analysis are the tools instantly required in this modern era not only to unlock the potential of the plants but to curb the ineffectiveness of synthetic antimicrobial agents.

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References

1. Liang, J.; Huang, X.; Ma, G. Antimicrobial activities and mechanisms of extract and components of herbs in East Asia. *RSC Adv.* **2022**, *12*, 29197-29213. DOI: 10.1039/ D2RA02389J
2. Yuan, H.; Ma, Q.; Ye, L.; Piao, G. The traditional medicine and modern medicine from natural products. *Molecules* **2016**, *21(5)*, Art. No: 559. DOI: 10.3390/ molecules21050559
3. Keskin, C. Medicinal plants and their traditional uses. *JAPB* **2018**, *1(2),* 8-12. DOI: 10.14302/issn.2638-4469.japb-18-2423
4. Khumalo, G.P.; Van Wyk, B.E.; Feng, Y.; Cock, I.E. A review of the traditional use of southern African medicinal plants for the treatment of inflammation and inflammatory pain. *J. Ethnopharmacol.* **2022**, *283*, Art. No: 114436. DOI: 10.1016/j.jep.2021.114436
5. Marković, M.S.; Pljevljakušić, D.S.; Matejić, J.S.; Nikolić, B.M.; Zlatković, B.K.; Rakonjac, L.B., et al. Traditional uses of medicinal plants in Pirot District (southeastern Serbia). *Genet. Resour. Crop Evol.* **2024**, *71*, 1201-1220. DOI: 10.1007/s10722-023-01685-7
6. Niazi, P.; Monib, A.W. The role of plants in traditional and modern medicine. *J. Pharmacogn. Phytochem.* **2024**, *13(2)*, 643-647. DOI: 10.22271/phyto.2024 .v13.i2d.14905
7. Morse, S.S. Factors in the Emergence of Infectious Diseases. In *Plagues and Politics: Infectious Disease and International Policy*, 1st ed,; Price-Smith, A., Eds.; Palgrave Macmillan: London, UK, **2001**; pp. 8-26.
8. Janeway, C.; Travers, P.; Walport, M.; Shlomchik, M. Immunobiology: the immune system in health and disease. 5th ed.; Garland Science: New York, USA, **2001**; p. 154.
9. Mostafa, A.A.; Al-Askar, A.A.; Almaary, K.S.; Dawoud, T.M.; Sholkamy, E.N.; Bakri, M.M. Antimicrobial activity of some plant extracts against bacterial strains causing food poisoning diseases. *Saudi J. Biol. Sci.* **2018**, *25*, 361-366. DOI: 10.1016/j.sjbs.2017.02.004
10. Cherrada, N.; Elkhalifa Chemsa, A.; Gheraissa, N.; Zaater, A.; Benamor, B.; Ghania, A., et al. Antidiabetic medicinal plants from the Chenopodiaceae family: A comprehensive overview. *Int. J. Food Prop.* **2024**, *27*, 194-213. DOI: 10.1080/10942912.2023.2301576
11. Mehraj, N.; Alam, M. Karafs (*Apium graveolens* Linn) An in-depth review of its historical context, therapeutic properties, ethno pharmacological applications, and scientific research. *J. Pharmacogn. Phytochem.* **2024**, *13*, 401-405. DOI: 10.22271/phyto.2024.v13.i3e.14981
12. Bagheri, R.; Bohlouli, S.; Maleki Dizaj, S.; Shahi, S.; Memar, M.Y.; Salatin, S. The antimicrobial and anti-biofilm effects of *Hypericum perforatum* oil on common pathogens of periodontitis: an in vitro study. *Clin. Pract.* **2022**, *12*, 1009-1019. DOI: 10.3390/clinpract12060104
13. Wang, L.; Ibi, A.; Chang, C.; Solnier, J. A new UHPLC analytical method for St. John's Wort (*Hypericum perforatum*) extracts. *Separations* **2023**, *10(5)*, Art. No: 280. DOI: 10.3390/separations10050280
14. Rode, S.B.; Dadmal, A.; Salankar, H.V. Nature's gold (*Moringa oleifera*): miracle properties. *Cureus* **2022**, *14*, Art. No: e26640. DOI: 10.7759/cureus.26640
15. Milla, P.G.; Peñalver, R.; Nieto, G. Health benefits of uses and applications of *Moringa oleifera* in bakery products. *Plants* **2021**, *10(2)*, Art. No: 318. DOI: 10.3390/plants10020318
16. Vassiliou, E.; Awoleye, O.; Davis, A.; Mishra, S. Anti-inflammatory and antimicrobial properties of thyme oil and its main constituents. *Int. J. Mol. Sci.* **2023**, *24(8)*, Art. No: 6936. DOI: 10.3390/ijms24086936
17. Aleem, M.; Khan, M.I.; Shakshaz, F.A.; Akbari, N.; Anwar, D. Botany, phytochemistry and antimicrobial activity of ginger (*Zingiber officinale*): A review. *Int. J. Herb Med.* **2020**, *8(6),* 36-49. DOI: 10.22271/flora. 2020.v8.i6a.705
18. Abdalla, W.E.; Abdallah, E.M. Antibacterial activity of ginger (*Zingiber Officinale* Rosc.) rhizome: A mini review. *Int. J. Pharmacogn. Chinese Med.* **2018**, *2(4)*, Art. No: 000142. DOI: 10.23880/ipcm-16000142
19. Yadav, N.; Singh, P.K.; Harijan, D.K.; Nayeem, M.; Kashyap, S.; Kumar, S.N., et al. A comprehensive review on therapeutic potentials of *Matricaria chamomilla* (chamomile) against inflammation-

mediated chronic diseases. *J. Pharma. Insight Res.* **2024**, *2*, 226-235.

20. Alzohairy, M.A. Therapeutics role of *Azadirachta indica* (Neem) and their active constituents in diseases prevention and treatment. *Evid. Based Complement. Alternat. Med.* **2016**, Art. No: 7382506. DOI: 10.1155/2016/7382506

21. Bhatwalkar, S.B.; Mondal, R.; Krishna, S.B.N.; Adam, J.K.; Govender, P.; Anupam, R. Antibacterial properties of organosulfur compounds of garlic (*Allium sativum*). *Front. Microbiol.* **2021**, *12*, Art. No: 613077. DOI: 10.3389/fmicb.2021.613077

22. Kumar, M.; Kaur, P.; Garg, R.; Patil, R.; Patil, H. A study on antibacterial property of curcuma longa-herbal and traditional medicine. *Adesh Univ. J. Med. Sci. Res.* **2020**, *2*, 103-108. DOI: 10.25259/ AUJMSR_11_2020

23. Muhamed, I.A.; Ahmad, W.A.N.W.; Ramli, N.S.; Ghafar, N.A. Antimicrobial and antioxidant property of *Curcuma longa* Linn. *Int. J. Basic Clin. Pharmacol.* **2019**, *8*, 2383–2388. DOI: 10.18203/2319-2003. ijbcp20194772

24. Izquierdo-Vega, J.A.; Arteaga-Badillo, D.A.; Sánchez-Gutiérrez, M.; Morales-González, J.A.; Vargas-Mendoza, N.; Gómez-Aldapa, C.A., et al. Organic acids from roselle (*Hibiscus sabdariffa* L.)—A brief review of its pharmacological effects. *Biomedicines* **2020**, *8(5)*, Art. No: 100. DOI: 10.3390/biomedicines8050100

25. Lechkova, B.; Karcheva-Bahchevanska, D.; Ivanov, K.; Todorova, V.; Benbassat, N.; Penkova, N., et al. A Study of the chemical composition, acute and subacute toxicity of Bulgarian *Tanacetum parthenium* essential oil. *Molecules* **2023**, *28(13)*, Art. No: 4906. DOI: 10.3390/molecules28134906

26. Shafaghat, A.; Ghorban-Dadras, O.; Mohammadhosseini, M.; Akhavan, M.; Shafaghatlonbar, M.; Panahi, A. A comparative study on chemical composition and antimicrobial activity of essential oils from *Tanacetum parthenium* (L.) Schultz. Bip. and *Tanacetum punctatum* (Desr.) Grierson. leaves from Iran. *J. Essent. Oil-Bear. Plants* **2017**, *20(4)*, 1143-1150. DOI: 10.1080/0972060X. 2017.1383859

27. Lou, R.; Rottinghaus, G.; Thomas, A.L.; Monroe, D.; Tran, K.; Smith, R.E. Identification of Unknown Compound in *Apocynum cannabinum* by High Resolution Mass Spectrometry (HRMS) and 600 MHz NMR. *J. Regul. Sci.* **2016**, *4*, 14-19. DOI: 10.21423/JRS-V04N03P014

28. Sammaiah, A.; Kaki, S.S.; Manoj, G.N.S.; Poornachandra, Y.; Kumar, C.G.; Prasad, R. Novel fatty acid esters of apocynin oxime exhibit antimicrobial and antioxidant activities. *Eur. J. Lipid Sci. Technol.* **2015**, *117*, 692-700. DOI: 10.1002/ ejlt.201400471

29. Burlou-Nagy, C.; Bănică, F.; Negrean, R.A.; Jurca, T.; Vicaș, L.G.; Marian, E., et al. Determination of the bioactive compounds from *Echinacea purpurea* (L.) Moench leaves extracts in correlation with the antimicrobial activity and the in vitro wound healing potential. *Molecules* **2023**, *28(15)*, Art. No: 5711. DOI: 10.3390/molecules28155711

30. Petkova, N.; Petrova, A.; Ivanov, I.; Hambarlyiska, I.; Tumbarski, Y.; Dincheva, I., et al. Chemical composition of different extracts from *Echinacea Purpurea* (l.) moench roots and evaluation of their antimicrobial activity. *ChemEngineering* **2023**, *7(5)*, Art. No: 94. DOI: 10.3390/chemengineering7050094

31. Coelho, J.; Barros, L.; Dias, M.I.; Finimundy, T.C.; Amaral, J.S.; Alves, M.J., et al. *Echinacea purpurea* (L.) Moench: chemical characterization and bioactivity of its extracts and fractions. *Pharmaceuticals* **2020**, *13(6)*, Art. No: 125. DOI: 10.3390/ph13060125

32. Rahbardar, M.G.; Hosseinzadeh, H. Therapeutic effects of rosemary (*Rosmarinus officinalis* L.) and its active constituents on nervous system disorders. *Iran J. Basic Med. Sci.* **2020**, *23(9)*, 1100-1112. DOI: 10.22038/ijbms.2020.45269.10541

33. Oualdi, I.; Brahmi, F.; Mokhtari, O.; Abdellaoui, S.; Tahani, A.; Oussaid, A. *Rosmarinus officinalis* from Morocco, Italy and France: Insight into chemical compositions and biological properties. *Mater Today Proc.* **2021**, *45*, 7706-7710. DOI: 10.1016/j.matpr. 2021.03.333

34. da Silva Bomfim, N.; Kohiyama, C.Y.; Nakasugi, L.P.; Nerilo, S.B.; Mossini, S.A.G.; Romoli, J.C.Z., et al. Antifungal and antiaflatoxigenic activity of rosemary essential oil (*Rosmarinus officinalis* L.) against *Asspergillus flavus*. *Food Addit. Contam.: Part A* **2020**, *37(1)*, 153-161. DOI: 10.1080/19440049. 2019.1678771

35. Carbone, K.; Gervasi, F. An updated review of the genus humulus: A valuable source of bioactive compounds for health and disease prevention. *Plants* **2022**, *11(24)*, Art. No: 3434. DOI: 10.3390/ plants11243434

36. Olsovska, J.; Bostikova, V.; Dusek, M.; Jandovska, V.; Bogdanova, K.; Cermak, P., et al. *Humulus lupulus* L.(hops)-a valuable source of compounds with bioactive effects for future therapies. *Military Med. Sci. Lett.* **2016**, *85*, 19-30. DOI: 10.31482/mmsl. 2016.004

37. Gortzi, O.; Rovoli, M.; Katsoulis, K.; Graikou, K.; Karagkini, D.-A.; Stagos, D., et al. Study of stability, cytotoxic and antimicrobial activity of chios mastic gum fractions (neutral, acidic) after encapsulation in liposomes. *Foods* **2022**, *11(3)*, Art. No: 271. DOI: 10.3390/foods11030271

38. Soulaidopoulos, S.; Tsiogka, A.; Chrysohoou, C.; Lazarou, E.; Aznaouridis, K.; Doundoulakis, I., et al. Overview of chios mastic gum (*Pistacia lentiscus*) effects on human health. *Nutrients* **2022**, *14(3)*, Art. No: 590. DOI: 10.3390/nu14030590

39. Paluch, Z.; Biriczova, L.; Pallag, G.; Marques, E.C.; Vargova, N.; Kmoníčková, E. The therapeutic effects of *Agrimonia eupatoria* L. *Physiol. Res.* **2020**, *69(Suppl 4)*, S555-S571. DOI: 10.33549/physiolres. 934641

40. He, L.; Cheng, H.; Chen, F.; Song, S.; Zhang, H.; Sun, W., et al. Oxidative stress-mediated antibacterial activity of the total flavonoid extracted from the *Agrimonia pilosa* ledeb. in methicillin-resistant

Staphylococcus aureus (MRSA). *Vet. Sci.* **2022**, *9(2)*, Art. No: 71. DOI: 10.3390/vetsci9020071

41. Teles, A.M.; Silva-Silva, J.V.; Fernandes, J.M.P.; Calabrese, K.d.S.; Abreu-Silva, A.L.; Marinho, S.C., et al. *Aniba rosaeodora* (Var. amazonica Ducke) essential oil: Chemical composition, antibacterial, antioxidant and antitrypanosomal activity. *Antibiotics* **2020**, *10(1)*, Art. No: 24. DOI: 10.3390/antibiotics10010024
42. Batiha, G.E.-S.; Wasef, L.; Teibo, J.O.; Shaheen, H.M.; Zakariya, A.M.; Akinfe, O.A., et al. *Commiphora myrrh*: A phytochemical and pharmacological update. *Naunyn Schmiedebergs Arch. Pharmacol.* **2023**, *396(3)*, 405-420. DOI: 10.1007/s00210-022-02325-0
43. Häkkinen, S.T.; Soković, M.; Nohynek, L.; Ćirić, A.; Ivanov, M.; Stojković, D., et al. Chicory extracts and sesquiterpene lactones show potent activity against bacterial and fungal pathogens. *Pharmaceuticals* **2021**, *14(9)*, Art. No: 941. DOI: 10.3390/ph14090941
44. Demmers, A.; Mes, J.J.; Elbers, R.G.; Pieters, R.H. Harms of *Momordica charantia* L. in humans; A systematic review. *Fortune J. Health. Sci.* **2023**, *6(2)*, 222-236. DOI: 10.1101/2022.10.22.22281390
45. Damiani, E.; Aloia, A.; Priore, M.; Pastore, A.; Lovecchio, A.; Errico, M., et al. IgE-mediated reaction induced by arugula (*Eruca sativa*) ingestion compared with a spectrum of brassicaceae proteins. *Allergol. Immunopathol.* **2014**, *42(5)*, 501-503. DOI: 10.1016/j.aller.2013.05.003
46. Shang, Y.-x.; Shen, C.; Stub, T.; Zhu, S.-j.; Qiao, S.-y.; Li, Y.-q., et al. Adverse effects of andrographolide derivative medications compared to the safe use of herbal preparations of *Andrographis paniculata*: results of a systematic review and meta-analysis of clinical studies. *Front. Pharmacol.* **2022**, *13*, Art. No: 773282. DOI: 10.3389/fphar.2022.773282
47. Miu, B.A.; Dinischiotu, A. New green approaches in nanoparticles synthesis: An overview. *Molecules* **2022**, *27(19)*, Art. No: 6472. DOI: 10.3390/molecules 27196472
48. Verma, A.; Gautam, S.P.; Bansal, K.K.; Prabhakar, N.; Rosenholm, J.M. Green nanotechnology: Advancement in phytoformulation research. *Medicines* **2019**, *6(1)*, Art. No: 39. DOI: 10.3390/medicines6010039
49. Neupane, N.P.; Kushwaha, A.K.; Karn, A.K.; Khalilullah, H.; Khan, M.M.U.; Kaushik, A., et al. Anti-bacterial efficacy of bio-fabricated silver nanoparticles of aerial part of *Moringa oleifera* lam: Rapid green synthesis, in-vitro and in-silico screening. *Biocatal. Agric. Biotechnol.* **2022**, *39*, Art. No: 102229. DOI: 10.1016/j.bcab.2021.102229.
50. Abdellah, A.M.; Sliem, M.A.; Bakr, M.; Amin, R.M. Green synthesis and biological activity of silver-curcumin nanoconjugates. *Future Med. Chem.* **2018**, *10(22)*, 2577-2588. DOI: 10.4155/fmc-2018-0152
51. Fierascu, I.C.; Fierascu, I.; Baroi, A.M.; Ungureanu, C.; Ortan, A.; Avramescu, S.M., et al. Phytosynthesis of biological active silver nanoparticles using *Echinacea purpurea* L. extracts. *Materials* **2022**, *15(20)*, Art. No: 7327. DOI: 10.3390/ma15207327
52. Sarwar, M.F.; Zahra, A.; Awan, M.F.; Ali, S.; Shafiq, M.; Muzammil, K. Assessing the efficacy of cinnamon compounds against *H. pylori* through molecular docking, MD Simulations and ADMET analyses. *Plos One* **2024**, *19(3)*, Art. No: e0299378. DOI: 10.1371/journal.pone.0299378
53. Elfaky, M.A.; Okairy, H.M.; Abdallah, H.M.; Koshak, A.E.; Mohamed, G.A.; Ibrahim, S.R., et al. Assessing the antibacterial potential of 6-gingerol: combined experimental and computational approaches. *Saudi Pharm. J.* **2024**, *32(5)*, Art. No: 102041. DOI: 10.1016/j.jsps.2024.102041
54. Lahiri, D.; Nag, M.; Dey, S.; Dutta, B.; Dash, S.; Ray, R.R. Phytocompounds of Curcuma longa extract are more effective against bacterial biofilm than pure curcumin only: An in-vitro and in-silico analysis. *Kuwait J. Sci.* **2021**, *48(2)*, 1-14. DOI: 10.48129/kjs.v48i2.8310
55. Seddoqi, S.; Aouinti, F.; Conte, R.; Elhachlafi, N.; Gseyra, N. Exploring phytochemical composition, antioxidant, antibacterial properties, and in-silico study of aqueous leaf extract of *Pistacia lentiscus* L. from the eastern region of Morocco. *Trop. J. Nat. Prod. Res.* **2024**, *8*, 6891-6900. DOI: 10.26538/tjnpr/v8i4.20
56. Kebede, T.; Gadisa, E.; Tufa, A. Antimicrobial activities evaluation and phytochemical screening of some selected medicinal plants: A possible alternative in the treatment of multidrug-resistant microbes. *PloS one* **2021**, *16(3)*, Art. No: e0249253. DOI: 10.1371/journal.pone.0249253
57. Huang, W.; Wang, Y.; Tian, W.; Cui, X.; Tu, P.; Li, J., et al. Biosynthesis investigations of terpenoid, alkaloid, and flavonoid antimicrobial agents derived from medicinal plants. *Antibiotics* **2022**, *11(10)*, Art. No: 1380. DOI: 10.3390/antibiotics11101380
58. Alemu, M.; Lulekal, E.; Asfaw, Z.; Warkineh, B.; Debella, A.; Abebe, A., et al. Antibacterial activity and phytochemical screening of traditional medicinal plants most preferred for treating infectious diseases in Habru District, North Wollo Zone, Amhara Region, Ethiopia. *Plos one* **2024**, *19(3)*, Art. No: e0300060. DOI: 10.1371/journal.pone.0300060
59. Angelini, P. Plant-derived antimicrobials and their crucial role in combating antimicrobial resistance. *Antibiotics* **2024**, *13(8)*, Art. No: 746. DOI: 10.3390/antibiotics13080746
60. Ullah, B.; Esa, M.; Kamal, Z.; Khan, K.A.; Shafique, M. Plant Secondary Metabolites: A Comprehensive Review of Their Role in Combating Antimicrobial and Multidrug-Resistant Bacteria. *Heliyon*, **2024**, (Preprint). DOI: 10.2139/ssrn.4830805
61. El-Aziz, A.; El Sheikh, S.; Galal, A.; Refky, Y. Possible Alternative Strategies to Combat Antimicrobial Resistance. *Zagazig Vet. J.* **2024**, *52(1)*, 1-24. DOI: 10.21608/zvjz.2024.241916.1222
62. Iyer, D.; Soni, M.; Mulchandani, V.; Siddiqui, N. Pharmacognostical Investigation on Fruits of *Apium graveolens* L.: An ayurvedic herb. *J. Ayu. Herb. Med.* **2021**, *7*, 232-236. DOI: 10.31254/jahm.2021.7404
63. Al-Aboody, M.S. Cytotoxic, antioxidant, and

antimicrobial activities of celery (*Apium graveolens* L.). *Bioinformation* **2021**, 17, 147-156. DOI: 10.6026/97320630017147

64. Jiang, L.; Liu, Z.; Cui, Y.; Shao, Y.; Tao, Y.; Mei, L. Apigenin from daily vegetable celery can accelerate bone defects healing. *J. Funct. Foods* **2019**, *54*, 412-421. DOI: 10.1016/j.jff.2019.01.043

65. Illes, J.D. Blood pressure change after celery juice ingestion in a hypertensive elderly male. *J. Chiropr. Med.* **2021**, *20*, 90-94. DOI: 10.1016/j.jcm.2021.04.001

66. Pérez-Ruiz, E.; Melero, I.; Kopecka, J.; Sarmento-Ribeiro, A.B.; García-Aranda, M.; De Las Rivas, J. Cancer immunotherapy resistance based on immune checkpoints inhibitors: Targets, biomarkers, and remedies. *Drug Resist. Updat.* **2020**, *53*, Art. No: 100718. DOI: 10.1016/j.drup.2020.100718

67. Schepetkin, I.A.; Özek, G.; Özek, T.; Kirpotina, L.N.; Khlebnikov, A.I.; Quinn, M.T. Chemical composition and immunomodulatory activity of *Hypericum perforatum* essential oils. *Biomolecules* **2020**, *10(6)*, Art. No: 916. DOI: 10.3390/biom10060916

68. Nobakht, S.Z.; Akaberi, M.; Mohammadpour, A.H.; Moghadam, A.T.; Emami, S.A. *Hypericum perforatum*: Traditional uses, clinical trials, and drug interactions. *Iran J. Basic. Med. Sci.* **2022**, *25(9)*, 1045-1058. DOI: 10.22038/IJBMS.2022.65112.14338

69. Alahmad, A.; Alghoraibi, I.; Zein, R.; Kraft, S.; Dräger, G.; Walter, J.-G., et al. Identification of major constituents of *Hypericum perforatum* L. extracts in Syria by development of a rapid, simple, and reproducible HPLC-ESI-Q-TOF MS analysis and their antioxidant activities. *ACS Omega* **2022**, *7(16)*, 13475-13493. DOI: 10.1021/acsomega.1c06335

70. Nicolussi, S.; Drewe, J.; Butterweck, V.; Meyer zu Schwabedissen, H.E. Clinical relevance of St. John's wort drug interactions revisited. *Br. J. Pharmacol.* **2020**, *177(6)*, 1212-1226. DOI: 10.1111/bph.14936

71. Monteiro, M.-d.-C.; Dias, A.C.; Costa, D.; Almeida-Dias, A.; Criado, M.B. *Hypericum perforatum* and its potential antiplatelet effect. *Healthcare* **2022**, *10(9)*, Art. No: 1774. DOI: 10.3390/healthcare10091774

72. Ben-Eliezer, D.; Yechiam, E. *Hypericum perforatum* as a cognitive enhancer in rodents: A meta-analysis. *Sci. Rep.* **2016**, *6(1)*, Art. No: 35700. DOI: 10.1038/srep35700

73. Ma, Z.; Ahmad, J.; Zhang, H.; Khan, I.; Muhammad, S. Evaluation of phytochemical and medicinal properties of moringa (*Moringa oleifera*) as a potential functional food. *S. Afr. J. Bot.* **2020**, *129*, 40-46. DOI: 10.1016/j.sajb.2018.12.002

74. Xiong, Y.; Rajoka, M.S.R.; Mehwish, H.M.; Zhang, M.; Liang, N.; Li, C., et al. Virucidal activity of moringa a from *Moringa oleifera* seeds against influenza a viruses by regulating TFEB. *Int. Immunopharmacol.* **2021**, *95*, Art. No: 107561. DOI: 10.1016/j.intimp.2021.107561

75. Hammi, K.; Essid, R.; Tabbene, O.; Elkahoui, S.; Majdoub, H.; Ksouri, R. Antileishmanial activity of *Moringa oleifera* leaf extracts and potential synergy with amphotericin B. *S. Afr. J. Bot.* **2020**, *129*, 67-73. DOI: 10.1016/j.sajb.2019.01.008

76. Fouad, E.A.; Elnaga, A.S.A.; Kandil, M.M. Antibacterial efficacy of Moringa oleifera leaf extract against pyogenic bacteria isolated from a dromedary camel (*Camelus dromedarius*) abscess. *Vet. World* **2019**, *12(6)*, 802-808. DOI: 10.14202/vetworld.2019.802-808

77. Mao, Q.-Q.; Xu, X.-Y.; Cao, S.-Y.; Gan, R.-Y.; Corke, H.; Beta, T., et al. Bioactive compounds and bioactivities of ginger (*Zingiber officinale* Roscoe). *Foods* **2019**, *8(6)*, Art. No: 185. DOI: 10.3390/foods8060185

78. Saleem, S.; Muhammad, G.; Hussain, M.A.; Bukhari, S.N.A. A comprehensive review of phytochemical profile, bioactives for pharmaceuticals, and pharmacological attributes of *Azadirachta indica*. *Phytother. Res.* **2018**, *32*, 1241-1272. DOI: 10.1002/ptr.6076

79. Khan, M.A.; Yaqoob, S.; Ahmad, S. Antimicrobial activity of *Azadirachta indica*, against target pathogens and its utility as a disinfectant and floor cleaner. *J. Evol. Med. Dent. Sci.* **2021**, *10(25)*, 1899-1903. DOI: 10.14260/jemds/2021/392

80. Yetgin, A.; Canlı, K.; Altuner, E.M. Comparison of antimicrobial activity of *Allium sativum* cloves from China and Taşköprü, Turkey. *Adv. Pharmacol. Pharm. Sci.* **2018**, *2018*, Art. No: 9302840. DOI: 10.1155/2018/9302840

81. Dosoky, N.S.; Setzer, W.N. Chemical composition and biological activities of essential oils of curcuma species. *Nutrients* **2018**, *10*, Art. No: 1196. DOI: 10.3390/nu10091196

82. Su, C.-C.; Wang, C.-J.; Huang, K.-H.; Lee, Y.-J.; Chan, W.-M.; Chang, Y.-C. Anthocyanins from *Hibiscus sabdariffa* calyx attenuate in vitro and in vivo melanoma cancer metastasis. *J. Funct. Foods* **2018**, *48*, 614-631. DOI: 10.1016/j.jff.2018.07.032

83. Portillo-Torres, L.A.; Bernardino-Nicanor, A.; Gómez-Aldapa, C.A.; González-Montiel, S.; Rangel-Vargas, E.; Villagómez-Ibarra, J.R., et al. Hibiscus acid and chromatographic fractions from *Hibiscus sabdariffa* calyces: Antimicrobial activity against multidrug-resistant pathogenic bacteria. *Antibiotics* **2019**, *8(4)*, Art. No: 218. DOI: 10.3390/antibiotics8040218

84. Abass, A.A.; Al-Magsoosi, M.J.N.; Kadhim, W.A.; Mustafa, R.; Aljdaimi, A.I.; Al-Nasrawi, S.J., et al. Antimicrobial effect of red roselle (*Hibiscus Sabdariffa*) against different types of oral bacteria. *J. Med. Life* **2022**,*15(1)*, 89-97. DOI: 10.25122/jml-2021-0184

85. Takeda, Y.; Okuyama, Y.; Nakano, H.; Yaoita, Y.; Machida, K.; Ogawa, H., et al. Antiviral activities of *Hibiscus sabdariffa* L. tea extract against human influenza A virus rely largely on acidic pH but partially on a low-pH-independent mechanism. *Food Environ. Virol.* **2020**, *12*, 9-19. DOI: 10.1007/s12560-019-09408-x

86. de Macedo, L.M.; Santos, É.M.d.; Militão, L.; Tundisi, L.L.; Ataide, J.A.; Souto, E.B., et al. Rosemary (*Rosmarinus officinalis* L., syn *Salvia rosmarinus*

Spenn.) and its topical applications: A review. *Plants* **2020**, *9(5)*, Art. No: 651. DOI: 10.3390/plants9050651

87. Saleh, A.; Al Kamaly, O.; Alanazi, A.S.; Noman, O. Phytochemical analysis and antimicrobial activity of Rosmarinus officinalis L. Growing in Saudi Arabia: Experimental and computational approaches. *Processes* **2022**, *10(11)*, Art. No: 2422. DOI: 10.3390/ pr10112422

88. Bolton, J.L.; Dunlap, T.L.; Hajirahimkhan, A.; Mbachu, O.; Chen, S.-N.; Chadwick, L., et al. The multiple biological targets of hops and bioactive compounds. *Chem. Res. Toxicol.* **2019**, *32(2)*, 222-233. DOI: 10.1021/acs.chemrestox.8b00345

89. Pachi, V.K.; Mikropoulou, E.V.; Gkiouvetidis, P.; Siafakas, K.; Argyropoulou, A.; Angelis, A., et al. Traditional uses, phytochemistry and pharmacology of *Chios mastic* gum (*Pistacia lentiscus* var. Chia, Anacardiaceae): A review. *J. Ethnopharmacol.* **2020**, *254*, Art. No: 112485. DOI: 10.1016/j.jep.2019. 112485

90. Jin, T.; Chi, L.; Ma, C. Agrimonia pilosa: A phytochemical and pharmacological review. *Evid. Based Complement. Alternat. Med.* **2022**, *2022*, Art. No: 3742208. DOI: 10.1155/2022/3742208

91. da Silva, Y.C.; Silva, E.M.S.; Fernandes, N.d.S.; Lopes, N.L.; Orlandi, P.P.; Nakamura, C.V., et al. Antimicrobial substances from Amazonian Aniba (Lauraceae) species. *Nat. Prod. Res.* **2021**, *35(5)*, 849-852. DOI: 10.1080/14786419.2019.1603225

92. Mohamed, A.A.; Ali, S.I.; EL-Baz, F.K.; Hegazy, A.K.; Kord, M.A. Chemical composition of essential oil and in vitro antioxidant and antimicrobial activities of crude extracts of *Commiphora myrrha* resin. *Ind. Crops Prod.* **2014**, *57*, 10-16. DOI: 10.1016/j.indcrop. 2014.03.017

93. Alhussaini, M.S.; Saadabi, A.; Alghonaim, M.I.; Ibrahim, K.E. An evaluation of the antimicrobial activity of *Commiphora myrrha* Nees (Engl.) oleo-gum resins from Saudi Arabia. *J. Med. Sci.* **2015**, *15(4)*, 198-203. DOI: 10.3923/jms.2015.198.203

94. Nwafor, I.C.; Shale, K.; Achilonu, M.C. Chemical composition and nutritive benefits of chicory (*Cichorium intybus*) as an ideal complementary and/or alternative livestock feed supplement. *Sci. World J.* **2017**, *2017*, Art. No: 7343928. DOI: 10.1155/2017/7343928

95. Madhavi, N.; Chandu, B.L.; Rithika, G.; Niharika, B.; Rao, T.R. Insight on phytochemical and pharmacognostic review of *Cichorium intybus*. *Pharmacog. Res.* **2023**, *15(3)*, 405-409. DOI: 10.5530/pres.15.3.044

96. Saeed, F.; Afzaal, M.; Niaz, B.; Arshad, M.U.; Tufail, T.; Hussain, M.B., et al. Bitter melon (*Momordica charantia*): A natural healthy vegetable. *Int. J. Food Prop.* **2018**, *21(1)*, 1270-1290. DOI: 10.1080/ 10942912.2018.1446023

97. Pagnotta, E.; Ugolini, L.; Matteo, R.; Righetti, L. Bioactive compounds from *Eruca sativa* seeds. Encyclopedia **2022**, 2(4), 1866-1879. DOI: 10.3390/ encyclopedia2040129.

98. Qaddoumi, S.; El-Banna, N. Antimicrobial activity of arugula (Eruca sativa) leaves on some pathogenic bacteria. *Int. J. Biol.* **2019**, *11(3)*, 10-15. DOI: 10.5539/ijb.v11n3p10

99. Septiani, D.A.; Hakim, A.; Patech, L.R.; Zulhalifah, Z.; Siswadi, S. Isolation and identification of andrographolide compounds from the leaves of sambiloto plant (*Andrographis paniculata* Ness). *Acta Chimica Asiana* **2021**, 4(1), 108-113. DOI: 10.29303/ aca.v4i1.65

100. Raman, S.; Murugaiyah, V.; Parumasivam, T. Andrographis paniculata dosage forms and advances in nanoparticulate delivery systems: An overview. *Molecules* **2022**, *27(19)*, Art. No: 6164. DOI: 10.3390/ molecules27196164

101. Kim, S.; Woo, E.R.; Lee, D.G. Apigenin promotes antibacterial activity via regulation of nitric oxide and superoxide anion production. *J. Basic Microbiol.* **2020**, *60*, 862-872. DOI: 10.1002/jobm.202000432

102. Lyles, J.T.; Kim, A.; Nelson, K.; Bullard-Roberts, A.L.; Hajdari, A.; Mustafa, B., et al. The chemical and antibacterial evaluation of St. John's Wort oil macerates used in Kosovar traditional medicine. *Front. Microbiol.* **2017**, *8*, Art. No: 1639. DOI: 10.3389/fmicb.2017.01639

103. Chen, H.; Muhammad, I.; Zhang, Y.; Ren, Y.; Zhang, R.; Huang, X., et al. Antiviral activity against infectious bronchitis virus and bioactive components of *Hypericum perforatum* L. *Front. Pharmacol.* **2019**, *10*, Art. No: 1272. DOI: 10.3389/fphar.2019.01272

104. Kakouri, E.; Daferera, D.; Trigas, P.; Charalambous, D.; Pantelidou, M.; Tarantilis, P.A., et al. Comparative study of the antibacterial activity, total phenolic and total flavonoid content of nine hypericum species grown in Greece. *Appl. Sci.* **2023**, *13(5)*, Art. No: 3305. DOI: 10.3390/app13053305

105. van den Berg, J.; Kuipers, S. The antibacterial action of *Moringa oleifera*: A systematic review. *S. Afr. J. Bot.* **2022,** *151*, 224-233. DOI: 10.1016/j.sajb. 2022.09.034

106. Diniz, A.; Santos, B.; Nóbrega, L.; Santos, V.; Mariz, W.; Cruz, P., et al. Antibacterial activity of *Thymus vulgaris* (thyme) essential oil against strains of *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Staphylococcus saprophyticus* isolated from meat product. *Braz. J. Biol.* **2023**, *83*, 1-9. DOI: 10.1590/ 1519-6984.275306

107. Mehrishi, P.; Agarwal, P.; Broor, S.; Sharma, A. Antibacterial and antibiofilm properties of *Azadirachta indica* (Neem), *Aloe vera* (Aloe vera), and *Mentha piperita* (Peppermint) against multidrug-resistant clinical isolates. *Biomed. Biotechnol. Res. J.* **2022**, *6(1)*, 98-104. DOI: 10.4103/bbrj.bbrj_178_21

108. Petropoulos, S.; Fernandes, Â.; Barros, L.; Ciric, A.; Sokovic, M.; Ferreira, I.C. Antimicrobial and antioxidant properties of various Greek garlic genotypes. *Food Chem.* **2018**, *245*, 7-12. DOI: 10.1016/j.foodchem.2017.10.078

109. Magryś, A.; Olender, A.; Tchórzewska, D. Antibacterial properties of *Allium sativum* L. against the most emerging multidrug-resistant bacteria and

its synergy with antibiotics. *Arch. Microbiol.* **2021**, *203*, 2257-2268. DOI: 10.1007/s00203-021-02248-z

110. Choo, S.; Chin, V.K.; Wong, E.H.; Madhavan, P.; Tay, S.T.; Yong, P.V.C., et al. Antimicrobial properties of allicin used alone or in combination with other medications. *Folia Microbiol.* **2020**, *65*, 451-465. DOI: 10.1007/s12223-020-00786-5

111. Fufa, B.K. Anti-bacterial and anti-fungal properties of garlic extract (*Allium sativum*): A review. *Microb. Res. J. Int.* **2019**, *28(3)*, 1-5. DOI: 10.9734/ mrji/2019/v28i330133

112. Marathe, S.A.; Kumar, R.; Ajitkumar, P.; Nagaraja, V.; Chakravortty, D. Curcumin reduces the antimicrobial activity of ciprofloxacin against *Salmonella Typhimurium* and *Salmonella Typhi*. *J. Antimicrob.Chemother* **2013**, 68(1), 139-152. DOI: 10.1093/jac/dks375

113. Tyagi, P.; Singh, M.; Kumari, H.; Kumari, A.; Mukhopadhyay, K. Bactericidal activity of curcumin I is associated with damaging of bacterial membrane. *PloS One* **2015**, *10(3)*, Art. No: e0121313. DOI: 10.1371/journal.pone.0121313

114. Hussain, Y.; Alam, W.; Ullah, H.; Dacrema, M.; Daglia, M.; Khan, H., et al. Antimicrobial potential of curcumin: therapeutic potential and challenges to clinical applications. *Antibiotics* **2022**, *11(3),* Art. No: 322. DOI: 10.3390/antibiotics11030322

115. Nieto, G.; Ros, G.; Castillo, J. Antioxidant and antimicrobial properties of rosemary (*Rosmarinus officinalis,* L.): A review. *Medicines* **2018**, *5(3),* Art. No: 98. DOI: 10.3390/medicines5030098.

116. Do Nascimento, P.G.; Lemos, T.L.; Bizerra, A.M.; Arriaga, Â.M.; Ferreira, D.A.; Santiago, G.M., et al. Antibacterial and antioxidant activities of ursolic acid and derivatives. *Molecules* **2014**, *19(1)*, 1317-1327. DOI: 10.3390/molecules19011317

117. Yang, Y.; Ma, S.; Li, T.; He, J.; Liu, S.; Liu, H., et al. Discovery of novel ursolic acid derivatives as effective antimicrobial agents through a ROS-mediated apoptosis mechanism. *Front. Chem. Sci. Eng.* **2023**, *17*, 2101-2113. DOI: 10.1007/s11705-023-2361-5

118. Phanchana, M.; Harnvoravongchai, P.; Wongkuna, S.; Phetruen, T.; Phothichaisri, W.; Panturat, S., et al. Frontiers in antibiotic alternatives for *Clostridioides* difficile infection. *World J. Gastroenterol.* **2021**, *27(42)*, 7210-7232. DOI: 10.3748/wjg.v27.i42.7210

119. Mharti, F.Z.; Lyoussi, B.; Abdellaoui, A. Antibacterial activity of the essential oils of *Pistacia lentiscus* used in Moroccan folkloric medicine. *Nat. Prod. Commun.* **2011**, *6(10),* 1505-1506. DOI: 10.1177/1934578 X1100601024

120. Milia, E.P.; Sardellitti, L.; Eick, S. Antimicrobial Efficiency of *Pistacia lentiscus* L. derivates against oral biofilm-associated diseases—A narrative review. *Microorganisms* **2023**, *11(6)*, Art. No: 1378. DOI: 10.3390/microorganisms11061378

121. Al-Zaben, M.; Zaban, M.A.; Naghmouchi, S.; Nasser Alsaloom, A.; Al-Sugiran, N.; Alrokban, A. Comparison of phytochemical composition, antibacterial, and antifungal activities of extracts from three organs of *Pistacia lentiscus* from Saudi Arabia. *Molecules* **2023**, *28(3)*, Art. No: 5156. DOI: 10.3390/molecules28135156

122. Kim, J.W.; Park, S.; Sung, Y.W.; Song, H.J.; Yang, S.W.; Han, J., et al. Evaluation of antibacterial and antiviral Compounds from *Commiphora myrrha* (T. Nees) Engl. resin and their promising application with biochar. *Appl. Sci.* **2023**, *13(18)*, Art. No: 10549. DOI: 10.3390/app131810549

123. Bezerra, M.S.; Zeferino, K.S.; Menezes, L.D.; Bezerra, A.S.; Lopes, L.Q.S.; Marquezan, F.K., et al. Antimicrobial and antibiofilm activities of *Cichorium intybus*: A review. *Res. Soc. Dev.* **2022**, *11(2)*, Art. No: e10911225384. DOI: 10.33448/rsd-v11i2.25384

124. Rahmi, M.; Sari, T. Antibacterial activity of ethanol extract, n-hexan, ethyl acetate and butanol fraction of *Momordica charantia* L. seed against *Staphylococcus epidermidis*. *J. Phys. Conf. Ser.* **2021**, *1918*, Art. No: 052013. DOI: 10.1088/1742-6596/1918/5/052013

125. Muribeca, A.d.J.B.; Gomes, P.W.P.; Paes, S.S.; da Costa, A.P.A.; Gomes, P.W.P.; Viana, J.d.S., et al. Antibacterial activity from *Momordica charantia* L. leaves and flavones enriched phase. *Pharmaceutics* **2022**, *14(9)*, Art. No: 1796. DOI: 10.3390/ pharmaceutics14091796

126. Bassyouni, R.H.; Kamel, Z.; Algameel, A.A.; Ismail, G.; Gaber, S.N. In-vitro determination of antimicrobial activities of *Eruca sativa* seed oil against antibiotic-resistant gram-negative clinical isolates from neonates: A future prospect. *BMC Complement. Med. TheR.* **2022**, *22*, Art. No: 229. DOI: 10.1186/s12906-022-03710-1

127. Farhana, S.; Aziz, S.; Rahman, S.; Afrin, S.; Bhuiyan, M.N.I.; Al-Reza, S.M. Chemical composition of fixed oil and in vitro antimicrobial activity of *Andrographis paniculata* root. *J. King Saud. Univ. Sci.* **2022**, *34(4)*, Art. No: 101921. DOI: 10.1016/j.jksus.2022.101921

128. Hossain, S.; Urbi, Z.; Karuniawati, H.; Mohiuddin, R.B.; Moh Qrimida, A.; Allzrag, A.M.M., et al. *Andrographis paniculata* (burm. F.) wall. Ex nees: an updated review of phytochemistry, antimicrobial pharmacology, and clinical safety and efficacy. *Life* **2021**, *11(4)*, Art. No: 348. DOI: 10.3390/life11040348