THE CHEMISTRY INSIDE SPICES & HERBS: RESEARCH AND DEVELOPMENT

VOLUME 7

Editors:

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The Chemistry Inside Spices & Herbs: Research and Development

(Volume 7)

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CONTENTS

FOREWORD

"**The Chemistry Inside Spices & Herbs: Research and Development (Volume 7)**" is a unique collection of nine pharmacologically valuable chapters written by international and national experts in the field. Each chapter is developed on an admirable topic and is full of scientific information. Chapter 1 explores the nanotechnology unlocking the potential of herbal therapeutics. Chapter 2 describes the role of Indian spices in targeting cellular oxidative stress and associated diseases. Chapter 3 elaborates on the herb-based biosensors in analytical applications. Descriptive approach on the phytochemical and medicinal roles of some specific medicinal plants like *Celastrus paniculatus, Elsholtzia* species, *Tinospora* species, *Curcuma longa* L., *Salvia rosemarinus* (rosemary), and *Boerhaavia diffusa* provides excellent literature for the researchers and scientists interested in the field of phytochemistry and phytochemical medications.

A comprehensive approach to the various informative topics related to the plant sciences makes this volume highly interesting and an essential reference book.

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PREFACE

This book, **Volume 7** of the book series **"The Chemistry Inside Spices & Herbs: Research and Development"**, presents miscellaneous roles of phytochemistry in the form of nine chapters written by experts in the field, with extensive discussion and assessment of herbal medication. This volume deals with the comprehensive information on nanotechnology in the field of herbal medication, spices as antioxidants, herb-based biosensors, detailed phytochemistry, and medicinal applications of *Celastrus paniculatus, Elsholtzia* genus, *Tinospora, Curcuma longa* L., *Salvia rosemarinus* (rosemary), and Boerhaavia diffusa.

Chapter 1, by Noor and Kohli delves into the role of various herbal medicine-based Nanoformulations like Phytosomes, Solid lipid carriers (SLNs), Nanostructured Lipid Carriers (NLCs), Nanoemulsions, Nanogels, Polymeric nanoparticles, etc, bypassing the limitations of herbal medicines like bioavailability, solubility, stability, and therapeutic activity. The chapter also covers the latest advancements in nanotechnology, which not only overcome the key challenges of herbal medicines but also convert them into safer, sustainable, and effective formulations. The chapter explores the futuristic opportunities for herbal drug delivery, implementing nanotechnology as the key to unlock the power of herbal therapeutics.

Chapter 2, written by Adhikary *et al*, reviews a multitude of spice compounds as exogenous antioxidants that have been corroborated to control cellular oxidative stress and their roles in ameliorating concomitant disease conditions.

Chapter 3, by Halpani *et al* focuses on the progress of various herb-based biosensor and their advances in biosensing applications and development in analytical science over the last three decades. It also highlights the construction, mechanism, and key characteristics of biosensors based on herbs, as well as discussing their properties, limitations, and future perspectives.

Chapter 4, by Kolambkar *et al* delves into the ethnopharmacological applications, phytochemical profile, and diverse pharmacological activities of *Celastrus paniculatus* Wild (CP.).

Chapter 5, by Sahu *et al* comprehensively explores the phytochemical and pharmacological properties and applications of the *Elsholtzia* genus.

Chapter 6, by Kumar *et al* aims to review phytochemistry and pharmacology of Tinospora with emphasis on bioactive compounds and contending pharmacological behaviours. It focuses on techniques used in isolating and chemically characterizing these compounds. In addition, the chapter revisits the current and prospective clinical uses, toxicity profile, and possible future investigations of *Tinospora*-derived drugs.

Chapter 7, written by Riaz *et al*, presents a very comprehensive assessment of the chemistry and biology of *Curcuma longa* L. This chapter also provides an up-to-date chemical synthesis of curcumin and its major pharmaceutical natural products, along with its derivatives/analogs. This work provides phytochemistry, pharmacology, synthesis, and essential oils from *C. longa.* It provides relevant scientific data to facilitate medicinal chemistry research for designing and developing new molecular medicine and nutraceuticals.

Chapter 8, written by Kumar and co-authors, provides a comprehensive update of the phytochemistry of rosemary (*Salvia rosemarinus*) plants and pharmacological effects of its phyto-compounds.

Chapter 9, created by Shil *et al*, presents a comprehensive overview of phytochemistry and pharmacological applications of *Boerhaavia diffusa*, a perennial creeping plant belonging to the Nyctaginaceae family. The study provides a comprehensive overview of the phytochemical and pharmacological properties of *Boerhaavia diffusa*, offering valuable insights for students, academicians, and future research.

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CHAPTER 1

Nanotechnology: A Laudable Key to Unlock the Potential of Herbal Therapeutics

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Abstract: Nanotechnology serves as a plausible tool for the transformation of traditional medicines into high-precision therapeutics with unmatched efficacy. Nanotechnological approaches bridge the gap between ancient knowledge and modern science, enabling the transformation of herbal medicines in terms of bioavailability, potency, and enhanced therapeutic activity. The chapter examines the role of various herbal medicine-based nanoformulations—such as phytosomes, Solid Lipid Nanoparticles (SLNs), nanostructured lipid carriers (NLCs), nanoemulsions, nanogels, and polymeric nanoparticles—in overcoming key limitations of herbal medicines, including poor bioavailability, low solubility, instability, and reduced therapeutic efficacy. The chapter also covers the latest advancements in nanotechnology, which not only overcome the key challenges of herbal medicines but also convert them into safer, sustainable, and effective formulations. The chapter explores future prospects in herbal drug delivery, highlighting nanotechnology as a crucial approach for unlocking the therapeutic potential of herbal medicines.

Keywords: Enhanced bioavailability, Herbal nanomedicine, Inorganic nanoparticles, Lipid-based nanocarriers, Nanotechnology, Polymeric nanoparticles, Quality, Regulatory aspects, Safety, Techniques.

INTRODUCTION

The use of herbal medicines has been trusted since ancient times due to their safety, affordability, therapeutic properties, and high acceptance in the general population. Herbal medicines are recognized worldwide because of their low toxicity and feasibility compared to conventional medicines. The growing popularity of herbal medicines is largely attributed to safety concerns associated with synthetic drugs, the limited effectiveness of many conventional treatments

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

for common health disorders, and the proven therapeutic efficacy and lower toxicity of herbal remedies. Studies have also shown that conventional drug delivery mainly suppresses symptoms, ignoring the underlying cause of the disease [1]. However, various challenges, including instability, poor solubility, limited absorption, and low bioavailability, hinder the pathway of herbal therapeutics. While overcoming these challenges, nanotechnology offers a solution for the hurdles faced by herbal therapeutics.

The enhanced therapeutics of herbal medicines are magnified by the lens of nanotechnology in an unprecedented way. Nanotechnology serves as a promising tool for enhancing the therapeutic efficacy and precision of herbal medicines. It increases stability, solubility, pharmacological activity, and resistance to degradation from physical and chemical environments, reduces toxicity, enhances tissue macrophage localization, and provides sustained and targeted delivery [2]. Reduction of size to the nanoscale overcomes the various challenges faced by herbal medicines and augments their solubility, stability, and bioavailability. Herbal medicines are also easily degraded by acidic gastric pH and metabolized by the liver, which hinders the attainment of the desired minimum effective concentration and reduces their therapeutic activity simultaneously [1]. A decrease in therapeutic activity also results in the consumption of large doses to achieve the desired effects [3]. Nowadays, various in silico tools are useful for the initial screening of herbal compounds and predicting their activity on various targets, which can be utilized as an initial step for nanotechnology-based herbal drug development [4]. Nanotechnology encompasses a range of advanced drug delivery systems—such as phytosomes, nanoemulsions, liposomes, herbosomes, and nanoparticles—that help overcome the inherent limitations of herbal therapeutics and enable therapeutic outcomes.

RATIONALE FOR INTEGRATING NANOTECHNOLOGY FOR MODERNIZING HERBAL TREATMENTS.

Reduce Toxicity

Many herbal extracts contain solvents like methanol, chloroform, and acetone, which are harmful for consumption. It is unsuitable for consumption and can cause toxic effects on the body. By incorporating it into a novel drug delivery system, this issue can be resolved, and toxicity can be reduced [5].

Dose Reduction

Herbal compounds are primarily bulk drugs, so they cannot be delivered in bulk amounts; an optimized dose incorporated into a suitable formulation is required for better therapeutic activity with minimal side effects [5].

Treatment of Chronic Diseases

Conventional dosage forms, which are available commercially, face issues with target specificity and resistance, as well as in various antibiotic treatments. Herbal bioactives incorporated into nanocarriers can serve as alternative therapies for the treatment of various chronic diseases for which conventional treatments fail to deliver the desired therapeutic activity [5].

Bioavailability Enhancement

Herbal bioactives often face permeability and solubility issues, which decrease their bioavailability. Owing to its nanoscale dimensions, nanotechnology reduces the size of bioactive compounds, enhances their permeability through target membranes, and improves solubility and absorption as a result of the increased surface area. All these factors lead to increased bioavailability [5].

Degradation

Herbal extract undergoes degradation from the acidic pH of the gastric environment, biological fluids, and enzymes. Nanotechnology-based drug delivery acts as a shield for herbal compounds, protecting them from degradation, and delivers the bioactive compounds to specific targets without loss of their inherent therapeutic activity [5].

Patient Compliance

Lower efficacy and a large dose lead to less patient compliance. With the aid of nanotechnology, the dose can be reduced, dosing frequency is reduced, and efficacy also increases, leading to more patient compliance [5].

The advantages of nanotechnology-based herbal drug delivery are depicted in Fig. (**1**).

TECHNIQUES FOR NANOTECHNOLOGY-BASED HERBAL DRUG DELIVERY

Nanotechnology-based herbal drug delivery can be made through the following commonly used techniques [6]:

Homogenization Method (High Pressure)

The homogenization technique involves high shear of 100 to 2000 bar pressure, which breaks the particles into a nano-sized. It is a secure, effective method for bulk manufacturing of nanocarriers like nanostructured lipid carriers,

CHAPTER 2

Targeting Cellular Oxidative Stress and Associated Diseases through Indian Spices: A Review

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Abstract: Antioxidants are important to the cells as they are involved in scavenging free radicals. When the rate of free radical production in the cells is greater than the rate of clearance, the cell is considered to be under oxidative stress. A number of disease conditions, including several inflammatory diseases, cancer progression, and cardiovascular diseases, are associated with oxidative stress. Indian cuisine is famous for its extensive use of spices, which are used to enhance the taste, aroma, and colour of the preparation. Interestingly, spices are also a rich source of antioxidants. The phytochemicals, primarily consisting of phenolic compounds, flavonoids, sulfur-containing compounds, phenolic diterpenes, alkaloids, tannins, and vitamins present in spices, exhibit antioxidant properties. Their antioxidant function is brought about by redox properties and their ability to obstruct Reactive Oxygen Species (ROS) production. Therefore, many phytochemicals are of great interest to modern researchers, who aim to explore their therapeutic potential for tailored clinical applications. This paper reviews a multitude of spice compounds that have been corroborated as exogenous antioxidants, which have been shown to control cellular oxidative stress and show immense potential in ameliorating concomitant disease conditions.

Keywords: Antioxidants, Flavonoids, Oxidative stress, Polyphenols, ROS, Spices.

INTRODUCTION

The disparity between the yield and subsequent build-up of Reactive Oxygen Species (ROS) in cells and their competence to neutralize and scavenge them coalesce into the generation of oxidative stress. ROS are stereotypically yielded as

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

byproducts of the metabolism of oxygen. Nonetheless, environmental irritants, such as pollutants, UV radiation, ionizing radiation, heavy metals, and certain xenobiotics, significantly promote ROS production [1]. Oxidative stress exerts roles in carcinogenesis as well as in various diseases, such as Chronic Obstructive Pulmonary Disease (COPD), atherosclerosis, Alzheimer's disease, *etc*. [2].

In the human body, the antioxidant machinery is designed to neutralize these reactive radicals, thereby maintaining a balance between the processes of oxidation and antioxidation. Proficiently scavenging these detrimental species helps preserve cellular wellbeing and avoid oxidative damage [3]. Increasing the consumption of external antioxidants can considerably mitigate the harmful consequences of oxidative stress. These antioxidants affect oxidative chain reactions in various ways, such as quenching singlet oxygen, neutralizing free radicals, and acting as reducing agents [4].

Spices are a source of phytochemicals - a broad group of bioactive compounds derived from plants and recognized for their prospective medicinal values. This includes phenolic compounds, plant sterols, flavonoids, carotenoids, sulfur-containing compounds, and glucosinolates [5]. India, often referred to as the 'Land of Spices', stands out in the global spice market with its impressive cultivation of 52 to 60 varieties among the 109 spices recognized by the International Organization for Standardization (ISO). The usage of spices beyond culinary practices as flavouring or colouring agents has been employed as home remedies for certain ailments since time immemorial, as ingredients in Ayurvedic preparations [6].

Currently, interest in consuming natural products as foods and beverages is rising, and people are gradually inclining towards products with natural constituents, driven by their awareness of the potential undesirable health outcomes of synthetic products, particularly several synthetic antioxidants [5]. Since certain spices have garnered substantial interest due to their strong natural antioxidant properties, this review discusses the most up-to-date understandings of the established spice antioxidants, along with their sources and chemistry, and explores their antioxidant features in the context of therapeutic approaches. It has been established that phenolic compounds show antioxidant properties that exceed the efficacy of natural antioxidant α-tocopherol and are on par with synthetic antioxidants like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) [7]. As the potential of spices as antioxidants is getting established, it is becoming more important to summarize the role of spices in resolving cellular oxidative stress to figure out the research gaps and future prospects.

OXIDATIVE STRESS (OS): AN OVERVIEW

The Production of ROS

These ROS are crucial as secondary messengers in numerous intracellular signaling pathways. Nevertheless, at higher cellular concentrations, they can trigger injury to cellular functioning [8].

An oxygen atom holds a single unpaired electron in its outer valence shell. On the other hand, molecular oxygen possesses two unpaired electrons. Consequently, atomic oxygen functions as a free radical, whereas molecular oxygen operates as a bi-radical. Oxygen's univalent (single-electron) reduction yields reactive intermediates. This route differs from the more stable tetravalent reduction of oxygen in the electron transport chain present in the mitochondria of the cell, which safely generates water [9].

Resulting as metabolic by-products, superoxide radicals ($O_2^{\bullet-}$), hydroxyl radicals (•OH), hydrogen peroxide (H_2O_2), and singlet oxygen ($^1O_2$) are some common ROS [1]. Maintaining a lower level of ROS is crucial for some important cellular processes. These include activation of several transcription factors, protein phosphorylation, differentiation, immunity, and programmed cell death [10].

Free radicals are produced both from exogenous and endogenous sources (Fig. **1**). Internally, the production of ROS relies on both enzymatic and non-enzymatic chemical reactions. Enzymatic reactions involved in ROS yield include the processes occurring in the respiratory chain, during phagocytosis, prostaglandin production, and the cytochrome P450 system. Superoxide radicals ($O^{2\bullet-}$) are generated by NADPH oxidase, peroxidases, *etc.* These are able to take part in several subcellular reactions, yielding hydroxyl radicals (OH•), hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), and peroxynitrite ($ONOO^-$), which are some significant ROS of the cellular environment. Hydrogen peroxide (H_2O_2) is also produced by several oxidase enzymes. These include xanthine oxidase and amino acid oxidase. The Fenton reaction, involving the reaction of $O_2^{\bullet-}$ with H_2O_2 catalysed by Fe^{2+} or Cu^+, produces one of the most reactive free radicals - the hydroxyl radical (OH•). Oxidation of arginine to citrulline by the enzyme nitric oxide synthase (NOS) results in the yield of Nitric Oxide radical (NO•).

CHAPTER 3

Chemistry of Herb-Based Biosensors and Their Analytical Applications

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Abstract: Biosensors are analytical tools designed to detect chemical or physiological changes in an environment through the integration of biological recognition parts with physical transducers. They are widely used in clinical diagnostics, environmental monitoring, food safety, and pharmaceutical analysis due to their rapid response times, high sensitivity, and ease of operation. These devices offer a reliable and cost-effective alternative to conventional analytical techniques. Herb-based biosensors, which use bioactive phytochemicals including enzymes, flavonoids, terpenoids, and polyphenols derived from plants, have emerged as a sustainable and ecologically friendly alternative in recent years. These compounds interact with specific analytes through chemical mechanisms such as redox reactions, hydrogen bonding, and catalytic oxidation, enabling the detection of a wide range of targets, including drugs, hormones, pesticides, and amino acids. Examples include the use of banana or asparagus pulp to track pesticide residues and palm fruit fibers to detect adrenaline. Tissues from broccoli, potato, and tomato have also been employed to detect phenolic compounds, achieving detection limits in the micromolar range and performance comparable to standard electrochemical methods. The chemical basis of these sensors lies in the functional groups of herbal compounds, which contribute to signal generation through electron transfer, pH-sensitive color change, or catalytic reactions, depending on the transduction method used. These herb-derived materials are not only biocompatible and biodegradable, but also available at low cost, making them attractive for green analytical technologies. The chemistry of sensor-analyte interactions, manufacturing techniques, and material design are highlighted in this chapter, which summarizes thirty years of study in the creation of herb-based biosensors. Additionally, it examines new developments that have the potential to revolutionize analytical science, including polymeric encapsulation for stability, AI-assisted diagnostics, IoT-enabled real-time monitoring, and nanomaterial-enhanced sensitivity.

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

Keywords: Biosensor, Enzymes, Electrochemical transducers, Herbs, Herbicide.

INTRODUCTION

Overview of Biosensors

Biosensors are analytical tools that detect and measure analytes of interest by combining a physicochemical transducer with a biological recognition element [1]. An electrical, optical, or thermal transducer is the part that transforms the biological interaction into a measurable signal [2]. Trapped biological elements, such as antibodies, enzymes, or cells that bind to target molecules, lead to tangible signs [3 - 5]. Biosensors also have an extensive number of potential uses, including medical examinations, environmental surveillance, food hygiene, and enabling rapid, accurate, and specific detection [1, 3, 6]. A number of various kinds of biosensors, including immune sensors, microbial biosensors, and biosensors with electrochemical activity, have been developed for the detection of biological and chemical analytes [7]. Recent improvements in biological approaches and nanoparticles have enhanced the sensitivity of biosensors [3, 4]. The encapsulation of macromolecules on support structures is vital for biosensor functioning [4]. Biosensors offer advantages such as cost-effectiveness, excellent sensitivity, and specificity, making them valuable tools in several fields from scientific research to everyday applications [4].

Physicochemical transducers and biological recognition components are incorporated in biosensors to convert biochemical signals into quantifiable outputs. Biological or chemical interactions are converted into a measurable signal, usually electrical, optical, or thermal, using a transducer. Biocompatibility, chemical stability, and the ability to form specific interactions with target analytes are among the key qualities that materials suitable for biosensing must possess [5, 8].

Many contemporary biosensors use innovative methods to enhance their performance, such as integrating bioactive compounds on Field-Effect Transistors (FETs) and photonic systems or immobilizing them into electrode surfaces. Because of their natural abundance, inherent redox activity, and selectivity, herbal chemicals are being increasingly investigated for these kinds of uses. Drugs, hormones, poisons, and neurotransmitters are just a few of the analytes that can be detected by successfully integrating these natural compounds with sensor technologies.

This chapter outlines the basic concepts of biosensors to provide a clear framework. Next, the incorporation of herbal materials, their chemical properties, and the unique benefits they offer are discussed. This logical approach ensures technical depth and readability for readers from a variety of fields.

Role of Herbs in Biosensor Development

The wide availability and varied phytochemical composition of herbs and plant-derived materials make them suitable biorecognition components for biosensor design. These bioactive substances, which include enzymes, polyphenols, flavonoids, alkaloids, and terpenoids, possess inherent chemical reactivity that facilitates the detection of specific analytes using molecular recognition mechanisms, redox reactions, and hydrogen bonds [9 - 11].

Herbs like basil (*Ocimum basilicum*) and green tea (*Camellia sinensis*) are rich in polyphenols, which are redox-active compounds that take part in electron transfer reactions [12 - 15]. These substances undergo oxidation or reduction at the electrode surface, resulting in detectable currents, which permit electrochemical sensing of antioxidants and phenolic pollutants [16]. Multiple hydroxyl groups in flavonoids, which are present in foods like hibiscus (*Hibiscus sabdariffa*) and green tea (*Camellia sinensis*), allow them to form hydrogen bonds with metal ions or reactive oxygen species. Heavy metals, oxidative stress biomarkers, and free radicals are all detected by taking advantage of this interaction [17, 18]. Furthermore, many flavonoids exhibit colorimetric shifts and are pH-sensitive, making them suitable for optical biosensors [19 - 21].

Alkaloids with nitrogen-containing functional groups, like linalool from *O. basilicum* and berberine from turmeric (*Curcuma longa*), interact with proteins, DNA, or metabolites to provide high specificity in pharmaceutical analysis and biomedical diagnostics [22, 23]. In sensor systems, enzymes such as horseradish peroxidase from horseradish (*Armoracia rusticana*) and polyphenol oxidase from *O. basilicum* serve as biocatalysts, accelerating biochemical reactions that generate detectable signals. These are particularly useful for identifying phenols, hydrogen peroxide, and other redox-active substances [24 - 28].

When these phytochemicals interact with analytes, their chemical functionality, such as hydroxyl, carboxyl, amine, or methoxy groups, allows them to bind, change, or produce signals. The stability, sensitivity, and selectivity of herb-based biosensors are dependent on these mechanistic functions [16, 29]. Utilizing this molecular-level reactivity, herb-based biosensors offer a low-cost and sustainable sensing method in addition to exhibiting powerful performance in a variety of applications, such as food quality evaluation, environmental monitoring, and medical diagnostics.

CHAPTER 4

Unveiling the Cognitive Enhancer: A Comprehensive Review of *Celastrus paniculatus*

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Abstract: *Celastrus paniculatus* (CP) is an evergreen climbing plant that occurs in the subtropical and tropical parts of India. This plant is used in traditional Indian medicine, primarily in Ayurveda, Unani, and Siddha. CP seeds and oil are traditionally used for treating various neurological disorders, including cognitive impairment, paralysis, epilepsy, and insomnia, and for other disorders like rheumatism and arthritis. Phytochemical analysis revealed the presence of several classes of compounds, including monoterpenes, sesquiterpene esters, diterpenoids, triterpenoids, alkaloids, fatty acids, steroids, and flavonoids. Gas chromatography-mass spectrometry revealed that CP was high in various types of monoterpenes, including linalool, α-terpinyl acetate, and nerol acetate. Sesquiterpene esters, such as malkanguniol, malkangunin, valerenal, globulol, and viridiflorol, are also present. The plant also contains diterpenoids, including phytone and isophytol, as well as triterpenoids, including lupeol and pristimerin. CP contains phytochemicals with diverse activities and may be complementary to its therapeutic effects. This plant exhibits various pharmacological effects, including cognitive improvement, neuroprotection, and mood-stabilizing properties. It also shows antimicrobial, anti-inflammatory, and antioxidant properties and is a promising healing agent for various diseases. This chapter reviews the ethnopharmacological uses, pharmacognostiCProperties, phytochemical characterization, and diverse pharmacological activities of CP

Keywords: *Celastrus paniculatus*, Jyotishmati, Neurological disorders, Pharmacological activities, Phytochemistry, Therapeutic potential, Traditional medicine.

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INTRODUCTION

Overview of *Celastrus paniculatus*

Celastrus paniculatus (CP) is an important plant in the Indian subcontinent. It has been used for centuries in Ayurvedic and other traditional systems of medicine [1 - 3]. CP has recently gained attention for its potential cognitive benefits. It contains bioactive compounds that can aid with memory, learning, and mental clarity [4, 5]. CP is a climbing shrub, evergreen with broad, dark green leaves and tiny, yellowish flowers [6, 7]. The Celastrus family has over 100 species of shrubs, four of which are native to India and are found in North America, Japan, China, and tropical Asia [8]. A popular "Medhya Rasayana" (nervine tonic) in Ayurveda, CP Wild. (family Celastraceae) is one of these, and is frequently referred to as the "Elixir of Life" [9]. This woody, climbing shrub can grow up to a height of 18 meters and is found mostly in the hilly areas of India, especially the Himalayas, Eastern Ghats, and Western Ghats, usually at altitudes of around 1800 meters. The yellow-reddish ripening fruits from a CP plant contain reddish brown seeds, with scarlet aril as the covering [10]. The small, oblong, and oily seeds are the parts that are most commonly used in medicinal formulations. The seeds are rich in unsaturated fatty acids and contain several active compounds, including alkaloids, flavonoids, sterols, and other phytochemicals, which are believed to contribute to their therapeutic properties [6, 7]. CP is a major Ayurvedic herb that positively affects cognitive function and enhances brain function. Its seeds and their oil are said to improve cognitive function and are beneficial for bones, joints, and the nervous system [11]. CP seeds and oil are traditionally used to treat a variety of neurological diseases, including epilepsy, dementia, and neurodegenerative diseases that result in nerve injuries and cognitive dysfunctions [4].

Importance of Cognitive Enhancement

Neurodegenerative disorders refer to a collection of diseases that gradually destroy the central nervous system. Examples include Alzheimer's disease, Parkinson's disease, Huntington's disease, amyotrophic lateral sclerosis, and other such debilitating conditions [12]. Neurodegenerative diseases are characterized by a progressive decline in cognitive skills, memory impairment, emotional changes, motor weakness, and problems with speech [13, 14]. The accumulation of pathological forms of particular proteins is a common feature of multiple major neurodegenerative diseases. For example, Alzheimer's disease is distinguished by the accumulation of tau and amyloid-β proteins, whereas Parkinson's disease is characterized by the aggregation of α-synuclein, and Huntington's disease is marked by the accumulation of mutant huntingtin protein [15 - 18]. Furthermore, additional proteins that are inherently prone to aggregation may also experience aberrant folding patterns if the misfolded protein species are not effectively cleared by the cell's quality control machinery, including the Unfolded Protein Response (UPR) pathway [19]. The gradual decline in sensory, motor, and cognitive abilities is a direct result of the abnormal changes that occur within neurons. These changes also initiate a series of downstream events, including increased oxidative stress, mitochondrial impairment, and cellular apoptosis [20]. Unravelling the molecular mechanisms underlying neuronal cell toxicity in neurodegenerative diseases could provide a crucial foundation for the development of novel, mechanism-based treatments that aim to halt or slow disease progression, ideally before symptoms emerge [21]. The primary area where CP has gained attention is in its ability to enhance cognitive function. In traditional systems like Ayurveda, it is regarded as a powerful herb for enhancing mental clarity, improving memory, and promoting overall brain health. The plant is typically used to treat conditions such as memory loss, anxiety, depression, and even epilepsy [22, 23].

ETHNOPHARMACOLOGY, PHARMACOGNOSTIC PROPERTIES, AND PHYTOCHEMICAL PROFILE

Ethnopharmacology

The CP plant exhibited potential in treating rheumatism, gout, insomnia, dyspepsia, epilepsy, and cognitive impairment [24]. CP has been used as a nervine tonic, stimulant, rejuvenator, sedative, and diuretic in Ayurveda [25]. The methanolic extract of CP has been found to exhibit antioxidant properties, reducing the cytotoxic effects of hydrogen peroxide and protecting against DNA damage in human fibroblasts. This herb is traditionally used to treat various central nervous system disorders, leveraging its neuroprotective effects [26]. CP prevents several types of disorders and gastrointestinal issues, including stomach ulcers and dyspepsia [27]. Additionally, CP has been used to treat cognitive deficiencies in children with intellectual disabilities. CP fruit seed oil has demonstrated antioxidant and neuroprotective properties [28]. The seeds of CP yield a dark brown oil when extracted with petroleum ether, commonly known as Malkanguni oil or Celastrus oil. Initial investigations into the oil's composition have identified a range of fatty acids, including palmitic, stearic, oleic, linoleic, and linolenic acids [29]. Oil analysis shows a high composition with sesquiterpene alkaloids such as celapanin, celapanigin, and celapagin, which have analgesic, anti-inflammatory, and anxiolytic effects [30]. Other studies have reported that oil can enhance learning and memory, likely through the regulation of biogenic amines or antioxidant effects. Historically, this oil was used for everything from pain management and skin concerns to nutritional deficiencies

CHAPTER 5

Phytochemistry and Pharmacology of *Elsholtzia*: Research Advancements and Comprehensive Assessment

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Abstract: *Elsholtzia* (family Lamiaceae) is a genus of aromatic plants long utilized in Traditional Chinese Medicine (TCM) to treat ailments such as colds, fever, and pneumonia. This genus comprises approximately 48 species (with 33 varieties) predominantly distributed in East Asia. Several *Elsholtzia* species are ingredients in patented herbal formulations (*e.g.*, the Chinese "Huangshi Cold Tablet" for respiratory infections) and are available over-the-counter. *Elsholtzia* plants exhibit notable antioxidant, anticancer, and anti-inflammatory activities, attributable to their rich arsenal of bioactive constituents, including volatile oils, flavonoids, terpenoids, and phenylpropanoids. These metabolites are utilized as spices, flavorings, herbal infusions, cosmetic substances, and aromatherapeutic chemicals, as well as to enhance the genus's therapeutic potential. Phytochemical investigations have identified a plethora of compounds (*e.g.*, diverse flavonoids, terpenes, and other volatiles) in *Elsholtzia*, and extracts and pure compounds from this genus display a broad spectrum of pharmacological effects in both *in vitro* and *in vivo* studies. This chapter provides a comprehensive overview of the traditional uses, distribution, phytochemistry, and pharmacological activities of *Elsholtzia*, highlighting recent research advancements to facilitate further drug development and clinical exploration.

Keywords: Elsholtzia, Herbal medicine, Natural compound, Pharmacological activities, Phytochemicals.

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INTRODUCTION

Introduction of *Elsholtzia*

For millennia, plants have been a vital source of medicine, with humans relying on nature to meet basic health needs. Ancient systems such as Greek, Roman, Ayurvedic, and TCM have significantly contributed to the development of natural medicine. TCM, in particular, remains one of the few enduring ethnomedical traditions. Due to its affordability, proven efficacy, local availability, and minimal side effects, TCM has become increasingly accepted globally despite challenges in standardization and integration into modern healthcare [1]. *Elsholtzia* is a genus of aromatic plants in the mint family (Lamiaceae), named in honor of Prussian botanist Johann Sigismund Elsholtz. This genus comprises approximately 70–71 species distributed mainly in East and Southeast Asia, with a few species in North America. *Elsholtzia* species are mostly herbs (with a few woody subshrubs) and are ecologically significant, particularly in the Sino-Himalayan region. Molecular phylogenetic studies suggest that woodiness in this group has evolved multiple times from herbaceous ancestors [2]. *Elsholtzia* has a rich history in traditional medicine and folk usage. These plants have been used to treat fever, headaches, diarrhea, colds, and other ailments. They also appear in herbal teas, foods, spices, and fragrances, and some species are employed for phytoremediation of heavy-metal–contaminated soils. Phytochemically, *Elsholtzia* is characterized by an extensive profile of secondary metabolites, including cyanogenic glycosides, flavonoids, terpenoids, phenylpropanoids, and phytosterols. Correspondingly, *Elsholtzia* extracts and compounds exhibit diverse bioactivities such as antibacterial, antiviral, anti-inflammatory, and antioxidant effects. The combination of wide traditional use and broad pharmacological potential makes *Elsholtzia* an important genus for drug discovery and ethnobotanical research [3]. The *Lamiaceae,* also known as the mint family, is the sixth-largest family of flowering plants. This family is also one of the most economically important because most of its members have fragrant qualities. Historically, it has been believed that Verbenaceae and Lamiaceae are closely related, even though many genera that were once included in Verbenaceae should now be included in Lamiaceae [4 - 6]. Only a small number of *Elsholtzia* species-the only ones in the tribe that exhibit a woody habit-display this trait, making the genus diverse. All of Elsholtzia's woody species are found in the Sino-Himalayan subkingdom, though it's unclear if they had a common ancestor. Woody species have often evolved independently of their herbaceous origins, according to several molecular phylogenetic analyses of unrelated plant groups [7]. Folk medicine uses *Elsholtzia* plants to treat a variety of ailments, including colds, headaches, diarrhea, and fever. Herbal teas, food, beverages, spices, cosmetics, fragrances, and aromatherapy all contain them. Some species are used to treat soil contaminated with heavy metals. *Elsholtzia* plants can be found growing in North America, Europe, Asia, and Africa in both temperate and tropical climates. The highest diversity of *Elsholtzia* species may be found in the province of Yunnan, China. They consist of cyanogenic glycosides, flavonoids, terpenoids, phenylpropanoids, and phytosterols. *Elsholtzia* plants have antibacterial, antiviral, anti-inflammatory, and antioxidant properties [8, 9].

Historical Background, Distribution, and Traditional Use of *Elsholtzia*

Historical Background

Prussian botanist Johann Sigismund Elsholtz was honored with the naming of the species *Elsholtzia*, which is a member of the Lamiaceae family [mint family]. Traditional medicine and various cultural practices have utilized this collection of aromatic plants for centuries. *Elsholtzia* has garnered attention for its medicinal and biological potential due to its extensive phytochemical profile [10].

Traditional Uses

Across East Asia, Africa, North America, and Europe, *Elsholtzia* species have been indispensable in traditional medicine, valued for their aromatic properties and diverse therapeutic applications. Common ethnomedicinal uses include treatment of respiratory conditions (tonsillitis, cough, pharyngitis, colds), gastrointestinal disorders (diarrhea, dysentery, hepatitis, gastroenteritis), pain and inflammation (toothache, arthritis), and other ailments such as skin itching, nephritis, night blindness, menstrual disorders, hypertension, and fever [11, 12]. For example, in Chinese folk medicine, extracts of *Elsholtzia* flowers and leaves are used to alleviate colds and fevers. In Northeastern India, *Elsholtzia* (locally known as “Lomba”) is employed as a carminative, astringent, and general tonic, as well as a culinary spice. Such traditional uses underscore the genus’s significance as a source of natural remedies and justify further pharmacological investigations.

Distribution

Elsholtzia species are prevalent in temperate and tropical regions of Asia. They flourish in a variety of habitats, including forests, thickets, valleys, waste areas, rocky crevices, and grasslands. Altitude plays a significant role in their distribution [12]:

- *Mid-altitude species:* The majority of *Elsholtzia* species thrive at elevations of 1000–3000 m.

CHAPTER 6

Phytochemical and Pharmacological Insights on *Tinospora* Species

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Abstract: This chapter offers a comprehensive review of the phytochemical constituents and pharmacological potential of Tinospora species. The lianas and small trees of the Tinospora genus are currently utilized in Ayurveda and traditional medicine for various applications. This review aims to examine the chemical constituents of Tinospora, isolation techniques, and pharmacological and therapeutic relevance, with a focus on bioactive compounds and diverse pharmacological activities. The key bioactive classes identified in Tinospora possess significant medicinal value. The present work emphasizes the techniques used to isolate and chemically characterize these compounds through chromatographic (*e.g.*, HPLC, GC-MS) or spectroscopic (*e.g.*, NMR, IR) methods. It also provides comprehensive information on pharmacological functions, such as anti-inflammatory, immunomodulatory, antidiabetic, antioxidant, and hepatoprotective effects. Additionally, this review discusses the current and prospective clinical uses, toxicity profiles, and potential future investigations of Tinospora-derived drugs. This review endeavors to present an extensive literature review of existing Tinospora research, aiming to bridge traditional ethnomedicinal knowledge with modern pharmacological validation and explore its pharmacological importance and potency based on existing scientific literature.

Keywords: Alkaloids, Antidiabetic activity, Immunomodulatory effects, Hepatoprotective properties.

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

INTRODUCTION

Tinospora is a family of deciduous twining shrubs containing some of the most esteemed medicinal plants in traditional medicine, especially Tinospora cordifolia, called Guduchi or Giloy in India [1]. This plant is a major part of Ayurveda and is regarded as a Rasayana, a herb thought to enhance longevity, vitality, and even immunity. The term 'Amrita' embodies the traditional perception of Tinospora as a life-enhancing herb. Historically, it has been used as an antipyretic, hepatoprotective, antidiabetic, stomachic, and depurative agent and in the treatment of skin diseases. Additionally, its immunomodulatory and adaptogenic properties bolster the body's resistance to stress and illness [2]. Siddha, Unani medicines, and Southeast Asian and African traditional medicines use Tinospora fleshy fruit for treating fever, inflammation, gastrointestinal disorders, malaria, and rheumatism. In traditional Chinese medicine, it is utilized as a detoxifier and immune system enhancer. Tinospora is a rich source of bioactive compounds, including alkaloids, diterpenoid lactones, glycosides, steroids, and phenolic glycolates, which contribute to its multifaceted pharmaceutical properties [3, 4]. Various methods have been employed to extract and characterize these constituents of the essential oils. Tinospora exhibits pharmacological properties, such as anti-inflammatory, immunomodulatory, antidiabetic, antioxidant, hepatoprotective, and antimicrobial effects. Understanding the molecular and cellular mechanisms underlying these effects is crucial for determining their therapeutic actions and synergistic potential. Additionally, it is essential to assess its safety and toxicology while also focusing on regulatory aspects and quality assurance practices, which are vital for the standardization of herbal medicines. The historical and widespread use of Tinospora globally, coupled with contemporary pharmacological studies, underscores its relevance in current medical practice and highlights its significance as a subject for scientific research [5, 6].

PHYTOCHEMISTRY OF *TINOSPORA*

Alkaloids

Alkaloids are another widespread bioactive compound in Tinospora that determines the plant's wide range of pharmacological effects. These nitrogen-containing compounds are primarily obtained from the stems, roots, and leaves of *Tinospora cordifolia*. The most abundant alkaloids in berberine are jatrorrhizine, palatine, and magnoflorine. Berberine's ability to fight germs, reduce inflammation, and lower blood sugar shows how effective it is, and it is important for Tinospora's effectiveness [7]. Jatrorrhizine and palatine exhibited hepatoprotective and antioxidant activities, whereas Magno Florine showed immunomodulatory activity (Table **1**). Recent advances in chromatographic and spectrometric technologies have facilitated the isolation and structural determination of alkaloids, vindicating their pharmacological importance [8, 9].

Table 1. Key bioactive compounds in *Tinospora* and their therapeutic roles.

Bioactive Compound	Class	Therapeutic Role	Key Reference	Reference
Berberine	Alkaloid	Antidiabetic, Antimicrobial	Modern Pharmacological Study	[14]
Tinosporide	Diterpenoid lactone	Anti-inflammatory, Antioxidant	Traditional Texts and Research	[15]
Tinosporin	Glycoside	Immune modulation	Clinical Studies	[16]
β-Sitosterol	Steroid	Hepatoprotective, Cardiovascular health	Phytochemical Review	[17]
Quercetin	Phenolic compound	Antioxidant, Neuroprotective	Antioxidant Research	[18]

Diterpenoid Lactones

Diterpenoid lactones revealed that the Tinospora CRM-enriched fraction contains many active compounds that are important for treatment, and the compounds, mainly composed of diterpenoid lactones, are crucial for Tinospora's healing effects. Tinospora lactone, Furanolactones, and clerodane derivatives can be illustrated here. Tinospora lactone can help the immune system and reduce inflammation by lowering the levels of substances that cause it and increasing the activity of macrophages. Furanolactones are helpful in treating diabetes because they influence glucose homeostasis and insulin receptor sensitivity (Table **1**). The characterization of these lactones, such as their structural elucidation through NMR coupled with MS, has been informative in understanding their biological activity and developing their therapeutic uses [10].

Glycosides

Plant glycosides in Tinospora are recognized for their heart-protecting and stress-relieving benefits on plant materials, such as syringes and cardioids, which are sugar-based forms that help stabilize cell functions (Table **1**). Syringing increases immune responses and has antipyretic effects, whereas cardioid is implicated in cardiovascular function. The process of extracting glycosides may require hydroalcoholic solvents, and HPLC methods are used to determine their concentration. The process of extracting glycosides may require hydroalcoholic solvents, while HPLC methods are used to determine their concentration. These

CHAPTER 7

Chemistry and Biology of *Curcuma longa* L.: A Comprehensive Approach

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Abstract: Human health is a fundamental priority of scientific research, and medicinal plants continue to play a vital role in the discovery and development of novel therapeutic agents. *Curcuma longa* L. (turmeric), belonging to the Zingiberaceae family, is widely recognised as an important spice, functional food ingredient, nutraceutical, and a valuable source of bioactive compounds. So far, more than 17,000 publications and several patents have been reported, and its global market share has reached USD 3 billion with a CAGR of 18%. This chapter covers over 360 natural products reported from various extracts and essential oils of *C. longa*. This chapter describes their chemical structures, traditional uses, and reported nutraceutical and pharmacological properties. Furthermore, the chapter summarises recent advances in the chemical synthesis of curcumin and its analogs. By detailing the phytochemistry, pharmacology, and synthetic strategies of *C. longa* compounds, this chapter provides valuable insights to guide the development of novel molecular therapeutics and nutraceutical applications.

Keywords: *Curcuma longa*, Curcuminoids, Essential Oil, Natural products, Pharmacology, Synthesis.

INTRODUCTION

Humans have relied on plants for food and medicine for centuries. The use of plants as pharmaceuticals and nutraceuticals can be traced back to ancient times, notably to the Greek physician Hippocrates, who stated, "Let food be thy medicine" (400 BC) [1]. Medicinal plants serve as key reservoirs of therapeutic

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

compounds with typically fewer side effects and continue to play a crucial role in both healthcare and economic development. Approximately 80% of the global population depends on medicinal plants and their bioactive constituents for primary healthcare needs. The global herbal medicine market was valued at USD 216.40 billion in 2023 and is projected to reach USD 371.45 billion by 2030, growing at a Compound Annual Growth Rate (CAGR) of 8.02% [2]. Additionally, an estimated USD 110 billion is spent globally on research and development related to drug discovery from medicinal plants [3]. The nutraceutical sector has also grown rapidly in recent decades, driven by rising consumer awareness of the health benefits of natural food products. As of 2023, the global nutraceutical market is valued at USD 538.88 billion and is expected to reach USD 1007.48 billion by 2033, with a CAGR of 6.45% [4].

The Zingiberaceae family, comprising over 53 genera and 1200 species, is distributed across tropical regions of Africa, Asia, and the Americas. This family has several medicinally important species, such as *Zingiber officinale* Roscoe (ginger) and *Curcuma longa* L. (turmeric), which are renowned for their rich phytochemistry and diverse therapeutic roles, particularly due to their essential oils and oleoresins [5, 6]. The genus *Curcuma* is of notable cultural, economic, and medicinal significance [7]. Its taxonomic classification is as follows: Kingdom: Plantae; Class: Liliopsida; Subclass: Commelinids; Order: Zingiberales; Family: Zingiberaceae; Genus: *Curcuma* [8]. Comprising over 100 rhizomatous species, this genus is native to tropical and subtropical regions, including Pakistan, China, Indonesia, Malaysia, Australia, India, and Latin America [9, 10]. *Curcuma longa* has been used for over 4000 years in South Asia for culinary, medicinal, and religious purposes. During the Vedic period, it served as both a spice and a healing agent. In Ayurveda, a 3,000-year-old traditional Indian medicine system, turmeric is valued for its antimicrobial, anti-inflammatory, and antioxidant effects [11, 12]. Its therapeutic use is also documented in ancient Chinese medicine, particularly in “Materia Medica,” compiled during the Tang Dynasty (618-907 CE) [13, 14]. Turmeric spread across the Middle East, Europe, and Africa *via* trade routes in the medieval era [15]. Historically, it has been used to treat a variety of ailments, including jaundice, indigestion, skin infections, and liver disorders. Today, turmeric remains widely used in food, herbal medicine, nutraceuticals, skincare, and pharmaceuticals. Modern research supports its pharmacological potential, identifying anti-inflammatory, anti-diabetic, anti-cancer, anti-microbial, and hepatoprotective activities [16, 17]. The global market for turmeric was valued at USD 4.42 billion in 2023 and is growing at a CAGR of 5.5%. Meanwhile, the market for curcumin alone reached USD 80.63 billion in 2023 and is projected to rise to USD 206.45 billion by 2033, with a CAGR of 9.86% [18].

Extensive research has explored the phytochemistry and pharmacological potential of the *Curcuma* genus. Each species contributes unique secondary metabolites with diverse biological activities. Researchers have reported a total of 368 natural products from *C. longa* alone. Among these, *Curcuminoids*, such as curcumin, demethoxycurcumin, and bisdemethoxycurcumin are the most studied, particularly for their anti-inflammatory, neuroprotective, cardiovascular, and dermatological applications [19 - 21].

This chapter provides an updated, comprehensive overview of natural products, pharmacological activities, and curcumin synthesis strategies related to *C. longa*. It covers both traditional medicinal uses and emerging applications in modern pharmaceutical science. The chapter serves as a foundational resource for future research and development. Literature was gathered using up-to-date scientific databases, including PubMed, SciFinder, and Google Scholar.

PHYTOCHEMISTRY OF *CURCUMA LONGA*

The genus *Curcuma* is renowned for its rich phytochemical diversity, attributed to various classes of secondary metabolites with distinctive chemical structures and biological activities. Among its species, *Curcuma longa* (syn. *Curcuma domestica* Valeton), commonly known as turmeric, has received significant scientific attention due to its broad pharmacological potential. It contains a complex mixture of bioactive compounds, including curcuminoids, essential oils, sesquiterpenes, and polysaccharides, which are produced through diverse biosynthetic pathways. These compounds exert modulatory effects on multiple biological processes, including anti-inflammatory and antioxidant responses, immune system regulation, antimicrobial activity, modulation of lipid and glucose metabolism, neuroprotective effects, and cytoprotective actions against cellular stress and apoptosis. Notably, curcumin, the principal curcuminoid, has been extensively studied for its anti-inflammatory, antioxidant, antimicrobial, and anticancer properties, making turmeric a promising candidate for the treatment of chronic diseases [22, 23]. Its constituents are classified into 5 main groups, including diphenylalkanoids, terpenoids, alkaloids, phenolic compounds, and miscellaneous compounds.

Diphenylalkanoids

Diphenylalkanoids are the most widely explored diverse class of chemical compounds characterized by two phenyl groups connected by an alkyl chain of five (diphenylpentanoids) or seven (diphenylheptanoids) carbon atoms. Structural variations on the alkyl chain and phenyl rings confer diverse physicochemical properties, underlying a broad range of biological activities, including antioxidant,

CHAPTER 8

Salvia rosemarinus (Rosemary) Phytocompounds and their Pharmacological Effects

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Abstract: Rosemary, *Salvia rosmarinus*, an herbaceous member of the Lamiaceae family, native to the Mediterranean region, is grown worldwide. Rosemary is widely used in cooking as a seasoning and is also valued for its role in food preservation. Besides this, it contains many phytocompounds like caffeic acid, carnosic acid, rosmarinic acid, ursolic acid, alpha-pinene, camphor, carnosol, eucalyptol, rosmadial, and many more, which are reported to have several pharmacological effects. Several pharmacological effects of its phytocompounds include antioxidant, anti-infectious, anti-inflammatory, analgesic, neuroprotective, and cholinergic, anti-tumour activities. Furthermore, these phytocompounds found in rosemary are believed to offer protective benefits against several neurological conditions, including stroke, epilepsy, dementia, Alzheimer's disease, Parkinson's disease, and migraines. This chapter provides an updated overview of the phytochemical profile and pharmacological properties of rosemary.

Keywords: Alzheimer's disease, Anti-inflammatory, Antioxidants, Anti-tumor, Neurological, Parkinson's disease, Pharmacological, Phytocompounds.

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

INTRODUCTION

Salvia rosmarinus, formerly known as *Rosmarinus officinalis* Linn., widely known as rosemary, is a versatile plant from the Lamiaceae family, valued for its medicinal, ornamental, and aromatic properties (Table **1**). Native to the Mediterranean region, rosemary is celebrated for its distinctive aroma and widespread culinary applications [1]. The name “rosemary” comes from the Latin terms *ros* (dew) and *marinus* (sea), meaning “dew of the sea” [2]. With widespread cultivation, rosemary has been known with various common names such as mi die xiang in China, asmerino in Ethiopia, romero in Spain, rosmarin in Germany, and mehendi in India. Rosemary can be propagated from seeds, cuttings, or by dividing the roots. Rosemary can be characterized by its perennial nature, sharp needle-like leaves, and flowers of various shades like blue, purple, pink, and white. The leaves are typically harvested three to four times a year. Rosemary plants exhibit diverse growth habits, from upright to trailing forms, with the upright varieties reaching heights of up to 1.5 meters (5 feet) and occasionally up to 2 meters (6 feet 7 inches). The evergreen leaves of rosemary can have a length varying from 2-4 cm and a width from 0.2-0.5 cm. The leaves are green on the upper side with a white shade beneath, with the presence of dense and woolly hairs [3]. The blooming season for rosemary has been known for the spring and summer season; however, in the northern hemisphere, rosemary can bloom outside its usual season with the initiation of early flowering in mid-February or late flowering in the first fortnight of December. The economically important parts of rosemary may vary as per the usage, which can be fresh or dried leaves, stems, or other plant parts for oil extraction [4]. As a result, rosemary is often cultivated for its needle-like leaves, which are processed into both solid and liquid forms through various value-added methods.

Table 1. Scientific taxonomy or classification of rosemary.

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Genus	*Salvia*
Species	*rosmarinus*

Source: Chatterjee *et al.* [5]

Rosemary has a distinctive flavor, often described as a combination of lemony and pine-like notes, with hints of mint, sage, and pepper. Its potent taste means that it is used sparingly in cooking, as a small amount goes a long way [5]. Among the various plant parts, the leaves of rosemary contain the highest concentration of essential oil [6].

Spain, Tunisia, and Morocco are the leading global producers and exporters of rosemary essential oil, benefiting from favorable climates that allow for the cultivation of high-quality rosemary, crucial for both the culinary and the pharmaceutical industries [7]. While rosemary has traditionally been valued for its culinary applications, it has also long been appreciated for its medicinal properties, with indigenous populations using the herb for various therapeutic purposes.

Although rosemary holds cultural and historical significance in India, it has limited prevalence as an important crop. Introduction of rosemary in India can be attributed to Europeans, who valued it for its fragrant leaves as a garden herb.

Historically, rosemary has been recognized for its potential health benefits. In ancient Greece and Rome, it was believed to improve memory, earning the title “herb of remembrance and fidelity.” In ancient and medieval times, rosemary was used as a common remedy for liver disease and prescribed by renowned figures such as Hippocrates, Galen, and Dioscorides.

In 2001, the International Herb Association officially named rosemary the “Herb of the Year”. It remains a popular culinary herb in Britain and Italy. Despite its limited presence in traditional Indian medicine, rosemary's broader applications in the pharmaceutical, food, and cosmetic industries underscore its global importance.

Rosemary is rich in essential oils with notable pharmacological properties such as anti-inflammatory, antioxidant, antibacterial, antinociceptive, antifungal, antidiabetic, and antithrombotic effects [8]. The pharmacological interest in rosemary lies in its complex chemical composition, which includes triterpenoids, diterpenoids, flavonoids, and phenolic acids. Additionally, rosemary extracts are used in a range of products, including food items, pest control products, traditional medicines, and cosmetics [9].

The composition and bioactivity of rosemary's constituents can vary depending on factors such as developmental stage, plant variety, harvest season, and extraction methods. Herbal medicine, with its reliance on plant parts to treat various ailments, remains a significant aspect of traditional healthcare practices. In India, which boasts a rich repository of medicinal herbs, approximately 25,000 plant-based formulations are documented in traditional texts, and at least 25% of modern drugs are derived from plant sources [10].

CHAPTER 9

Phytochemistry and Medicinal Roles of *Boerhaavia diffusa*: A Comprehensive Overview

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Abstract: *Boerhaavia diffusa*, a perennial creeper herb, belongs to the *Nyctaginaceae* family. Punarnava is frequently translated as "regaining life". *Boerhavia diffusa* has a range of phytometabolite classes, comprising lignins, lipids, proteins, carbohydrates, alkaloids, triterpenoids, flavonoids, and glycoproteins. The plant also contains boerhavin, boerhaavic acid, punarnavine, boeravinone, and punarnavoside. β-Sitosterol, α-2-sitosterol, and arachidic acid. The highest possible alkaloid concentration (2%) is found in the roots of mature plants that are typically four years old. Lipids and proteins are prevalent in the herb and roots. The plant contains 15 amino acids, six of which are essential amino acids. The root of the plant also contains 14 amino acids, out of which 7 are essential amino acids. Numerous pharmacological activities, including antibacterial, hepatoprotective, hypoglycemic, anti-proliferative, anti-estrogenic, anti-inflammatory, anti-convulsant, anti-nociceptive, anti-stress, and anti-metastatic properties, have been documented on punarnava due to its wide range of bioactive phytoconstituents. The herb is also used to alleviate jaundice, inflammation, abdominal pain, stress, and dyspepsia. The study provides an extensive discussion of the pharmacological and phytochemical characteristics of *Boerhaavia diffusa*, offering valuable insights for students, academicians, and future research.

Keywords: Alkaloids, Amino acids, Analgesic, Anti-oxidant, Anti-diabetic, Anti-lymphoproliferative, *Boerhaavia diffusa*, Bioactive constituents, Flavonoids, Glycosides, Immunomodulatory, Immunosuppressive, Phenolic compounds, Punarnava, Saponins, Tannins, Terpenoids.

INTRODUCTION

Herbal remedies are increasingly favored in primary healthcare services across both developed and developing nations, because of their diverse biological and therapeutic properties [1].

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Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

Boerhaavia diffusa has established itself as a significant curative plant widely utilized in Ayurveda, Unani medication, and diverse traditional therapies around the world. In Ayurveda, the plant Shothagni (also known as Rakta Punarnava) is commonly referred to as Punarnava. This is due to the fact that it dies off during the hot summer months and then produces fresh shoots after the rainfall [2]. The name Punarnava comes from the Sanskrit phrase "Punahpunarnavabhawatiiti," which translates to "that which becomes fresh again and over." It likely reflects the plant's perennial nature, enduring the summer in a state of dormancy and blooming. Additionally, it is associated with the phrase "Karotisharirampunarnavam", meaning "that which rejuvenates the body" [3].

The steamy, subtropical, and warmest regions of the planet are home to an array of species in the genus Boerhaavia. About 40 species are available among these six, which originated from India: *Boerhaavia diffusa*, *Boerhaavia chinensis*, *Boerhaavia erecta*, *Boerhaavia repens*, *Boerhaavia rependa*, and *Boerhaavia rubicunda* [4]. The plant thrives well in wasteland and fields, particularly after the monsoon.

SYNONYMS

In the Indian context, *Boerhaavia diffusa* is known by various names in different languages [5].

Assamese: Punarnabha Ranga

Bengali: Rakta Punarnava

Hindi: Gadapurna, Snathikari.

Sanskrit: Punarnava, Raktakanda

Kannada: Sanadika, Kommeberu, Komma

Kashmiri: Vanjula Punarnava

Malayalam: ChuvannaTazhutawa

Marathi: Tambadivasu;

Oriya: Lalapuiruni, Nalipuruni;

Punjabi: ltcit (Ial), Khattan;

Tamil: Mukurattai (Shihappu);

Telugu: Atikamamidi, Erra galijeru

Boerhaavia diffusa has the potential to reach a length of one metre. It thrives in the monsoon, with mature seeds forming in October and November [6]. The plant has the capacity to grow to a length of one metre. The leaves are ovate-oblong to round in shape, with smooth upper surfaces, while hairy on the underside. Leaves are generally 5.5 × 3.3 cm^2 in size [7]. Flowers are 1.5 mm long and can be pink, white, or pinkish-red, arranged in clusters. The tubular perianth features five small lobes and two or three stamens, while the fruit is a detachable achene. The tuberous taproot is conical to cylindrical, thick, meaty, usually pale yellow to brown, and extremely bitter [8]. Tissue culture has been used in some research to investigate plant regeneration.

The entire plant, including its specific parts, such as leaves, stem, and roots, is recognized for its healing properties and has extended use among native and tribal communities in India [9]. Its therapeutic value in treating various human ailments is documented in traditional texts like Ayurveda, the Charaka Samhita, and the Sushruta Samhita [10].

PHYTOCHEMISTRY

Boerhaavia diffusa was extracted utilising various solvents, including ethanol, ethyl acetate, chloroform, aqueous solutions, and methanol. The study found a wide variety of phytopharmaceuticals in the plant such as Proteins, amino acids, phenols, quinones, sterols, furanoids, alkaloids, glycosides, triterpenoids, flavonoids, proteins, amino acids and tannins [11]. Among these flavonoids, phenolic substances, saponins, glycosides, alkaloids, tannins, terpenoids, and steroids were observed in root extracts [12, 13]. The Boeravinone B (type of flavonoid) extracted from the hydroalcoholic and methanolic extracts of the complete *Boerhaavia diffusa* plant was identified and quantified using TLC and reverse-phase HPLC, respectively [14, 15].

A variety of phenolic compounds isolated from *Boerhaavia diffusa* and identified through HPLC-PAD-MS/MS, such as kaempferol 3-O-(2-rhamnos-l)-robinobioside, quercetin 3-O-rhamnosyl (1-6) galactoside 3-O-galactosyl (1→2) glucoside, eupalitin 3-O-galactoside, caffeoyl tartaric acid, quercetin-3-O-(2-rhamnosyl)-robinobioside, and kaempferol 3-O-robinobioside. The primary phenolic components detected in the leaves and roots were quercetin 3-O- (2-rhamnosyl)-robinobioside and caffeoyl tartaric acid, respectively [16, 17]. According to reports, *Boerhaavia diffusa* is an excellent source of dietary

SUBJECT INDEX

A

Pankaj Kumar Chaurasia, Shashi Lata Bharati & Nand Kishor Gour (Eds.)

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

U

V

W

X

Z

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