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Antioxidant Activity of Herbal Plants

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ABSTRACT

Herbal plants have been extensively studied for their antioxidant potential, which plays a crucial role in preventing and managing oxidative stress-related diseases. Antioxidants are compounds that neutralize free radicals—unstable molecules that can damage cells, proteins, and DNA—contributing to aging and various chronic conditions such as cancer, cardiovascular diseases, and neurodegenerative disorders. Herbal sources are rich in naturally occurring antioxidants like flavonoids, phenolic acids, tannins, alkaloids, and vitamins, which exhibit significant free radical scavenging and metal-chelating activities.

This review highlights the antioxidant activity of various medicinal plants such as *Curcuma longa* (turmeric), *Camellia sinensis* (green tea), *Ocimum sanctum* (holy basil), *Embllica officinalis* (amla), and *Allium sativum* (garlic), among others. The phytochemical constituents of these herbs have shown promising results in both in vitro and in vivo models, indicating their potential as therapeutic agents. Moreover, advancements in extraction techniques and analytical tools have enhanced our understanding of their antioxidant mechanisms.

Given the increasing interest in plant-based therapies and the limitations of synthetic antioxidants, herbal antioxidants offer a safe, effective, and sustainable alternative. Further research and clinical studies are essential to validate their efficacy, optimize dosage, and ensure safety for long-term use in human health management. Herbal plants have long been utilized in traditional medicine systems across the globe, valued for their broad spectrum of therapeutic properties, particularly their antioxidant activity. Antioxidants are bioactive compounds that inhibit or neutralize oxidative stress caused by reactive oxygen species (ROS) and free radicals. Prolonged oxidative stress is implicated in the pathogenesis of numerous chronic and degenerative diseases, including cancer, diabetes, atherosclerosis, rheumatoid arthritis, and neurodegenerative disorders like Alzheimer's and Parkinson's diseases.

Natural antioxidants derived from herbal plants are gaining increasing attention due to their effectiveness and fewer side effects compared to synthetic antioxidants, which may have potential toxicities upon prolonged use. Herbal plants such as *Curcuma longa* (turmeric), *Camellia sinensis* (green tea), *Ocimum sanctum* (holy basil), *Embllica officinalis* (amla), *Allium sativum* (garlic), and *Ginkgo biloba* are rich in polyphenols, flavonoids, alkaloids, tannins, and essential oils, which contribute significantly to their antioxidant capacity. These bioactive compounds act through various mechanisms, including free radical scavenging, inhibition of lipid peroxidation, metal ion chelation, and enhancement of endogenous antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase.

Keywords: Antioxidants, Free radicals, Herbal Plants.

Introduction

A number of chronic diseases, such as cancer, heart disease, diabetes, and neurological problems, are mostly brought on by oxidative stress, which is an imbalance between free radicals and the body's capacity to counteract them with antioxidants. Reactive oxygen species (ROS) in particular are free radicals that can harm lipids, proteins, and DNA, causing cellular malfunction and the advancement of illness [1-7]. Because they neutralise these free radicals, antioxidants are essential for defending the body against oxidative damage. Although synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are frequently utilised, worries about their possible toxicity and adverse effects have raised interest in natural substitutes [8-10]. Traditional medical systems have long utilised herbal plants, which are abundant in natural antioxidants such as flavonoids, phenolic acids, alkaloids, tannins, and vitamins. These bioactive substances reduce inflammation, alter antioxidant enzyme systems, and scavenge free radicals [11-12]. Numerous investigations have shown that several medicinal plants contain antioxidant capacity, making them interesting candidates for the creation of safe and efficient antioxidant medicines. This study aims to demonstrate the medicinal potential of certain herbal plants and promote their usage in health-promoting applications by assessing their antioxidant activity using well-established in vitro techniques [13].

Antioxidant Properties in Herbal Plants [14-19]

- Metal Ion Chelation
 - DNA Protection
 - Anti-Inflammatory Effects
 - Regeneration of Other Antioxidants
 - Modulation of Cell Signaling Pathways
 - Anti-Aging Properties
 - Cardioprotective Effects
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Herbal Antioxidant mechanism of action

The main way that herbal antioxidants provide protection is by scavenging free radicals and lowering oxidative stress, which is linked to ageing, inflammation, and a number of chronic illnesses [20-23]. The following provides a more thorough explanation of how herbal antioxidants work:

Scavenging Free Radicals: Free radicals are extremely reactive molecules with unpaired electrons that are frequently produced during regular bodily functions like breathing. They can contribute to ageing, cancer, heart disease, and neurological disorders by oxidatively damaging cells, proteins, lipids, and DNA. Herbs contain antioxidants that scavenge free radicals [24-26]. In order to neutralise free radicals and stop them from interacting with and harming healthy cells, they give electrons. The risk of oxidative stress is decreased by this neutralisation. In Amla (Indian gooseberry), for instance, vitamin C functions as a scavenger of free radicals, neutralising reactive species such as superoxide anions and hydroxyl radicals, therefore lowering oxidative damage [27-30].

Enhancing Antioxidant Enzyme Activity: In addition to scavenging free radicals, several herbal antioxidants also increase the activity of natural antioxidant enzymes such as catalase, glutathione peroxidase (GPx), and superoxide dismutase (SOD) [31-34]. The body naturally produces these enzymes, which help convert free radicals into innocuous molecules like oxygen and water. For instance, ginseng and ashwagandha can support the body's natural defences against oxidative stress by increasing the activity of these enzymes [35-40].

Regeneration of Other Antioxidants: After neutralising free radicals, several herbal antioxidants aid in the regeneration or recycling of other antioxidants, including vitamin C and vitamin E. They prolong the antioxidants' protective action in the body in this way [41-43]. For instance, oxidised vitamin C can be restored by green tea and turmeric (curcumin), which increases the vitamin's capacity to scavenge more free radicals [44-48].

Anti-Lipid Peroxidation: The oxidative breakdown of lipids, known as lipid peroxidation, produces hazardous byproducts that have the potential to harm cell membranes [49-52]. Cell membranes can be shielded from oxidative damage by herbal antioxidants, especially flavonoids and phenolic substances, which can prevent lipid peroxidation. For instance, it has been demonstrated that hibiscus and rosemary lower lipid peroxidation, preserving the integrity of cell membranes [53-56].

Anti-Aging Mechanism: Herbal antioxidants can slow or stop age-related changes in the body by lowering inflammation and fighting oxidative stress [57-60]. They slow down ageing and age-related illnesses like Alzheimer's and cardiovascular disorders by minimising damage to cellular components like proteins, lipids, and DNA. For instance, ginseng and green tea (EGCG) help shield the skin from oxidative damage, which slows down the ageing process and the development of wrinkles [61-63].

Anti-Inflammatory Effects: Chronic inflammation is one of the body's main causes of oxidative stress [64-66]. In addition to their anti-inflammatory qualities, several herbal antioxidants also help lower the synthesis of inflammatory chemicals that encourage oxidative damage, such as pro-inflammatory cytokines [67-69]. Turmeric (curcumin) and holy basil (tulsi), for instance, have strong anti-inflammatory properties that lessen oxidative stress by lowering the generation of inflammatory markers like TNF- α and IL-6 [70].

Gene Expression Regulation: Certain herbal antioxidants have the ability to affect the expression of genes linked to antioxidant defence systems [71-73]. These herbs have the potential to improve the body's ability to fight oxidative stress over time by stimulating genes that produce antioxidant enzymes or proteins. For instance, it has been documented that ashwagandha affects the expression of Nrf2 and other genes involved in the body's antioxidant defences [74-77].

COMMONLY USED HERBAL ANTIOXIDANTS

Cocculus hirsutus: As a first step in this direction, we assessed the ethanol extract's antioxidant capacity on *Cocculus hirsutus* Diels' aerial parts. It was determined that the ethanol extract has promising free radical scavenging activity in a dose-dependent manner when tested for its ability to scavenge 1, 1-Diphenyl-2-picrylhydrazyl, nitric oxide, superoxide, and hydroxyl radicals [78]. The extract's phenolic components and antioxidant vitamins may be responsible for this antioxidant efficacy [79]. These findings unequivocally show that *Cocculus hirsutus* Diels is beneficial in treating illnesses brought on by free radicals [80].

Withania somnifera (Ashwagandha): For ages, Indian traditional medical systems have utilised ashwagandha (*Withania somnifera*), a member of the Solanum family, to cure a variety of diseases [81]. It is frequently referred to as Indian ginseng due to its similar therapeutic benefits to ginseng, which is well-known for its ability to treat illnesses brought on by stress. Ashwagandha's tuberous roots, whose extracts are commonly sold as an over-the-counter herbal supplement, are primarily responsible for its therapeutic benefits. Adaptogens, such as ashwagandha, are thought to help maintain homeostasis by restoring the physiological and biochemical alterations brought on by stress. Ashwagandha's wide use in extending life is justified by its anti-inflammatory, anticancer, and immunomodulatory properties [82]. The antioxidant activity of ashwagandha raises the possibility that its various biological effects are caused by a single molecular mechanism [83].

Zingiber officinale (Ginger): Around the world, ginger is a popular herbal supplement that is frequently used in a variety of culinary preparations. It is a rhizome of *Zingiber officinale*, a member of the Zingiberaceae family of herbs. It is widely utilised in alternative therapies including Chinese medicine, Ayurveda, Siddha, and Unani because of its many therapeutic benefits. Ginger is recommended as a *kaya karpam*, or rejuvenator, in Indian medical systems [84]. It is used to treat indigestion, diabetes mellitus, rheumatoid arthritis, nausea and vomiting, and some cardiovascular conditions in both fresh and dried form. Ginger's anti-oxidant, anti-inflammatory, anti-cancer, and antimicrobial qualities have been shown in numerous research [85]. Ginger's numerous biological characteristics lend credence to its use in medicine as a natural rejuvenator.

Azadirachta indica (Neem): A big, evergreen tree with numerous therapeutic uses, *Azadirachta indica*, also referred to as neem, is a member of the Meliaceae family. Indian alternative medicine systems use a variety of neem tree parts, including leaves, blossoms, seeds, roots, and bark, as traditional treatments for a range of illnesses [86]. But the broad range of therapeutic benefits of neem leaves is particularly notable in contrast to other tree sections. Neem leaves are antimicrobial, anti-inflammatory, analgesic, antidiabetic, immune-modulatory, antioxidant, and anti-cancer, according to numerous researches. Neem leaves are utilised as a *kaya karpam* to foster lifespan because of their many pharmacological properties [87].

Benincasa hispida: *Benincasa hispida* crude extracts, namely methanolic extract (M.E.) and aqueous extract (A.E.), were examined using conventional protocols to detect and identify phytochemicals such as alkaloids, saponins, steroids, carbohydrates, and flavonoids. The extracts were then utilised for an in vitro assessment of the findings. action of antioxidants [88]. Phytochemical screening and the potential of aqueous and methanolic extracts of dried ripe peels of *Benincasa hispida* to scavenge free radicals were the goals of the current investigation. The DPPH (1,1-diphenyl-2-picrylhydrazyl) test was used to assess the free radical scavenging performance [89].

Sonchus asper: Phenolic content and antioxidant activity of *Sonchus asper* (L.) Hill solvent extracts are evaluated. The SA extracts demonstrated an impressive ability to scavenge every reactive species that was tested, with IC₅₀ values obtained at the µg/ml level. Additionally, SAME demonstrated the best activities in scavenging superoxide and hydrogen peroxide radicals as well as potentially scavenging hydroxyl radicals. It was found to have the highest TPCs and the lowest IC₅₀ values for the DPPH•, ABTS•+ radical scavenging capacities and iron chelating scavenging efficiency. These findings imply that *S. asper* may be used as a medication to prevent oxidative damage linked to free radicals [90].

Moringa oleifera: The objective is to evaluate the phytochemical components, total phenolic content, cytotoxicity, and in vitro antioxidant activity of *Moringa oleifera* (M. oleifera) stem bark extracts (Moringaceae) [91]. Investigations on the cytotoxic effects were conducted using the brine shrimp lethality (BSL) bioassay. The demonstration of antioxidant activity was done using DPPH and nitric oxide radical scavenging activity.

Momordica charantia: Examining the in vitro antioxidant activity of *Momordica charantia* leaf extracts in aqueous and methanol form was the goal of this investigation. Additionally, the plant extract's antioxidant activity was assessed using the DPPH and ABTS techniques, which used gallic acid and ascorbic acid as standards, respectively [92].

Annona squamosa: It is commonly referred to as "Custard apple or Sitaphal." Rats with streptozotocin-induced diabetes were employed. It raises the activity of lipid peroxidation and decreases it. single oxygen quenchers, potent superoxide radicals, and antioxidant enzymes. Flavonoids are chemical components [93].

Origanum dictamnus: A methyl linoleate emulsion's oxygen consumption is decreased and free radicals produced by the Fenton reaction are scavenged by the aqueous extract. Flavonoids and phenolic acids are the primary phenolic compounds that are the active ingredients in herbs [94].

Glycyrrhiza glabra: It is known as "yastimadhu" (licorice). Its extract was evaluated by looking at how well rat liver microsomes inhibited radiation-induced lipid peroxidation. The chemical components include coumarins, flavones, and glycyrrhizin. Its ability to scavenge free radicals demonstrates its activity [95]. It also has diuretic, demulcent, tonic, and other effects [96].

Asparagus racemosus: It demonstrates antioxidant action by scavenging free radicals, superoxide anion radicals, hydrogen peroxide, nitric oxide, metal chelation, reduction power, and prevention of lipid peroxidation in rats [97]. Alkaloids, polyphenols, flavonoids, vitamin C, and saponins (Shatavarin I–V) are its chemical components.

Some other Examples of Herbal Antioxidants

Plant-based substances called herbal antioxidants aid in the neutralisation of free radicals, which are unstable molecules that can harm cells and induce oxidative stress [98]. The following herbs are frequently used and well-known for their antioxidant qualities:



Figure 1: Food Rich in Antioxidants

Green Tea (*Camellia sinensis*): rich in catechins, especially epigallocatechin gallate (EGCG), which has strong anti-inflammatory and antioxidant properties. renowned for its capacity to stave off ageing, cancer, and heart disease [99].

Turmeric (*Curcuma longa*): contains curcumin, an anti-inflammatory and potent antioxidant. frequently used because of its possible advantages in lowering inflammation and preventing a number of chronic illnesses [100].

Ginseng (*Panax ginseng*): has antioxidant qualities due to the presence of ginsenosides. renowned for increasing vitality, strengthening the immune system, and promoting mental clarity[101].

Rosemary (*Rosmarinus officinalis*): contains strong antioxidants carnosic acid and rosmarinic acid. It is frequently used for its ability to improve digestion and memory [102].

Clove (*Syzygium aromaticum*): contains eugenol, which has strong anti-oxidant properties. used for its anti-inflammatory, antiviral, and antibacterial qualities [103].

Cinnamon (*Cinnamomum verum*): contains cinnamon aldehyde, which has anti-inflammatory and antioxidant properties. frequently used to enhance digestive health and control blood sugar [104]

Chili Pepper (*Capsicum annuum*): contains the anti-inflammatory and antioxidant compound capsaicin. renowned for accelerating metabolism and easing discomfort [105].

Amla (Indian Gooseberry, *Phyllanthus emblica*): High in vitamin C and other polyphenolic components, delivering significant antioxidant effects. Widely used in Ayurvedic medicine for its immune-boosting and anti-aging benefits [106].

Holy Basil (Tulsi, *Ocimum sanctum*): contains ursolic acid and eugenol, which have anti-inflammatory and antioxidant qualities. used in conventional medicine to boost immunity and lessen stress [107].

Hibiscus (*Hibiscus rosa-sinensis*): abundant in anthocyanins, which offer protection against free radicals. It is frequently added to teas and is well-known for lowering cholesterol and blood pressure [108].

Milk Thistle (*Silybum marianum*): contains a substance called silymarin, which has potent antioxidant properties. used frequently to promote detoxification and liver health [109-110].

Conclusion

According to recent study, there are several possible uses for antioxidant and free radical manipulations in illness prevention or control. Natural items made from dietary ingredients like medicinal plants and Indian species are known to have antioxidant properties. An adequate antioxidant state and, thus, the regular physiological operation of a biological system may be maintained by increasing dietary antioxidant consumption. Humans have developed an

extremely complex and advanced antioxidant defence mechanism to shield the body's organ systems and cells against reactive oxygen species. Herbal plants' antioxidant content is essential for shielding the body from oxidative stress, which is connected to a number of chronic illnesses, ageing, and inflammation. Natural substances found in herbal plants, such as flavonoids, polyphenols, vitamins, and terpenoids, efficiently scavenge free radicals, minimising cellular damage to proteins, lipids, and DNA. In addition to their antioxidant activity, many herbs include anti-inflammatory qualities that further shield the body from chronic oxidative damage. Furthermore, by promoting the synthesis of endogenous antioxidant enzymes, several herbal antioxidants strengthen the body's defences. These herbal plants slowly down the ageing process and greatly lower the chance of chronic diseases including cancer, heart disease, and neurological illnesses by minimising oxidative stress and fostering cellular health. Herbal plants are a vital component of both conventional and contemporary wellness practices because they provide a safe, all-natural means of reducing oxidative stress while promoting general health and lifespan.

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