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Review Article

A Comprehensive Review on the Role of Natural Plants in Anti-Bacterial Activity

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Abstract

Natural plants have been an essential source of therapeutic agents for centuries. With the rising concern over antibiotic resistance, there is an increasing interest in exploring herbal plants as alternative sources of antibacterial agents. These plants contain a wide range of bioactive compounds that exhibit significant antibacterial properties, making them promising candidates for novel drug development. This review explores the various medicinal plants known for their antibacterial efficacy, their phytochemical constituents, and the mechanisms through which they exert their antibacterial effects. Additionally, the review highlights recent advancements in herbal-based antibacterial activity and their potential integration into modern therapeutic strategies. Understanding the antibacterial properties of natural plants can contribute to developing new, effective, and sustainable solutions to combat antibiotic resistance.

Keywords: Antibacterial activity, medicinal plants, phytochemicals, natural remedies, alkaloids, flavonoids, terpenoids, antibiotic resistance.

Introduction

Natural substances are the most important source for pharmaceuticals and therapeutic development. According to the World Health Organization, over 65% of people worldwide rely primarily on plant-based natural products for primary healthcare. In comparison, 35% of people in industrialized nations use them indirectly to maintain their wellness [1].

For the last ten years, plants have long been an essential source of natural elements for maintaining human health. Plant-based medicines have been increasing gradually in Brazil [2]. According to the World Health Organization, the best approach to obtain a variety of pharmaceuticals is through medicinal plants. Traditional medicine, which uses compounds derived from medicinal herbs, is used by almost 80% of people in wealthy countries. Therefore, more research on these plants is needed to fully comprehend their characteristics, effectiveness, and safety [3].

Due to chemicals produced in the secondary metabolism, many plants have been employed for their antibacterial properties [4]. Active ingredients like the tannin and phenolic compounds found in essential oils exert antibacterial action [5]. Strong effects are demonstrated by natural plant products multifaceted and comprehensive health benefits, which include antioxidant, immunomodulatory, and antimicrobial activities as well as protection against a range of illnesses, including cancer, and lifestyle diseases like diabetes, high blood pressure, obesity, hyperlipidemia, digestive disorders, diarrhoea, cephalgia, cough, constipation, renal dysfunction, and others [6-9].

Conversely, natural remedies make up a significant portion of social insurance globally. Since the dawn of human civilization, plants have been utilized to alleviate human suffering through their naturally occurring bioactive substances, known as Phytochemicals, which are extracted from a variety of natural sources, including fruits and vegetables, contain active phytonutrients that help treat a range of human illnesses.

The review addresses the value of medicinal plants as efficient substitutes for antibiotics, highlighting how the bioactive phytochemicals present in these plants work and the advantages of employing plant-based antibacterial compounds either by themselves or in

conjunction with other phytochemicals or antibiotics. The study highlights the hurdles and obstacles encountered in discovering plant-based pharmaceuticals and offers future insights on the subject.

Phytochemical Constituents Responsible for Antibacterial Activity

Chemical compounds known as phytochemicals give plants color, flavor, aroma, and texture. These compounds evolved over millions of years to protect living organisms from bacteria, fungi, viruses, and free radicals. Fruits, vegetables, legumes, whole grains, nuts, seeds, fungi, herbs, and spices contain them, as do plant-based drinks like tea and wine. Phytochemicals, such as terpenoids, polyphenols, sulfur-containing phytochemicals, and alkaloids, are classified based on their chemical composition.

Alkaloids

Alkaloids, produced by various organisms including plants, bacteria, fungi, and mammals, have been utilized in medicine for centuries. They have many effects, including antimalarial (quinine) and anti-asthmatic properties. Ephedrine has anti-hypertensive, anti-tumor, and anti-arrhythmic properties. Alkaloids, including cocaine, caffeine, and nicotine, have psychotropic and stimulant properties and can also have analgesic effects, similar to morphine. Alkaloids have been proven to have antibacterial activity and could potentially treat many infectious disorders [10].

Terpenoids

Terpenoids are a class of plant-produced chemicals with antibacterial properties activity [11]. Made from five-carbon isoprene units, having multicyclic structures with distinct carbon skeletons and functional groups. Monoterpenes, a type of terpene with two isoprene units, are commonly found in plant essential oils. Over the past two decades, research has demonstrated that thymol and carvacrol, phenolic monoterpenoids, can suppress the growth of certain bacteria. The efficacy of salvipisone and aethiopinone against MRSA and MRSE bacteria, as well as their combination with oxacillin, vancomycin, and linezolid, were investigated in another study. Salvipisone and aethiopinone were found to have bacteriostatic or bactericidal effects on planktonic cultures of the microorganisms under investigation. At 1/2 MIC, diterpenoids showed a synergistic effect with the studied antibiotics [12].

Polyphenols

Polyphenols are common compounds found in fruits, vegetables, nuts, seeds, stems, flowers, and beverages including coffee, tea, and red wine. Recent research has demonstrated the potential of dietary polyphenols as chemo preventive and therapeutic agents because of their direct antibacterial effect and antibiotic-modulating activity [13]. Natural flavonoids have varying pharmacological effects. It has the potential to prevent oxidative stress-related disorders like cancer, cardiovascular disease, and neurological disease [14-17].

Herbal Plants Show Anti-Bacterial Activity

1. Turmeric

Ginger and other members of the *Zingiberaceae* family include the herbaceous, evergreen plant known as turmeric. It's grown extensively in Asia, especially in China and India. Turmeric has been utilized for at least 2500 years in India & is widespread across the tropics. The plant's origin is unknown, but it is believed to have originated in South-East Asia, specifically India[18]. The primary sources of turmeric powder, widely accessible in Europe, are India and other Southeast Asian nations [19]. It is mainly frequent in southern Asia, specifically India. Turmeric's rhizome, a thick and fleshy underground stem surrounded by ancient leaf bases, has therapeutic properties. The characteristic bright yellow spice is made by roasting, drying, and grinding rhizomes into a powder. Turmeric powder has a spicy, bitter flavor with a subtle aroma similar to orange and ginger. A key ingredient in curries, turmeric powder also adds to ballpark mustard's vivid yellow hue. It is widely used in traditional medicine in India, Pakistan, and Bangladesh due to its benefits [20].

Figure 1: Turmeric

Bacterial and Viral Infections

Turmeric may kill viruses and bacteria, according to studies conducted on animals and in test tubes. Turmeric rhizomes' aqueous extract has antibacterial actions [21]. In vitro, curcumin prevents *Helicobacter pylori* CagA+ strains from growing. Curcumin and the oil fraction both inhibit growth. Bacteria include *Streptococcus*, *Staphylococcus,* and *Lactobacillus*. Curcumin exhibits antiviral action [22]. Turmeric, particularly its active compound curcumin, exhibits significant antibacterial properties against both Gram-positive and Gram-negative bacteria. Studies have demonstrated its effectiveness against various bacterial strains, including those that cause infections in healthcare settings and those resistant to antibiotics.

Curcumin's Mechanisms:

Curcumin can disrupt bacterial cell membranes, potentially leading to leakage of cellular contents and cell death. It can interfere with the production of bacterial proteins and DNA, which are essential for bacterial growth and virulence. It also induces oxidative stress in bacteria, leading to damage to cellular components like lipids, proteins, and DNA, ultimately causing cell death. Curcumin can act as a photosensitizer, meaning it becomes more reactive when exposed to blue light,

further enhancing its bactericidal effects. Studies have shown curcumin to be effective against a wide range of bacteria, including Gram-positive bacteria: *S. aureus, B. subtilis, E. faecalis* Gram-negative bacteria: *E. coli, P. aeruginosa, K. pneumoniae*. It has been shown to enhance the effects of certain antibiotics, suggesting its potential as an adjuvant therapy in treating bacterial infections.

Potential Applications:

Curcumin has been investigated for its potential in treating various infections, including skin and wound infections, urinary tract infections, and surgical infections. Curcumin's antimicrobial properties make it a potential natural food preservative. Curcumin's ability to target bacterial mechanisms beyond traditional antibiotic targets may offer a potential approach to combating antibiotic-resistant strains.

2. Ginger

Ginger is derived from the subterranean stems or rhizomes of *Zingiber officinale (Rosc.)*, a tropical herbaceous perennial in the *Zingiberaceae* family. The most common way to grow it is as an annual. While the entire plant has a pleasant perfume, the underground rhizome, whether raw or processed, is highly appreciated as a spice. Its medical value is becoming widely recognized. India is most likely where ginger first appeared in Southeast Asia [23].

Figure 2: Ginger

About 85 plant species in the Zingiber genus, which belongs to the *Zingiberaceae* family, are mostly grown in Asia, South and Central America, and Africa [24]. The rhizomatous perennial herb ginger (*Zingiber officinale Roscoe*) can reach a length of 90 cm. Rhizomes are aromatic, thickly lobed, and pale yellowish, with simple alternate distichous thin oblong-lanceolate leaves. The herb has lateral shoots in clusters that dry as the plant ages. The leaves are tall and 2-3 cm broad, with sheathing bases that gradually taper to a tip. Rectangular and cylindrical lateral radical pedunculate spikes on a single inflorescence. Flowers are scarce and small, with a superior, gamosepalous, three-toothed calyx that opens by splitting on one side. The corolla consists of three subequal, oblong lanceolate, and connate greenish segments [25].

Anti-bacterial Activity

Bacteria such as *Salmonella typhi, Salmonella typhimurium, Pseudomonas aeruginosa, Proteus sp., Streptococcus faecalis, Bacillus cereus, Bacillus subtilis, Bacillus megaterium, Staphylococcus aureus, Staphylococcus epidermidis, Klebsiella pneumonia, Entererococcus faecalis*, and others are tested for activity. Chemical compounds can inhibit the growth of various bacteria, including both Gram-positive and Gram-negative strains, and can also interfere with biofilm formation. Ginger extracts have shown antibacterial activity against various pathogens, including *E. coli, S. aureus, P. aeruginosa,* and *C. albicans*.

Antibacterial Mechanism:

Gingerol and shogaol, among other compounds, can penetrate bacterial cell membranes, leading to their disruption and leakage of intracellular components. Ginger essential oil (GEO) has been shown to disrupt the structure and metabolic activity of bacterial biofilms, preventing bacterial colonization and growth. Some ginger compounds can inhibit the synthesis of bacterial enzymes essential for growth and survival. Ginger extracts may interfere with bacterial DNA metabolism, hindering their ability to replicate and multiply.

Applications:

Ginger and its extracts can be used as natural preservatives in food products, inhibiting the growth of spoilage and pathogenic bacteria. Ginger has been used in traditional medicine for centuries for its various medicinal properties, including its antibacterial activity. Ginger and its bioactive compounds are being explored as potential alternative therapies for bacterial infections, particularly in cases of antibiotic resistance. Ginger extracts and essential oils can be used to protect plants from bacterial and fungal infections. Ginger oil can be used for water disinfection, reducing the number of bacteria in contaminated water.

Specific Compounds: A family of phenolic compounds, particularly 6-gingerol, are known for their potent antibacterial activity. Another group of phenolic compounds derived from gingerols also exhibits antibacterial properties. Ginger contains various other compounds, including monoterpenoids, sesquiterpenoids, and phenolic compounds, which contribute to its broad antimicrobial spectrum.

3. Clove

Clove (*Syzigium aromaticum L., Myrtaceae*) has significant promise as a food preservative against spoilage and pathogens. The dried, unexpanded flower buds known as commercial cloves are used as a spice or condiment in a wide range of culinary and medicinal applications. S. aromaticum buds' essential oil is frequently used for dental care and other medical applications. The essential oil combats oral germs that cause tooth caries and periodontal conditions [26,27].

Ayurveda and Chinese medicine both use cloves. Herbalism and Western medicine. Clove components have been demonstrated to be effective against bacterial and fungal illnesses [28]. Spices are aromatic, flavorful plant ingredients that can be native or exotic and are used to enhance food flavors [29]. Spices contain essential oils, alkaloids, glycosides, and other compounds that have antibacterial properties.

Figure 3: Clove

Anti-bacterial Activity

Clove has shown antibacterial properties against several bacteria and fungus types. Sofia et al. examined how several Indian spice herbs, including clove, garlic, mustard, ginger, cinnamon, and mint, have antibacterial qualities [30]. The just one specimen that effectively killed all food-borne pathogens tested, including *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*, was the 3% aqueous extract of clove. Clove extract, at 1% concentration, demonstrated effective inhibitory effects. Dorman and Dean 31 evaluated black pepper, geranium, nutmeg, oregano, thyme, and clove for antibacterial efficacy against 25 types of bacteria. Bacteria are classified as Gram-positive or Gram-negative. The most varied action was seen in the oils of clove, oregano, and thyme.

Clove has strong antibacterial properties, mainly attributed to its high eugenol content. It can inhibit the growth of various bacteria, including both Gram-positive and Gram-negative strains. Clove essential oil (CEO) has shown effectiveness against bacteria like *Staphylococcus aureus, Pseudomonas aeruginosa,* and *Escherichia coli*. The antibacterial activity of clove can be used in food preservation, oral hygiene, and potentially in treating bacterial infections.

Antibacterial Mechanism:

The antibacterial activity of clove is primarily linked to its eugenol content. Eugenol, a phenolic compound, can disrupt bacterial cell membranes, leading to cell death. Gram-positive bacteria: *Staphylococcus aureus, Bacillus subtilis.* Gram-negative bacteria: *Pseudomonas aeruginosa, Escherichia coli, and Klebsiella pneumoniae.* Helicobacter pylori: Research suggests clove oil may inhibit the growth of this bacteria, which can cause stomach ulcers and other digestive problems.

Applications:

Clove is used as a natural preservative in various foods due to its antibacterial and antioxidant properties. Clove oil can be used in mouthwashes to help combat oral bacteria and prevent dental problems. Clove's antibacterial properties make it a potential natural alternative or adjunct treatment for bacterial infections.

Mechanism of Action:

Eugenol can interfere with the integrity of bacterial cell membranes, leading to leakage of cellular contents and eventually cell death. Clove essential oil can also disrupt bacterial DNA replication, hindering their ability to multiply. Clove can also inhibit the expression of virulence factors in bacteria, reducing their ability to cause disease.

4. Tulsi

Ocimum tenuiflorum, formerly known as *Ocimum sanctum*, Tulsi, or Holy Basil from the *Lamiaceae* family, has been dubbed the "Queen of Plants" and the "Mother Medicine of Nature" due to its medical properties [32]. Tulsi is traditionally utilized in several ways, including aqueous extracts from fresh or dried leaves in herbal teas. Combine with additional herbs or honey for increased medicinal benefits. Tulsi aqueous extracts are traditionally used to cure several ailments such as poisoning, stomach pain, colds, headaches, malaria, inflammation, and cardiovascular disease [33].

Figure 4: Tulsi

Charaka mentioned it in the Charaka Samhita. Tulsi extracts are utilized in Ayurvedic medicines to treat common colds. Symptoms may include headaches, gastrointestinal issues, inflammation, heart disease, poisoning, and malaria [34]. Tulsi, the sacred basil, is revered for its religious and spiritual significance. It also plays a significant part in the Ayurvedic and Unani systems providing holistic health and herbal therapy in the east [35].

Anti-bacterial Activity

Ocimum sanctum L. exhibits antibacterial properties against several pathogenic pathogens. Bacteria tested included *Staphylococcus aureus*, *Bacillus pumius, Pseudomonas aeruginosa, Bacillus subtilis, and Escherichia coli* [36,37]. There is limited research on *Ocimum sanctum L.'s* antibacterial properties. Protects against caries-causing organisms such as *Streptococcus mutans* and *Lactobacillus acidophilus*. The study aimed to assess the antibacterial properties of *Ocimum sanctum L.* against *Streptococcus mutans* and *Lactobacillus acidophilus*. Extracts and essential oils from tulsi leaves have been shown to inhibit the growth of various bacteria, including *Staphylococcus aureus, Pseudomonas aeruginosa,* and *E. coli*. These antibacterial effects are attributed to compounds like eugenol and other essential oils present in tulsi.

Mechanism of Action:

Tulsi extracts and oils have been shown to inhibit the growth of several bacteria, including those responsible

for food spoilage, poisoning, and human infections. The presence of eugenol, methyl eugenol, carvacrol, and other compounds in Tulsi is believed to be responsible for its antibacterial activity. Tulsi exhibits antimicrobial activity against a wide range of bacteria, including both Gram-positive and Gram-negative species, as well as fungi and viruses. Researchers have demonstrated that Tulsi extracts and essential oils could be a potential alternative to traditional antibiotics due to their effectiveness and non-toxic nature.

Applications:

Tulsi has been used to treat dental caries, gingivitis, bleeding gums, oral ulcers, and halitosis. Extracts made from Tulsi leaves are thought to boost wound healing speed and protect against infections. Tulsi leaf extracts can be used to treat water and remove impurities. Tulsi has been used traditionally to treat a variety of bacterial, viral, fungal, and arthropod-borne diseases.

5. Liquorice

G. glabra is a common herbaceous perennial that can grow up to 1 m. The blooms are in a hermaphrodite arrangement and range in color from purple to pale white blue flower, while the fruit itself is an oblong legume that grows 2 to 3 cm long and has several seeds. The Fabaceae genus contains over thirty species, including *Glycyrrhiza. G. glabra, G. uralensis, G. inflata, G. aspera, G. korshinskyi, and G. eurycarpa.* Similar to other Fabaceae plants, *G. glabra* can fix nitrogen at the root level through symbiosis with bacteria of the genus Rhizobium; they work well in clay and sandy soils but prefer wet ones. Since ancient Egypt, *G. glabra's* medicinal benefits have been widely known [38].

Figure 5: Liquorice

Anti-bacterial Activity

In clinical medicine, multidrug-resistant microbes provide a significant challenge, prompting the hunt for novel active principles. The antibacterial qualities of *G. glabra* were documented by many authors, namely against Gram-positive and Gram-negative bacteria like *Bacillus subtilis, Pseudomonas aeruginosa, Candida albicans, Escherichia coli*, and *Staphylococcus aureus* [39]. Because of the presence of secondary metabolites, specifically flavonoids, alkaloids, and saponins, antibacterial activity has been discovered [40,41].

Liquorice root has demonstrated antibacterial properties in vitro against both Gram-positive and Gram-negative bacteria. Ethanolic and aqueous extracts of liquorice have shown good activity against various pathogens like *Salmonella sp., Staphylococcus epidermidis,* and *Escherichia coli*. Flavonoids, particularly chalcones, in liquorice play a role in inhibiting bacterial growth by limiting gene expression and toxin formation.

Antibacterial Mechanism:

Liquorice extracts, particularly those rich in glycyrrhizin, can effectively inhibit the growth of various bacteria, including *Staphylococcus aureus, Bacillus cereus,* and *Escherichia coli.* Some flavonoids in liquorice, like glabrol, have been shown to disrupt the cell membrane integrity of bacteria like *Staphylococcus aureus*, leading to a loss of their proton motive force and membrane permeability. Liquorice compounds can interfere with bacterial gene expression and the production of bacterial toxins, further contributing to their antibacterial effect. Glycyrrhizin, a major active component, can inhibit the activity of bacterial enzymes, hindering their metabolic processes and growth.

Applications of Liquorice's Antibacterial Properties:

Liquorice extracts and compounds may have potential for treating various infections, including those caused by secondary bacterial co-infections in patients with COVID-19 or other conditions. The antibacterial properties of liquorice can be used in dental applications, such as treating dental caries, periodontal disease, and digestive anabrosis. Liquorice has a long history of use in traditional medicine for treating respiratory conditions, including bronchitis, hoarseness, and sore throats.

6. Garlic

The bulbous perennial plant known as garlic (*Allium sativum*) has a strong onion-like scent and a strong flavor that have been used as a condiment, flavoring, and medicinal herb. For many years, many health authorities and fans have acknowledged the various health benefits of garlic, including its ability to promote greater health. Other names for garlic include rocambole, ajo, Allium, stinking rose, rustic treacle, nectar of the gods, poor man's treacle, camphor of the poor, and clove garlic. Crushed garlic preparations have been shown to be effective against a wide range of microorganisms, including bacteria, fungus, viruses, and protozoa. Garlic is one of many dietary supplements that lower the risk of cancer. Garlic has been used medicinally since ancient times. Garlic has also been shown to have anticancer properties and lower blood lipids. Garlic cloves have shown an unusually high quantity of sulfur-containing chemicals (1–3%) according to chemical investigations [42,43].

Figure 6: Garlic

Anti-bacterial Activity

The antibacterial properties of mashed garlic have long been known. Numerous garlic formulations have demonstrated a broad range of antibacterial properties action against both Gram-positive and Gram-negative bacteria, such as *Salmonella, Escherichia, Streptococcus, Staphylococcus, Klebsiella, Proteus, Bacillus,* and *Clostridium* species. Garlic can be harmed by bacteria that are acid-fast, including *Mycobacterium TB* [44]. Additionally, garlic extracts work well against the stomach ulcer-causing bacteria *Helicobacter pylori* [45].

Garlic's antibacterial properties stem primarily from allicin, a sulfur-containing compound produced when garlic is crushed or bruised. Allicin inhibits bacterial growth by reacting with sulfhydryl groups in bacterial proteins, disrupting their enzyme function and disrupting membrane integrity. Garlic extracts have shown effectiveness against a broad range of bacteria, including Gram-positive and Gram-negative strains, even multidrug-resistant bacteria.

Mechanism of Action:

Allicin, the main active compound, is a broad-spectrum antimicrobial agent. It inhibits bacterial DNA gyrase, an enzyme crucial for DNA replication, disrupting essential bacterial functions. Allicin and other garlic compounds can interact with the bacterial cell membrane, increasing its permeability and leading to cell lysis and death. It readily reacts with free thiol groups in bacterial enzymes and proteins, disrupting their function and further hindering bacterial growth. Garlic and its compounds can also inhibit the formation of bacterial biofilms, which are a major cause of bacterial resistance to antibiotic treatments.

Applications:

Garlic extracts and allicin have demonstrated effectiveness against various bacterial infections, including those caused by methicillin-resistant Staphylococcus aureus (MRSA) and other multidrug-resistant bacteria. Garlic can be used as a natural food preservative, helping to inhibit bacterial growth and spoilage in food products. Garlic extracts can enhance the effectiveness of conventional antibiotics, potentially overcoming antibiotic resistance by targeting different mechanisms of bacterial action.

7. Black Pepper

Because of its massive global market share, pepper, also known as *Piper nigrum L.*, is considered the "king of spices [46]. The name "pepper" is derived from the Sanskrit word pippali, meaning berry [47]. A perennial woody aromatic climber, Piper nigrum can grow to a height of 50 to 60 cm [48]. There are differences between black and white peppers in terms of when they are harvested and how they are processed. To obtain white pepper, the pulp from ripe Black pepper is made by drying immature berries, although Black pepper, which contains the pulp after the fruit has wrinkled. There is numerous use for both black and white peppers, such as in herbal medicine, as insecticides, seasonings, and preservatives [49].

Figure 7: Black Pepper

Anti-bacterial Activity

Staphylococcus aureus, Bacillus cereus, and *Streptococcus faecalis* were shown to be the pathogenic Gram-positive organisms that it was most efficient against [50]. Conversely, the Gram-negative Black pepper is known to reduce the susceptibility of certain bacteria, including *Salmonella typhi, Escherichia coli,* and *Pseudomonas aeruginosa* [51]. Furthermore, at a concentration of 10 ml/disc, black pepper aqueous extracts may already have an antibacterial impact due to their capacity to pass through the lipid membranes of Gram-positive bacteria [52,53].

Black pepper's antibacterial mechanism involves damaging bacterial cell membranes, disrupting cellular respiration, and inhibiting key metabolic pathways. This leads to cell membrane damage, leakage of cellular contents, and ultimately cell death. Black pepper extracts and essential oils, particularly piperine and other amides, have been shown to have antibacterial activity against various gram-positive and gram-negative bacteria.

Antibacterial Mechanisms:

Black pepper compounds, like piperine and volatile oils, can disrupt the integrity of bacterial cell membranes by interfering with their lipid structure and permeability. This leads to the leakage of intracellular components and ultimately cell death. Black pepper extracts can interfere with essential bacterial metabolic pathways, such as the tricarboxylic acid cycle (TCA cycle), hindering energy production and survival. Black pepper compounds may denature bacterial proteins, including enzymes involved in cell wall synthesis and other vital functions, leading to cellular dysfunction and death. Some studies suggest that black pepper extracts may also damage bacterial DNA, further contributing to cell death. The antioxidant properties of black pepper may indirectly contribute to its antibacterial activity by neutralizing reactive oxygen species (ROS), which can damage bacterial cells.

Applications:

Black pepper extracts and essential oils can be used to inhibit the growth of spoilage and pathogenic bacteria in food products, extending shelf life and improving food safety. It extracts have shown promise as potential natural antibacterial agents for treating infections, particularly in developing countries where access to conventional antibiotics may be limited. Extract can be used in topical formulations for their potential antimicrobial and wound-healing properties.

Table :1. Traditional uses and Active Constituents Present in Herbal Plants

Sr. no.	Herbal Plants	Traditional Uses	Active Chemical Constituents	Ref
1.	Turmeric	Promoting better digestion, enhancing intestinal flora, getting rid of worms, relieving gas, cleansing and strengthening the liver and gallbladder, restoring menstruation, reducing arthritis and swelling, warming and promoting proper metabolism, applying locally to sprains, burns, cuts, bruises, insect bites, and itches, soothing cough and asthma, acting as an antibacterial and antifungal, and treating any condition involving weakness or debility.	Polyphenolics as curcumin, demethoxycurcumin, and bisdemethoxycurcumins curcuminoids (3-6%)	54, 55
2.	Ginger	Garlic is one of the most significant bulb vegetables and is used as a seasoning and spice in meals. Due to its strong flavor, it is frequently used as a seasoning or condiment all over the world	Garlic includes a variety of sulfur compounds, such as peptides, steroids, terpenoids, flavonoids, phenols, allicin, ajoene, diallyl trisulfide, sallylcysteine, vinyldithiines, and S-allylmercapto-cysteine. Garlic also contains arginine, 17 amino acids, and their glycosides in addition to sulfur compounds	56, 57.
3.	Clove	A useful culinary herb, cloves can be added to salads, soups, herbal teas, tomatoes, and onions. Meat items, cookies, chewing gum, pickles, chocolates, soft drinks, puddings, sandwiches, pastries, and sweets are all flavored with it. Pharmaceuticals, toothpastes, soaps, and fragrances all contain volatile oil as an ingredient. In Indonesia, a unique cigarette known as "Kretek" is made by combining tobacco with cloves in a 1:2 ratio.	The caffeic, ferulic, elagic, and salicylic acids are additional phenolic acids present in cloves. Clove also contains lesser amounts of flavonoids such as kaempferol, quercetin, and its glycosilated derivatives. Clove flower buds contain concentrations of up to 18% essential oil, with eugenol accounting for around 89% of the essential oil and eugenol acetate and β-cariofileno for 5% to 15%	58, 59.
4.	Tulsi	Traditionally, fresh fruit and leaf juice were frequently used as a diuretic and to treat mild upper respiratory tract infections, worm infestations, general stress syndrome, superficial fungal infections, and coughs as a demulcent. The immunomodulatory, antistress, antimicrobial, anti-inflammatory, antiasthmatic, hypoglycemic, hypotensive, and analgesic properties of this plant have all been assessed pharmacologically.	About 71% eugenol and 20% methyl eugenol make up the 0.7% volatile oil found in *Ocimum sanctum* leaves. Carvacrol and the sesquiterpine hydrocarbon caryophyllene are also present in the oil. Phenolic substances (antioxidants) including cirsilineol, circumitritin, isothymusin, apigenin, androsameric acid, as well as significant amounts of eugenol, were found in fresh leaves and stem extract of *Ocimum sanctum.*	60, 64.
5.	Liquorice	Liquorice has been used to treat a wide range of illnesses, including rheumatism, skin conditions, acidity, leucorrhea, bleeding, hemorrhagic diseases, jaundice, coughs, stomach ulcers, heartburn, colic, swellings, asthma, tonsillitis, sore throat, hyperdipsia, flatulence, epilepsy, fever, sexual debility, paralysis, and swellings.It was also historically used as an insecticide, laxative, anti-inflammatory, anti-ulcer, antibiotic, anti-arthritic, antiviral, memory enhancer because of its anti-cholinergic, antitussive, anti-caries, hypolipidemic,	*Glycyrrhiza glabra* Some of the active substances found in L. roots include flavonoids like liquirtin, rhamnoliquirilin, liquiritigenin, prenyllicoflavone A, glucoliquiritin apioside, 1-metho-xyphaseolin, shinpterocarpin, shinflavanone, licopyranocoumarin, glisoflavone, licoarylcoumarin, and coumarin-GU-12, as well as saponins like glycyrrhizin.	65, 71

		anti-mycotic, estrogenic, antioxidant, anticancer, and anti-diuretic properties.		
6.	Garlic	One of the most significant bulb vegetables, garlic has a strong flavor and is used as a seasoning and spice all over the world. Its pungency effects and spicy scent are mostly caused by organosulfur compounds like DADS and allicin. It is often recognized that garlic may be used in both fresh and dehydrated forms while preparing meals, particularly when it comes to dried foods for storage and some kinds of soup.	Hundreds of phytochemicals have been found in *A. sativum* bulbs, including sulfur-containing compounds like ajoenes (E-ajoene, Z-ajoene), thiosulfinates (allicin), vinyldithiins (2-vinyl-(4H) -1,3-dithiin, 3-vinyl-(4H)-1,2-dithiin), sulfides (diallyl disulfide, DATS), and others that made up 82% of the sulfur content of garlic.	72, 73.
7.	Black Pepper	Black pepper has long been utilized in home treatments and traditional medicines in addition to human meals. Constipation, diarrhea, earaches, gangrene, heart disease, hernia, hoarseness, indigestion, insect bites, insomnia, joint pain, liver issues, lung disease, oral abscesses, sunburn, tooth decay, and toothaches can all be treated with black pepper (including long pepper). Although black pepper was used to treat certain ailments including fevers and diarrhea, it seems that its widespread use was to amplify the effects of numerous herbal treatments.	About 1.2–5% of volatile oil and 5–9% of the alkaloids piperine and piperettine are found in black pepper Plants in the genus Piper include a range of chemical compounds, including piperolides, propenylphenols, amides, neolignans, lignans, flavonoids, terpenes, and steroids, according to phytochemical research and advancements in extraction methods and procedures.	74, 76

Conclusion

Natural plants play a crucial role in the search for alternative antibacterial agents, particularly in response to the growing challenge of antibiotic resistance. This review highlights the vast potential of medicinal plants, emphasizing their bioactive compounds such as alkaloids, flavonoids, terpenoids, and polyphenols, which exhibit significant antibacterial properties. These compounds work through diverse mechanisms, including cell membrane disruption, inhibition of bacterial enzymes, and prevention of biofilm formation. Additionally, integrating herbal-based antibacterial formulations into modern therapeutic approaches is gaining traction, presenting a sustainable and effective solution to combat bacterial infections. While the antibacterial potential of medicinal plants is promising, further research, standardization, and clinical validation are essential to ensure their efficacy, safety, and consistent therapeutic application.

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