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A Review: Anti-Bacterial Activity of Some Common Medicinal Plants and Their Active Constituents

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Abstract

Antibiotic resistance is one of the primary issues facing the twenty-first century, and infectious diseases continue to rank as the second greatest cause of mortality globally, despite advancements in the field of antibiotic research. Medicinal plants include a variety of compounds that can be used to create novel medications. The primary source of chemical compounds is the plant kingdom, namely terpenoids, phenols, phenolic acids, and other secondary metabolites alkaloids. Numerous of these substances are tiny molecules that have antibacterial properties. Phyllanthus emblica L. (Amla), Syzygium aromaticum (Clove), Citrus limon L. (Lemon), Cinnamomum verum (Cinnamon), Allium sativum (Garlic), Allium cepa (Onion), Piper betle L. (Betel Leaf), Lawsonia inermis L. (Henna), Zingiber officinale (Ginger), Aegle marmelos (Bael), Carica papaya (Papaya), Spinacia oleracea (Spinach), Sanctum ocimum (Tulsi), and Camellia sinensis (Tea), Azadirachta indica L. (Neem), Coriandrum sativum L. (Coriander), Hibiscus rosa-sinensis L. (China Rose), Tamarindus indica L. (Tamarind), Manihot esculenta (Cassava), Eclipta alba L. (False daisy). The antibacterial properties of these commonly used medicinal plants are studied in this review.

Keywords - Anti bacterial activity, medicinal plants, active constituents, phytochemicals, secondary metabolites, bioactive ingredients.

INTRODUCTION

Plant-based natural resources have been crucial to the creation of novel medications and the improvement of the healthcare system. [1]

World Health Organization estimates that more than 80% of the world's population receives basic medical care from natural resources, with integrated natural resources being used by the remaining 20% of the population. [2]

Of the 252 essential medications that the World Health Organization recognized as essential in the twenty-first century, only 11% were derived from flowering plants. [3]

As of late, natural products have become increasingly important in the fight against cancer and infectious diseases (such as bacterial and fungal infections). [4]

Approximately 41% of the 175 compounds of licensed anticancer medications are natural products or their derivatives, with percentages of 25%, 13%, and 3% coming from medicinal plants, microbes, and animals, respectively. [5]

The use of over 35,000 plant species in different human civilizations for medical purposes has been documented in scientific literature worldwide. [6]

Nevertheless, the actual number of plant species may be substantially greater, as the traditional uses of medicinal herbs are primarily passed down orally from generation to generation and are not well recorded. Slightly more than 5 to 15% of the 250,000 known higher plant species have had their bioactive compounds investigated. [7]

Thus, it can be seen that medicinal plants have primary and secondary metabolites that can be incorporated into micro and nano formulations for application in existing therapies. [8]3

The following common bacteria have been demonstrated to be effectively combatted by medicinal plants

Escherichia coli.

Within the family Enterobacteriaceae, Escherichia coli are gram-negative bacteria that can either cause extraintestinal or intestinal infections, including severe invasive diseases like sepsis and bacteremia, or they can colonize the human gut in a harmless manner. [9]

More often than other major organisms that cause bacteremia, Similar to S.pneumoniae and Staphylococcus aureus, E. coli is the cause of neonates. Drug-resistant novel strains of Escherichia coli pose more therapeutic problems and raise the risk of bacteremia and death. [10]

Figure 1*: *Escherichia coli

Staphylococcus aureus

Thirty percent of healthy individuals carry the gram-positive commensal bacteria Staphylococcus aureus (S. aureus) in various body parts. [11]

It has a major role in the transmission of illnesses in hospitals and the community, ranging from mild to perhaps lethal. The organism spreads. [12]

Illnesses by the possession of many virulent genes that encode various virulent substances, including enzymes and poisons, among others. [13]

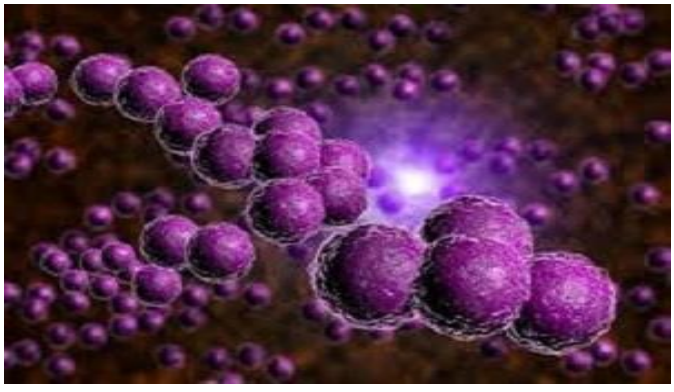

Figure 2*: *Staphylococcus aureus

Salmonella typhi:-

Enterobacter salmonella the gram-negative, rod-shaped, flagellated Salmonella typhi serotype bacterium is known to exist. It has a polysaccharide capsule that gives the bacteria pathogenicity by shielding it from phagocytosis. [14]

The majority of research also shown that, in contrast to Para Typhi infections, Salmonella Typhi bacteria typically exhibit significant resistance to several antibiotics. [15]

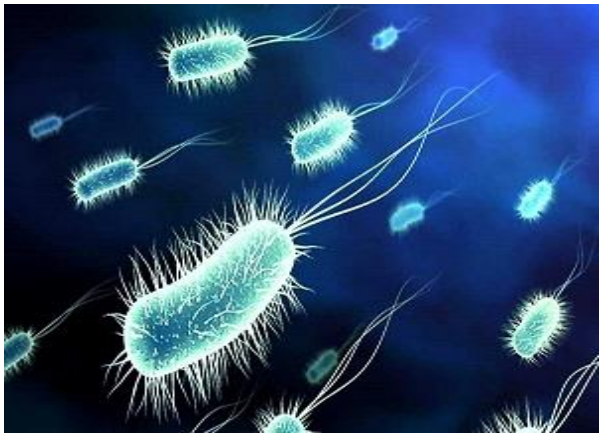

Figure 3*: *Salmonella typhi

Helicobacter pylori

One of the most common pathogens is the gram-negative bacterium Helicobacter pylori in humans; one of the main causes of is Helicobacter pylori a number of gastroduodenal disorders, such as gastric adenocarcinoma, peptic ulcers, chronic gastritis, and MALT lymphoma. [16]

Intricate interplay between host genetics, environmental factors, and bacterial virulence create distinct phenotypes of chronic gastritis. The various illnesses associated with H. pylori infection are explained by these interactions. [17]

Figure 4*: *Helicobacter pylori

Material

Plant acquisition

Randomly selected new plants or fragments of plants were collected. After being cleaned under running water, fresh plant materials were allowed to air dry before being ground into a fine powder and sealed in bottles. [18]

Methods

Crude Extraction

Aqueous Extraction

For six hours at low heat, distilled water was used to extract 10 grammes of dried powder.It was centrifuged for 15 minutes at 5000 g. after being filtered every two hours through layers of muslin fabric. They gathered the supernatant. [19]

After completing these steps twice, after six hours, the supernatant was concentrated to produce a final volume that was one-fourth of the starting volume. It was then autoclaved at 121 degrees Celsius and 15 pounds of pressure before being stored at 4 degrees Celsius. [20]

Solvent Extraction

10 g of dried powder were extracted using 100 ml of ethanol and agitated at 190–220 rpm for a whole day. It was then filtered through eight layers of muslin fabric and centrifuged for 15 minutes at 5000 g. After the solvent evaporated and the supernatant was collected, the final volume was one-fourth of the beginning volume. [21]

It was stored at 4° C in sealed bottles for further investigation. After the solvent evaporated and the supernatant was collected, the final volume was one-fourth of the beginning volume. It was stored at 4°C in sealed bottles for further investigation. [22]

Some common medicinal plants and their active constituents that show antibacterial activities are enlisted as below:

Sr. No.	Botanical names	Local names	Parts	Active constituents
1	Phyllanthus emblica L.	Amla	Fruit	Gallic acid, ellagic acid, tannins
2	Syzygium aromaticum	Clove	Fruit	Eugenol, beta-caryophyllene
3	Citrus limon L.	Lemon	Fruit	Hesperidin
4	Cinnamomum verum	Cinnamon	Bark	Eugenol and cinnamon aldehyde
5	Allium sativum	Garlic	Bulb	Allicin
6	Allium cepa	Onion	Bulb	Quercetin and allicin
7	Piper betle L.	Betel leaf	Leaf	Hydroxychavicol and eugenol.
8	Lawsonia inermis L.	Henna	Leaf	Lawsone
9	Zingiber officinale	Ginger	Rhizome	Shogaol and gingerol
10	Aegle marmelos	Beal	Leaf	Psoralen, lupeol, and marmelosin
11	Carica papaya	Papaya	Leaf	Flavonoids, chymopapain, papain
12	Spinacia oleracea	Spinach	Leaf	Flavonoids, carotenoids
13	Sanctum ocimum	Tulsi	Leaf	Carvacrol, ursolic acid, and eugenol
14	Camellia sinensis	Tea	Leaf	Polyphenols, flavonoids, catechin
15	Azadirachta indica L.	Neem	Leaf	Quercetin, nimbin, and azadirachtin
16	Coriandrum sativum L.	Coriander	Leaf	Linalol, geraniol, and coriandrin
17	Hibiscus rosa-sinensis L.	China rose	Leaf	Flavonoids, tannins, anthocyanins
18	Tamarindus indica L.	Tamarind	Leaf	Polyphenols, flavonoids, tartaric acid
19	Manihot esculenta	Cassava	Leaf	Saponins and cyanogenic glucosides
20	Eclipta alba L.	False daisy	Leaf	flavonoids, wedelolactone, and ecliptine

Table 1*: *Some common medicinal plants and their active constituents with antibacterial activities

***Phyllanthus emblica L.* (Amla)**

The plant Amla (*Phyllanthus emblica L.*), which possesses strong antibacterial qualities, has been thoroughly investigated for its capacity to combat a range of infections. Gallic acid, ellagic acid, and tannins are among the bioactive ingredients of amla that give it its potent antibacterial properties. Recent studies have revealed that amla extracts, particularly methanol and ethanol extracts, significantly suppress the development of bacteria like Escherichia coli, K. pneumoniae, and S.aureus. It was discovered that these extracts were more effective against bacteria than other solvents. [23]

Additionally, a theoretical and experimental investigation showed that amla phytocompounds strengthen the antibacterial action of antibiotics like ampicillin when combined with them. This combination suggests that amla may be used as a supportive therapy to fight resistant types of bacteria. [24]

Figure 5*: *Phyllanthus emblica L. (Amla)

***Syzygium aromaticum* (Clove)**

The antibacterial properties of clove (*Syzygium aromaticum*), a plant with many therapeutic uses, are especially well-known. Clove's antibacterial properties are largely attributed to its active ingredients, which include eugenol, beta-caryophyllene, and acetyl eugenol. Clove extracts have been shown to have strong antibacterial qualities in recent research. [25]

Because cloves can damage bacterial cell membranes, prevent the formation of biofilms, and obstruct vital enzymes, they have an antibacterial impact that causes bacterial cell death. [26]

The extracted clove essential oil was shown to contain a significant amount of antioxidants. which inhibited lipid peroxidation, reduced power, free radical scavenging, and metal chelation. Oil sensitivity was demonstrated by Staphylococcus aurous and Sheila dysenteries. [27]

Figure 6*: *Syzygium aromaticum (Clove)

***Citrus limon L.* (Lemon)**

Citric acid and essential oils found in lemons (*Citrus limon L.*) provide them antimicrobial qualities. Since essential oils, especially limonene, have been demonstrated to damage bacterial cell membranes, citric acid inhibits the growth of bacteria by creating an acidic environment. [28] Lemon's antibacterial properties are attributed to flavonoids like hesperidin, which prevent bacteria from synthesizing their cell walls and from growing as a whole. As a natural antibacterial agent, lemons have been shown in recent research to be effective against a variety of bacterial types [29].

Figure 7*: *Citrus limon L. (Lemon)

***Cinnamomum zeylanicum* (Cinnamon)**

Cinnamomum zeylanicum (Cinnamon) is well known for having strong antibacterial qualities, mostly because of the components of its essential oil, like eugenol and cinnamon aldehyde. [30] According to current research, extracts from Cinnamomum zeylanicum work in concert with antibiotics to increase the effectiveness of the former against forms of bacteria that are resistant to them [31].

***Figure 8**: Cinnamomum zeylanicum (Cinnamon)*

***Allium sativum* (Garlic)**

The sulfur-containing component allicin is largely responsible for the potent antibacterial qualities of garlic (*Allium sativum*). Through the disruption of bacterial cell membranes and the inhibition of essential enzyme activities, allicin demonstrates broad-spectrum antibacterial action. Resistant to methicillin it has been shown that drug-resistant strains of E. coli, K. pneumoniae, and S. aureus (MRSA) are more vulnerable to the antibacterial properties of garlic.[32]

Damage to bacterial cell membranes, prevention of biofilm development, and interference with DNA replication are the mechanisms by which garlic exerts its antibacterial action. Along with impairing vital enzyme activity, it also causes bacterial cells to die. [33]

Figure 9*: *Allium sativum (Garlic)

***Allium cepa* (Onion)**

Allium cepa, or onions, have shown antibacterial properties, mostly because of sulfur-containing substances like quercetin and allicin. These substances interfere with metabolic processes and break down bacterial cell walls to prevent bacterial development. [34]

It has been discovered that onion extracts are efficient against E coli and Salmonella typhimurium, together with other Gram-positive and Gram-negative bacteria like Staphylococcus aurous. [35]

Figure10*: Allium cepa (Onion)*

Piper betle L. **(Betel leaf)**

The Piperaceae family's betel leaf, or Piper betle, is well-known for its potent antibacterial properties, which are mostly attributed to bioactive substances like hydroxychavicol and eugenol. By rupturing bacterial cell walls and preventing vital enzymes from functioning, these substances successfully regulate the development of bacteria. [36]

Efficacy of betel leaf against together with Gram-positive S. aureus and Gram-negative bacteria like Bacillus subtilis, other examples of bacteria include Escherichia coli and Pseudomonas aeruginosa. [37]

Figure 11**:** *Piper betle L. (Betel leaf)*

Lawsonia inermis L. **(Henna)**

The Lythraceae family plant henna, or *Lawsonia inermis L.*, is well-known for its antibacterial qualities, mostly attributed to the chemical lawsone. Enzyme function is hampered and bacterial cell membranes are disrupted by lawsone, which is essential for bacterial viability. [38]

More investigation confirms that henna is efficient against several bacterium species, including S. aureus, E. coli, and Pseudomonas aeruginosa. These results demonstrate henna's potential as a broad-spectrum, naturally occurring antibacterial agent. [39]

Figure 12*: *Lawsonia inermis L. (Henna)

***Zingiber officinale* (Ginger)**

The Zingiberaceae family, which includes ginger (Zingiber officinale), is well recognised for its Antibacterial properties, mainly because of its active ingredients, which include shogaol and gingerol. It is well known that these substances obstruct the metabolic processes and bacterial cell membranes. [40]

In order to kill germs, ginger's antibacterial effect damages bacterial cell membranes, inhibits the formation of biofilms, and interferes with protein synthesis. [41]

Interestingly, studies have demonstrated the efficacy of ginger against Shewanella putrefaciens, Gram-negative bacteria linked to illnesses and food spoiling. [42]

Figure 13*: *Zingiber officinale (Ginger)

***Aegle marmelos* (Bael)**

Bael belongs to the Rutaceae family and is often referred to as Aegle marmelos and possesses significant antibacterial qualities. Its antibacterial effectiveness is attributed to its bioactive constituents, which also include psoralen, lupeol, and marmelosin. [43]

Extracts from Aegle marmelos are effective against a variety various bacterial illnesses, such as those caused by E. coli, Staphylococcus aureus, and P. aeruginosa.
Research has also demonstrated how it works against bacteria that are resistant to drugs, making bael a potentially effective natural antibacterial agent. [44]

Figure 14*: *Aegle marmelos (Bael)

***Carica papaya* (Papaya)**
Within the *Caricaceae* family, *Carica papaya* is known for its characteristics that make it antimicrobial because of strong bioactive components chymopapain, papain, and flavonoids, for example. These substances interfere with the bacterial cell membranes and impede their development. [45]
Strong antibacterial properties of *Carica papaya* are demonstrated against Salmonella typhi, Escherichia coli, and Staphylococcus aureus. Its extracts have a great deal of promise as a home treatment, especially for bacterial illnesses that are resistant to medications. [46]

Figure 15*: *Carica papaya (Papaya)

***Spinacia oleracea* (Spinach)**
The plant *Spinacia oleracea*, or spinach, is a member of the *Amaranthaceae* family. Its antibacterial activities are partly due to the existence of bioactive substances such carotenoids, phenolic acids, and flavonoids. They work well against several types of bacterial strains. [47]
Strong antibacterial activity of *Spinacia oleracea* extracts have been shown against pathogenic microorganisms such as Salmonella enterica and Escherichia coli. Because it naturally contains

antimicrobial components, spinach is valued as a natural resource for food safety applications and as a possible antibacterial agent to promote health. [48]

Figure 16*: *Spinacia oleracea (Spinach)

***Sanctum ocimum* (Tulsi)**

Ocimum sanctum, popularly known as holy basil or Tulsi, is a plant that belongs to the Lamiaceae family. It is well known for having antibacterial qualities because to substances including carvacrol, ursolic acid, and eugenol. [49]

Ocimum sanctum is a good remedy for bacterial infections, including Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. These results highlight its potential as a natural antibacterial agent that may be used for therapeutic and medical purposes. [50]

Figure 17*: *Sanctum ocimum (Tulsi)

***Camellia sinensis* (Tea)**

The Theaceae family plant Camellia sinensis is well-known for its antibacterial properties since it contains polyphenols, flavonoids, and catechin. [51]

Escherichia coli, Staphylococcus aureus, and Helicobacter pylori are just a few of the bacterial pathogens that extracts from Camellia sinensis have been shown to be effective against. Due to its antibacterial qualities, it may be used to prevent foodborne illnesses and is very helpful in medical treatments. [52]

Figure 18*: *Camellia sinensis (Tea)

***Azadirachta indica L.* (Neem)**

One plant in the Meliaceae family that is well-known for its antibacterial qualities is neem, or Azadirachta indica. This is mainly because to bioactive substances such as quercetin, nimbin, and azadirachtin. [53]

Through the disruption of bacterial cell membranes, inhibition of enzyme functions, and disruption of metabolic pathways that result in cell death, neem demonstrates antibacterial action through its bioactive components. [54]

Strong antibacterial qualities of neem have been demonstrated against pathogens such Pseudomonas aeruginosa, Escherichia coli, and Staphylococcus aureus. It is a viable candidate for medical usage for the creation of novel antibacterial medicines due to its naturally occurring antimicrobial components. [55]

Figure 19*: *Azadirachta indica L. (Neem)

***Coriandrum sativum L.* (Coriander)**

Coriandrum sativum, often known as coriander, is a plant in the Apiaceae family. Bioactive substances with antibacterial properties, including linalool, geraniol, and coriandrin, are present in it. [56]

Coriander extracts have been shown to be effective against strains of Salmonella enterica, Escherichia coli, and Staphylococcus aureus. Due to its ability to fight microbes, it can be used in both medical and food preservation purposes. [57]

Figure 20*: *Coriandrum sativum L. (Coriander)

***Hibiscus rosa-sinensis L.* (China Rose)**

A member of the Malvaceae family, Hibiscus rosa-sinensis is sometimes referred to as the China Rose. Bioactive substances found in the plant; including flavonoids, tannins, and anthocyanins, have significant antibacterial qualities these compounds cause the bacterial cell wall to become compromised, which leads to cell death. [58]

Antimicrobial agents including Pseudomonas aeruginosa, it has been noted that Hibiscus rosa-sinensis extracts have an impact on Escherichia coli and S. aureus. Because of its antibacterial properties, China Rose has long been used as a treatment for wounds, skin conditions, and UTIs.[59]

Figure 21*: *Hibiscus rosa-sinensis L. (China Rose)

***Tamarindus indica L.* (Tamarind)**

The Fabaceae family includes *Tamarindus indica*, often known as the tamarind. Tartaric acid, flavonoids, and polyphenols are examples of bioactive compounds that provide it antibacterial properties. [60]

It has potency against Salmonella typhi, Escherichia coli, and Staphylococcus aureus, among other bacterial infections. Tamarind's antibacterial qualities have long been used to cure infections and control digestive issues, such as gastroenteritis and diarrhea. [61]

Figure 22*: *Tamarindus indica L. (Tamarind)

***Manihot esculenta* (Cassava)**

Commonly referred to as cassava, Manihot esculenta is a member of the Euphorbiaceae family. The substance's antibacterial properties are believed to be caused by saponins and cyanogenic glucosides, which break down bacterial cell membranes and halt development. [62]

Due to its antimicrobial qualities, cassava has long been used to heal wounds and gastroenteritis and is a potential candidate for the development of natural antibacterial medicines. [63]

Figure 23*: *Manihot esculenta (Cassava)

***Eclipta alba L.* (False daisy)**

The false daisy, or Eclipta Alba, belongs to the family Asteraceae. Because it contains bioactive substances such flavonoids, wedelolactone, and ecliptine, it is well known for having antimicrobial qualities.

It works well against a variety of bacterial infections, such as E. coli, Staphylococcus aureus, and pseudomonas aeruginosa. Due to its antimicrobial qualities, it may be used to treat ailments including respiratory infections, wounds, and skin infections. [64]

Figure 24*: *Eclipta alba L. (False daisy)

CONCLUSION

Finally, the review article underscores the noteworthy capacity of medicinal plants can serve as sources of antibacterial compounds, especially considering the increasing problem of antibiotic resistance. By elucidating mechanisms of action and identifying the active pharmaceutical ingredients (APIs) present in these plants, the article reinforces the value of integrating traditional herbal knowledge with modern pharmacological research.

The detailed exploration of various plants, including their biological names and family classifications, provides a clear framework for understanding their therapeutic properties. Compounds such as flavonoids, alkaloids, and terpenoids exhibit diverse modes of action, ranging from disrupting bacterial cell membranes to inhibiting critical enzymatic pathways. This multifaceted approach highlights the complexity and effectiveness of plant-based treatments.

Ultimately, the review advocates for a paradigm shift in how we view and utilize natural products, positioning medicinal plants not just as traditional remedies but as integral components of modern healthcare strategies. This holistic approach could lead to creative fixes that not only treat the bacterial illnesses of today but also open the door to the creation of new therapeutic agents.

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