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Traditional Medicinal Plants

Chief Editor
Dr. P. Shivakumar Singh

Volume - 10



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Traditional Medicinal Plants

Volume - 10

Chief Editor

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Message



Prof. LB Laxmikanth Rathod
Vice Chancellor

I am immensely happy to know that, Dr. P Shivakumar Singh, Department of Botany, Palamuru University has authored the Book entitled “Traditional Medicinal Plants Vol. 8”. I congratulate him for his academic dedication. I hope this book will be useful for the faculty, students of plant science and interdisciplinary studies of life sciences.

I am sure the volumes books have all the content and wisdom in the related areas and will prove highly useful in enriching the knowledge and skill of readers.

I convey my best wishes and hope the author will come out with many more such works in the days to come.

I also appreciate AkiNik Publishers for their effort in volumes of books.

A handwritten signature in purple ink, consisting of stylized initials 'LB' followed by a horizontal line extending to the right.

Vice Chancellor

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Chapter - 6

Plants used as Antimicrobial Agents

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Chapter - 6

Plants used as Antimicrobial Agents

Dinesh Kumar, Navneet Verma, Sushil Kumar, Anesh Sagar and Kavya Vishnoi

Abstract

The increase incidence of resistance to synthetic antimicrobial has prompted the hunt for new antimicrobial agents, notably from natural sources such as medicinal plants. Traditional medicine has made extensive use of plants' antibacterial qualities, and research has shown that several plant extracts are beneficial against viral, bacterial, and fungal illnesses. Several medicinal plants' antibacterial properties, bioactive chemicals, and their uses in contemporary medicine are examined in this article.

Keywords: Antimicrobial, traditional medicine, alkaloids, phenolics, flavonoids etc.

Introduction

Plants are unquestionably one of the most important sources of antimicrobials. Plants derived phytoconstituents are very active against numerous infectious diseases for many years and saved millions of lives. Synthetic drugs produce many adverse effects due to this reason scientist going to the natural antimicrobial because natural antimicrobial produced less adverse effects as compare to synthetic antimicrobial. It is estimated that there are 2,50,000 to 5,00,000 species of plants on earth ^[1].

Alternative natural antimicrobial agents are being investigated as a result of the growing resistance of microorganisms to traditional antibiotics. Alkaloids, flavonoids, tannins, and essential oils are just a few of the many secondary metabolites that are known to be produced by plants and have strong antibacterial qualities. Discussing the antibacterial properties of specific medicinal plants and their bioactive components is the aim of this review.

Relatively small percentage (1 to 10%) of these are used as foods by both humans and other animal species. It is possible that even more are used for medicinal purposes ^[2].

Major classes of antimicrobial compounds from plants

Plant-derived antimicrobials belong to various chemical classes, each with distinct mechanisms of action against bacteria, fungi, and viruses. The major classes include:

Phenolics and polyphenols

Phenolics and polyphenols are the large class of compounds with strong antimicrobial properties. Phenolics are phytoconstituents having single substituted phenolic rings (Fig.1) Cinnamic acid and caffeic acids are common example of phenolics.

Phenolic compounds are naturally found in plants, where they serve as a defense mechanism against pathogens. Natural phenolic compounds are secondary metabolites produced by plants for numerous functions including antimicrobial defence. Different types of phenolic compounds, including phenolic acids (like gallic acid), flavonoids, and stilbenes, tannins, can inhibit the growth and activity of many microorganisms, including food-related pathogens as well as clinically important bacteria, fungi and protozoa [3, 4]. Some examples of phenolics and polyphenols as antimicrobial are listed in table 1.

Mechanism of action

Membrane disruption: Phenolics can interact with the cell membrane of microbes, causing damage and leakage of cellular components.

Enzyme inhibition: They can inhibit key enzymes necessary for microbial survival, disrupting metabolic processes.

Biofilm disruption: Some phenolic compounds can interfere with the formation of bacterial biofilms, which are important for microbial colonization.

Potential applications

Food preservation: Due to their antimicrobial activity, phenolic compounds can be used as natural preservatives in food products.

Wound care: Topical applications of phenolic compounds might be beneficial in wound healing by inhibiting microbial growth.

Drug development: Research is ongoing to develop new antimicrobial drugs based on phenolic compounds, particularly to address antibiotic resistance issues [4].

Table 1: Examples of phenolics and polyphenols as antimicrobials

Plant source	Phenolics	Active against
Coffee	Caffeic Acid	<i>Salmonella species</i>
Green tea, grapes	Gallic Acid	<i>Listeria monocytogenes</i>
Tea, grapes, pomegranates	Tannins	<i>E. coli, S. aureus</i>

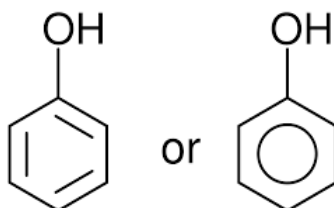


Fig 1: Basic structure of phenolics

Quinones

Quinones from plants have antimicrobial properties and are also used as anticancer, antioxidant, antimalarial, and anti-inflammatory agents. Quinones are aromatic ring compounds with two ketone substitutes (Fig. 2). These are extensively found in plants and produce antibacterial, antifungal and antiviral activities [5, 6, 7]. Some examples of quinone as antimicrobial are listed in table 2.

Major types of quinones in plants

Benzoquinones: Found in *Tectona grandis* (teak) and *Plumbago* species.

Naphthoquinones: Present in *Juglans regia* (walnut), *Lawsonia inermis* (henna), and *Diospyros* species.

Anthraquinones: Found in *Aloe vera*, *Rheum palmatum* (rhubarb), and *Cassia* species.

Table 2: Examples of quinone as antimicrobials

Plant source	Quinone	Active against
<i>Aloe vera</i>	Aloin	<i>E. coli</i> and <i>Salmonella</i>
<i>Rheum palmatum</i> (rhubarb)	Rhein	<i>H. pylori</i>
<i>Lawsonia inermis</i> (henna)	Lawsonone	<i>Aspergillus</i> and <i>Candida</i> species
<i>Juglans regia</i> (walnut)	Juglone	<i>Pseudomonas aeruginosa, Bacillus subtilis</i>
<i>Plumbago zeylanica</i>	Plumbagin	<i>Staphylococcus aureus, E. coli, Candida albicans</i>

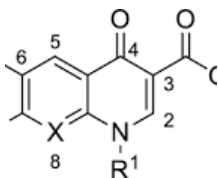


Fig 2: Basic structure of quinones

Flavonoids

Flavones, flavanols and flavonols all are flavonoids. These are polyphenolics that have C₆-C₃- C₆ structure (Fig. 3). These are found in plants and produce numerous pharmacological activities especially antimicrobial activity.

Major classes and their antimicrobial properties

Flavones: Found in parsley, celery, and chamomile, flavones such as apigenin and luteolin exhibit antibacterial properties against *Staphylococcus aureus* and *Escherichia coli*.

Flavanols (Catechins): Present in green tea, cocoa, and grapes, catechins have been shown to inhibit *Helicobacter pylori* and *Candida albicans*.

Flavonols: Found in onions, kale, and berries, flavonols like quercetin and kaempferol act against *Pseudomonas aeruginosa* and *Bacillus subtilis* by disrupting bacterial membranes and inhibiting biofilm formation [8, 9, 10]. Some examples of flavonoids as antimicrobial are listed in table 3.

Table 3: Examples of flavonoids as antimicrobials

Plant source	Flavonoids	Active against
Onions, Kala, Berries	Quercetin	<i>P. aeruginosa</i> , <i>B. subtilis</i>
Green tea, cocoa	Catechin	<i>H. pylori</i> , <i>c. albicans</i>
Spinach, broccoli	Kaempferol	<i>E. coli</i> , <i>S. aureus</i>
Green peppers, Celery	Luteolin	<i>Salmonella species</i>
Chamomile	Apigenin	<i>S. aureus</i> , <i>E. coli</i>

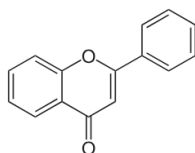


Fig 3: Basic structure of flavonoids

Tannins

Tannins are complex compounds and are found in many plants. These are derivatives of Gallic acid (Fig. 4). Tannins have various biological activities such as antibacterial, antioxidant, antitumor etc. Some examples of tannins as antimicrobial are listed in table 4.

Table 4: Examples of tannins as antimicrobial

Plant source	Tannins	Active against
Pomegranates, walnuts	Ellagitannins	<i>E. coli</i> , <i>S. aureus</i>
Grapes, tea	Condensed Tannins	<i>Candida albicans</i> , <i>Listeria monocytogenes</i>
Oak bark, sumac	Gallotannins	<i>Salmonella species</i> , <i>Pseudomonas aeruginosa</i>

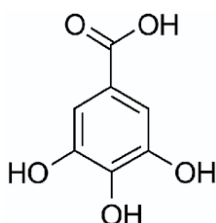


Fig 4: Basic structure of tannins

Coumarins

Chemically, coumarins are aromatic organic compounds that are made of benzene and α -pyrone rings. The chemical formula for coumarin is $C_9H_6O_2$ (Fig. 5). Coumarins are found in many plants, including tonka beans, strawberries, cinnamon, and lavender oil. They are very useful as antimicrobial^[11]. Some examples of coumarins as antimicrobial are listed in table 5. (Borges *et al.*, 2013).

Table 5: Examples of coumarin as antimicrobials

Plant source	Coumarin	Active against
Tonka beans	Warfarin	<i>Pseudomonas aeruginosa</i>
Clove, Cinnamon	Umbelliferone	<i>Candida albicans</i> , <i>Aspergillus species</i>
<i>Angelica archangelica</i>	Scopoletin	<i>E. coli</i> , <i>S. aureus</i>

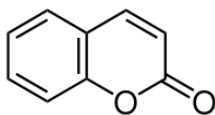


Fig 5: Basic structure of coumarin

Terpenoids and essential oils

Terpenoids and Essential oils are a class of naturally occurring organic compounds. They are known for their strong odors. They are derived from isoprene, a 5-carbon molecule (Fig. 6). They are classified into monoterpenes, sesquiterpenes, diterpenes, triterpenes, and more. They have many biological activities, including anti-inflammatory, antibacterial, and antiviral properties [12, 13]. Some examples of terpenoids and essential oils as antimicrobial are listed in table 6.

Table 6: Examples of terpenoids and essential oils as antimicrobial

Plant source	Phytoconstituents	Active against
Peppermint (<i>Mentha piperita</i>)	Menthol	<i>P aeruginosa</i> , <i>L monocytogenes</i>
Clove (<i>Syzygium aromaticum</i>)	Eugenol	<i>Aspergillus species</i>
Oregano (<i>Origanum vulgare</i>)	Carvacrol	<i>Escherichia coli</i> , <i>Salmonella species</i>
Thyme (<i>Thymus vulgaris</i>)	Thymol	<i>Staphylococcus aureus</i> , <i>Candida albicans</i>

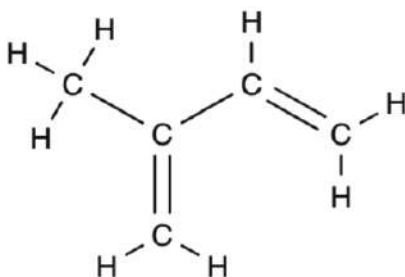


Fig 6: Basic structure of terpenoids

Alkaloids

Alkaloids are a group of naturally occurring organic compounds that contain nitrogen atoms. They are mainly found in plants and are the most biologically active group of compounds in plants [14]. Basic structure of some alkaloidal compounds (Fig. 7). Some examples of alkaloids as antimicrobial are listed in table 7.

Table 7: Examples of alkaloids as antimicrobial

Plant source	Alkaloids	Active against
<i>Hydrastis canadensis</i>	Berberine	<i>Staphylococcus aureus, Escherichia coli</i>
<i>Sanguinaria canadensis</i>	Solanine	<i>Streptococcus mutans, Candida albicans</i>
Nightshade	Sanguinarine	Fungus and Bacteria
Cinchona	Quinoline Alkaloids	<i>Plasmodium species, Mycobacterium tuberculosis</i>

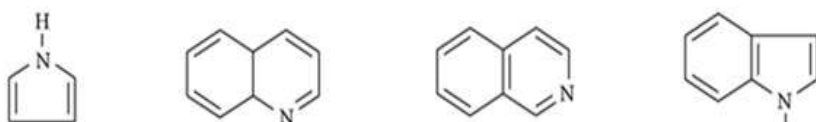


Fig 7: Basic structure of some alkaloidal compounds

Lectins and Polypeptides

Lectins and polypeptides, particularly antimicrobial peptides (AMPs), can both act as antimicrobial agents by binding to specific molecules on the surface of pathogens, disrupting their cell membranes, and ultimately inhibiting their growth; with lectins primarily targeting carbohydrates on microbial surfaces while AMPs interact with the cell membrane through various mechanisms depending on their structure and sequence [15]. Some examples of lectins and polypeptides as antimicrobial are listed in table 8 and list of some well-established plants as antimicrobial is listed in table 9.

Table 8: Examples of Lectins and polypeptides as antimicrobial

Plant source	Lectins and polypeptides	Active against
Rubiaceae family	Cyclotides	<i>Staphylococcus aureus</i>
Jack bean	Concanavalin A	<i>E. coli</i> and <i>Candida albicans</i>
Various plants	Defensins	Bacteria and Fungus

Table 9: List of Some well-established Plants Having Antimicrobial activity

Scientific name	Common name	Class	Compounds	Active against	Reference
<i>Withania somniferum</i>	Ashwagandha	Lactone	Withaferin A	Bacteria, Fungi	[16]
<i>Aegle marmelos</i>	Bael Tree	Terpenoids	Essential oil	Fungi	[17]
<i>Malus sylvestris</i>	Apple	Flavonoids	Phloretin		[16]
<i>Piper nigrum</i>	Black pepper	Alkaloids	Piperine	Fungi, <i>E. coli</i> , <i>Lacto bacillus</i>	[18]
<i>Carum carvi</i>	Caraway	Coumarin		Bacteria, Fungi, Viruses	[19]

<i>Anacardium pulsatilla</i>	Cashew	Polyphenol	Salicylic acids	Bacteria, Fungi	[20]
<i>Syzygium aromaticum</i>	Clove	Terpenoids	Eugenol	General	[21]
<i>Anethum graveolens</i>	Dill	Terpenoids	Essential Oil	Bacteria	[21]
<i>Eucalyptus globulus</i>	Eucalyptus	Polyphenolics	Tannins	Bacteria, Virus	[21]
<i>Allium sativa</i>	Garlic	Terpenoids	Allicin	General	[21]
<i>Panax Ginseng</i>	Ginseng	Saponins		<i>E. coli</i> , <i>Staphylococcus</i>	[21]
<i>Citrus paradisa</i>	Grapefruit peel	Terpenoids		Fungi	[21]
<i>Camellia sinensis</i>	Green Tea	Flavonoids	Catechin	General	[21]
<i>Lawsonia inermis</i>	Henna	Phenolics	Gallic acid	<i>S. aureus</i>	[21]
<i>Glycyrrhiza glabra</i>	Liquorice	Phenolics	Glabrol	<i>S. aureus</i> , <i>M. tuberculosis</i>	[21]
<i>Quercus rubra</i>	Oak	Tannins	Tannins		[21]
<i>Allium cepa</i>	Onion	Sulfoxide	Allicin	Bacteria	[21]
<i>Carica papaya</i>	Papaya	Terpenoids, Alkaloids	Latex	General	[21]
<i>Mentha piperita</i>	Peppermint	Terpenoids	Menthol	General	[21]
<i>Vinca minor</i>	Periwinkle	Alkaloids	Reserpine	General	[21]
<i>Cinchona Sp.</i>	Quinine	Alkaloids	Quinine	Plasmodium	[21]
<i>Cassia augustifolia</i>	Senna	Anthraquinone	Rhein	<i>S. aureus</i>	[21]
<i>Hypericum perforatum</i>	St. John's wort	Anthraquinone	Hypericin		[21]
<i>Curcuma longa</i>	Turmeric	Terpenoids	Curcumin	Bacteria, protozoa	[21]
<i>Rosmarinus officinalis</i>	Rosemary	Terpenoids	Essential oil	General	[21]
<i>Rauvolfia serpentina</i>	Rauvolfia	Alkaloids	Reserpine	General	[21]

Conclusion

Plant-derived antimicrobials represent a promising alternative to synthetic antibiotics, particularly in combating antibiotic resistance. Their diverse mechanisms of action and broad-spectrum activity make them valuable for future drug development.

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