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# Antioxidant Compounds Derived from Plants, Description and Mechanism of Phytochemicals

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**Abstract—***Free radicals are highly reactive, short-lived, toxic molecules that have one or more unpaired electrons and can damage DNA, proteins, lipids, and carbohydrates within the tissue, leading to many common diseases like early aging, atherosclerosis, cancer and many others. Antioxidants are the molecules, which can scavenge free radicals and prevent cellular damage by reducing the oxidative stress and therefore have a beneficial effect on human health. A number of antioxidants are known to provide protection against several diseases. Epidemiological studies have demonstrated that higher intake of antioxidants results in reduced risk of heart disease and many other diseases. This is the reason for the strong interest in natural antioxidants and their role in human health and nutrition. Several medicinal plants, spices, vegetables, fruits and fungi have been researched as sources of potentially safe natural antioxidants.*

**Keywords***: Antioxidants, Medicinal Plants, Spices, Essential Oil, Phenolic Compounds*

## 1. INTRODUCTION

### Antioxidants from plants

Medicinal plants

Currently there has been an increased interest globally to identify natural antioxidant compounds that are pharmacologically potent and have low or no side effects for use in preventive medicine and the food industry. As plants produce significant amount of phytochemicals with several biological activities, these phytochemicals are of particular interest. Phytochemicals are the chemicals extracted from plants. These chemicals are classified as primary or secondary constituents, depending on their role in plant metabolism. Primary constituents include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophyll's etc. Secondary constituents are the remaining plant chemicals such as alkaloids (derived from amino acids), terpenes (a group of lipids) and phenolics (derived from carbohydrates) [1]. Phytochemicals represent a potential source of new compounds with antioxidant activity and many of them have been reported by several workers [2]. Many plants contain large amounts of antioxidants like vitamin C, vitamin E, and phenolic compounds. Ascorbic acid has multi-functional properties. Based on conditions, ascorbic acid can act as an antioxidant, pro-oxidant, a metal chelator, a reducing agent or an oxygen scavenger. Ascorbic acid can act as a pro-oxidant in aqueous systems containing metals, by reducing them, which become more active catalysts of oxidation in their lower valence state. In the absence of added metals, ascorbic acid is an effective antioxidant at high concentrations. Vitamin E is a group of compounds with well known antioxidant functions. Among vitamin E compounds, tocopherol and especially alpha tocopherol possesses the strongest biological activity [3]. Selenium is a naturally occurring antioxidant that preserves tissue elasticity by delaying oxidation of polyunsaturated fatty acids. Selenium is an essential component of glutathione peroxidase. Selenium deficiency has been implicated as contributing factor to the development of cardiovascular disease (congestive cardiomyopathy), accelerated atherosclerosis, skeletal muscle myopathy, increased cancer risk, aging, cataract and low immune function. Small molecule dietary antioxidants such as vitamin C (ascorbate), vitamin E (tocopherol), and cartoneoids have generated particular interest as anticarcinogens and as defenses against degenerative diseases [3]. Crude extracts of fruits, herbs, vegetables, cereals, and other plant materials rich in phenolics are increasingly of interest in the food industry because they retard oxidative degradation of lipids and thereby improve the quality and nutritional value of food.

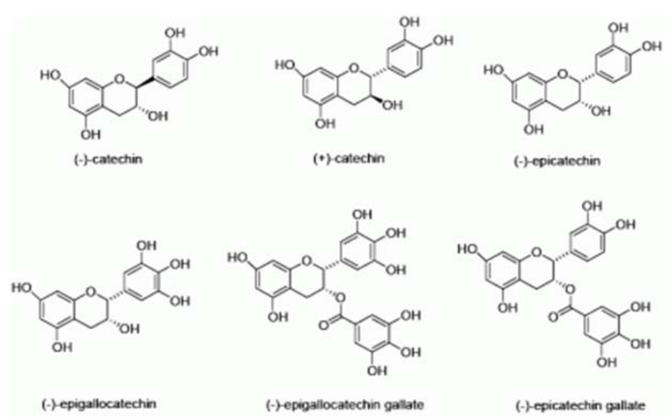


**Fig. 1 Structure of phenolic compounds of the tea**

Green and black teas have been extensively studied for antioxidant properties since they can contain up to 30% of the dry weight as phenolic compounds and the study proved them to be potent antioxidants. (±) epicatechin, (+) gallocatechin, (±) epigallocatechin, (±) epigallocatechin 3- gallate, (±) epicatechin 3-gallate, and (+) catechin are the major phenolic compounds present in tea (Fig. 1) .

Some of the active components of some medicinal products are flavonoids. Flavonoids are sub-group of phenolic compounds and possess various biological bioactivities including antioxidant activity. Flavones possess antioxidant and antimutagenic activity, flavanones and xanthones, exhibit antiviral, antimicrobial, antioxidant and anti-inflammatory activities, and isoflavones and coumestans present important antioxidant action. A number of studies deal with the antioxidant activity of extracts from herbs, medicinal plants and spices. The antioxidant activity of sage components has been widely studied. Ginger [4], *Ganoderma* species [5], dittany [6], green pepper [7], *Visnea mocanera* L.F.[8], *Chrysanthemum* [9], Honeybush are known to possess antioxidant activity.

Lavender has been widely studied due to its high polyphenol content which possesses potent antioxidant activity. A number of studies were focused on the composition of rosemary due to its potent antioxidant action. The elucidation of the antioxidant mechanisms of its components has also been studied [10].

A lot of medicinal plants, traditionally used for thousands of years, are present in a group of herbal preparations of the Indian traditional health care system (Ayurveda) named Rasayana proposed for their interesting antioxidant activities. Various *rasayana* plants (*Emblica officinalis* L., *Curcuma longa* L., *Mangifera indica* L., *Momordica charantia* L., *Santalum album* L., *Swertia chirata* Buch-Ham, *Withania somnifera* (L.) Dunal *Sida cordifolia*; *Evolvulus alsinoides* and *Cynodon dactylon*) have also been reported to possess high free radical scavenging activity both *in vitro* and *ex vivo*. These plant-based dietary antioxidants are believed to have an important role in the maintenance of human health because endogenous antioxidants provide insufficient protection against the constant and unavoidable challenge of reactive oxygen species [11].

Curcumin, a yellow pigment from *Curcuma longa*, is a major component of turmeric and is commonly used as a spice and food-coloring agent. It is also used as a cosmetic and in some medical preparations. The desirable preventive or putative therapeutic properties of curcumin have also been considered to be associated with its antioxidant and anti-inflammatory properties. Because free-radical-mediated peroxidation of membrane lipids and oxidative damage of DNA and proteins are believed to be associated with a variety of chronic pathological complications such as cancer, atherosclerosis, and neurodegenerative diseases, curcumin is thought to play a vital role against these pathological conditions. The anti-inflammatory effect of curcumin is most likely mediated through its ability to inhibit cyclooxygenase-2 (COX-2), lipoxygenase (LOX), and inducible nitric oxide synthase (iNOS). COX-2, LOX, and iNOS are important enzymes that mediate inflammatory processes. Improper upregulation of COX-2 and/or iNOS has been associated with the pathophysiology of certain types of human cancer as well as inflammatory disorders. Because inflammation is closely linked to tumor promotion, curcumin with its potent anti-inflammatory property is anticipated to exert chemopreventive effects on carcinogenesis. Hence, the past few decades have witnessed intense research devoted to the antioxidant and anti-inflammatory properties of curcumin [12].

A review by Alrawaiq and Abdullah, [13] scrutinized the capability of curcumin to induce transcription factor Nrf2 in a neurodegenerative model involving quinolinic acid in rats. The outcomes of this study are in line with the perception that neuroprotection brought about by curcumin is linked to its capacity for activating the Nrf2 cytoprotective pathway and enhancing the total superoxide dismutase and glutathione peroxidise activities. Curcumin fed to pregnant mice could in fact raise the hepatic levels of GST and acid-soluble sulfhydryl of translactationally exposed F1 pups. In a study employing curcumin to ward off cataractogenesis in rat lenses, the initiation of GST activity was proposed as the defensive procedure against lipid peroxidation. Curcumin is an effective generator of cytoprotective enzymes in cultured cell models. In spite of its modest ability to impede UGT activities, curcumin still brought about the expression of UGT 1A1 and 1A6 in Caco-2 cells [14].

Spices like turmeric, ginger, alliums are indispensable for the preparation of our daily food and are reported to possess compounds, which have varied beneficial biological effects and also prevent the microbial spoilage of food. The study carried out by Panpatil et al., [15] evaluated the antioxidant and antimicrobial activity of spice extracts such as ginger, turmeric and garlic by 2, 2'-Diphenyl-1-picrylhydrazyl (DPPH) Radical Scavenging Method and also to evaluate their antimicrobial effects by Slant method. The antioxidant activities when compared among ginger, turmeric and garlic the potency of these spices was found to be in the order of Vit C > Ginger > Turmeric ≥ Dry garlic > Fresh garlic.

**Essential oils**

Plant essential oils as antioxidant were researched with the view to investigating their protective role for highly unsaturated lipids in animal tissues. The oils have shown their action as hepatoprotective agent in aging mammals and these studies described the beneficial impact of volatile oils upon the poly unsaturated fatty acid (PUFA), in particular the long chain C20 and C22 acids. In addition, volatile oils also demonstrated a positive effect upon docosahexaenoic acid (DHA) levels in aging rodent retinas. It has been suggested that volatile oils could act as antioxidant agents. It has been found that certain volatile oils and their components are cytostatic to tumour cell lines and can offer potential as novel anti-proliferative agents. Dorman *et al*., [16] screened *Pelargonium* sp., *Monarda citriodora* var. *citriodora, Myristica fragrans, Origanum vulgare* ssp. *hirtum* and *Thymus vulgaris* for their antioxidative effect using a thiobarbituric acid (TBA) assay. The oils showed active antioxidant activity at extremely low levels of dilution. Rosemary has long been recognized to have antioxidant molecules like carnosic acid, carnasol, carsolic acid, rosmaridiphenol and rosmarinic acid. The study was carried out to assess the antioxidant activity of the essential oil of *Magnolia liliflora* Desr using 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay and results were found to be superior as compared to butylatedhydroxyanisole (BHA) [17].

Sharififar *et al*., [18] investigated the antioxidant activity of the essential oils from flowers and fruits of *Otostegia persica* (Burm.) Boiss., Lamiaceae. Chaieb *et al*., [19] investigated the antioxidant properties of the essential oil of clove (*Eugenia caryophyllata* (L.) Merril & Perry, Myrtaceae). The major components, as analysed by GC/MS, were eugenol (88.6%), eugenyl acetate (5.6%), b-caryophyllene (1.4%) and 2-heptanone (0.9%). The results exhibited that these oils showed a very strong radical scavenging activity with an $IC_{50}$ value of 0.2 mg/ml. A comparison was made with the synthetic antioxidant *tert*-butylated hydroxytoluene which exhibited an $IC_{50}$ value of 11.5 mg/ml. Furthermore, the oil showed promising anti-fungal effects.

The essential oils of Rutacean plants possess antioxidative properties. Misharina and Samusenko, [20] reported antioxidant properties of essential oils from lemon (*Citrus limon* L., Rutaceae), pink grapefruit (*Citrus paradisi* Macfad., Rutaceae), coriander (*Coriandrum sativum* L., Apiaceae), and clove (*Caryophyllus aromaticum* = *Syzygium aromaticum* (L.) Merril & perry, Myrtaceae) buds. The species *Salvia* is known on account of its antioxidant properties. Ben Farhat *et al*., [21] studied variations in the antioxidant activity of Tunisian *Salvia officinalis* L. (Lamiaceae) essential oil, cultivated in different habitats and the major components exhibited potent antioxidant activity.

Yang *et al*., [22] investigated the antioxidant activity of six popular and commercially available essential oils. The tested oils were from lavender (*Lavandula angustifolia* Mill., Lamiaceae), peppermint (*M. piperita* L., Lamiaceae), rosemary (*Rosmarius officinalis* L., Lamiaceae), lemon (*Citrus limon* L., Rutaceae), grapefruit (*Citrus paradise* Macfad. Rutaceae), and frankincense (*Boswellia carteri* (Birdw.), Burseraceae). The results of this study showed that all essential oils possess potent radical scavenging activity.

**Antioxidant compounds derived from plants**

**Phenolic compounds**: Polyphenols are the major phytoconstituents with antioxidant activity, although they are not the only ones. In addition, other biological properties such as anti-carcinogenicity, anti-mutagenicity, anti-inflammatory, anti-allergic and antimicrobial activity have also been reported [23]. The protection that fruits and vegetables provide against free radicals has been attributed to the various antioxidants (vitamin C, vitamin E, α-tocopherol, β-carotene) and phenolic compounds are one of them. In living systems, dietary antioxidants (α-tocopherol, β-carotene, ascorbic acid) and endogenous enzymes (superoxide dismutase, glutathione peroxidase, catalase) protect against oxidative damage. Recent scientific studies have proved that phenolic compounds are capable of protecting cells from free radical damage. Medicinal plant parts (roots, leaves, branches/stems, barks, flowers, and fruits) are commonly rich in phenolic compounds, such as flavonoids, phenolic acids, stilbenes, tannins, coumarins, lignans and lignins. They have multiple biological effects including antioxidant activity. Several studies have shown that phenolic compounds reduce *in vitro* oxidation of low density lipoprotein (LDL). The phenolics with multiple hydroxyl groups are generally most efficient for preventing lipid and low density lipoproteins oxidation and therefore, atherogenesis. Regeneration of α-tocopherol in human LDL was observed in the presence of tea catechins in a dose- dependent manner, although inhibition of LDL oxidation did not reduce arteriosclerotic lesions [24].

It is considered that the antioxidant activity of phenolic compounds is due to their high redox potential, which allows them to act as reducing agents, hydrogen donors and singlet oxygen quenchers. The antioxidant activity of the phenolic compounds is essentially determined by their structure, in particular the electron delocalization over an aromatic nucleus. When these compounds react with free radicals, the delocalization of the gained electron over the phenolic antioxidant occurs, and the stabilization by the resonance effect of the aromatic nucleus, which prevents the continuation of the free radical chain reaction. The presence of hydroxyl groups in positions 3′-, 4′- and 5′ in the B ring of phenolic compounds increases the antioxidant activity when compared with compounds with one hydroxyl group. Also, the presence of a hydroxyl group in position 3′, and a 2,3-double bond conjugated with the 4-oxo group seems to have importance in the antioxidant properties (Fig. 2) [25].

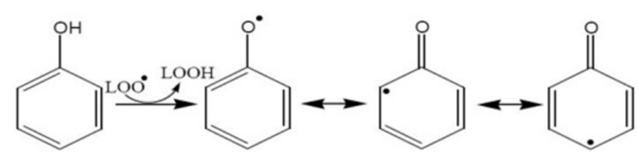


**Fig. 2 Antioxidant mechanism of phenolic compounds**

**Flavonoids:** Flavonoids are polyphenolic compounds that are ubiquitous in nature and are categorized into flavonols, flavones, flavanones, isoflavones, catechins, anthocyanidins and chalcones according to chemical structure (Fig. 3). Over 4,000 flavonoids have been identified, many of which occur in fruits, vegetables and beverages (tea, coffee, beer, wine and fruit drinks).They occur mostly as glycosylated derivatives, sometimes conjugated with sulphate or organic acids [26].

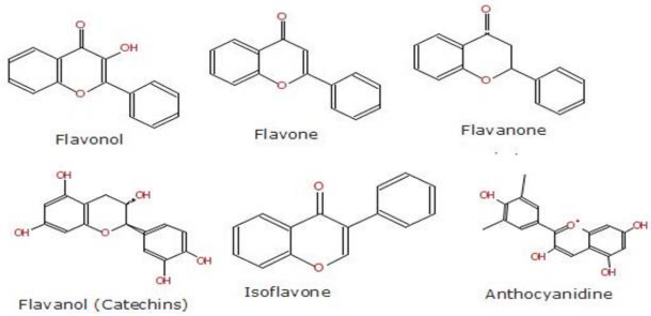


**Fig. 3 Structure of different flavonoids**

Flavonoids (or bioflavonoids) are also collectively known as vitamin P and citrin. The flavonoids have aroused considerable interest recently because of their potential beneficial effects on human health. They have been reported to have antiviral, anti-allergic, anti-platelet, anti-inflammatory, anti-tumor and antioxidant activities.

Like α-tocopherol (vitamin E), flavonoids contain chemical structural elements that may be responsible for their antioxidant activities. A study by Van Acker *et al*., [27] suggests that flavonoids can replace vitamin E as chain-breaking antioxidants in liver microsomal membranes. The contribution of flavonoids to the antioxidant defense system may be substantial considering that the total daily intake of flavonoids can range from 50 to 800 mg. This intake is high compared to the average daily intake of other dietary antioxidants like vitamin C (70 mg), vitamin E (7-10 mg) or carotenoids (2-3 mg). Flavonoid intake depends upon the consumption of fruits, vegetables, and certain beverages, such as red wine, tea, and beer [27].

Flavonoids and other polyphenols have powerful antioxidant activities *in vitro*, being able to scavenge a wide range of reactive oxygen, nitrogen, and chlorine species, such as superoxide, hydroxyl radical, peroxyl radicals, hypochlorous acid, and peroxynitrous acid. Flavonoids can also chelate metal ions, often decreasing the prooxidant activity of metal ions. They can inhibit the ability of myeloperoxidase to oxidize low-density lipoproteins (LDL). Flavonoids and their glycosides: hyperoside (quercetin-3-galactoside), quercetin, vitexin, vitexin-O-rhamnoside, isovitexin- O-rhamnoside, acetylvitexin-O-rhamnoside, rutin, quercitrin (quercetin-3-rhamnoside), orientin, kaempferol, spireoside, saponaretin, oligomeric procyanidins, catechins, and phenolic acids (chlorogenic acid, caffeic acid, triterpene saponins, etc.) purified from various plants are known to possess various bioactivities including antioxidant activity [28].

**Allyl sulphides:** Sulphur compounds are characteristics of several plants including garlic and they have strong antioxidant properties. The antioxidant activity of allyl sulphides is associated with their ability to reduce reactive oxygen species and their activation of antioxidative enyzmes (superoxide dismutase, catalase, glutathione peroxidase). Due to these properties, allyl sulphide compounds are important in the prevention of DNA damage as well as the prevention of cancer and cardiovascular diseases [29].

## 2. CONCLUSIONS

Phytochemicals are extensively found at different levels in many medicinal plants. Numerous plants used in traditional medicine are effective in treating various ailments caused by oxidative stress, bacterial and/or viral infections. Research has shown that medicinal plants exhibit antioxidant as well as antimicrobial activity. Because of their antibacterial and antioxidant properties, herbs are used as natural food and cosmetics preservatives and are considered in formulation of new functional food products. On further evaluation of their bio-efficacies, active constituents, and molecular and biological mechanisms in vitro as well as in vivo on antioxidation or cancer chemoprevention effects there will be possible applications of the selected target plant extracts as food supplement for human health care. The potency of these compounds could provide a chemical basis for some of the health benefits claimed for sage in folk medicine and warrant further studies to assess their potential as effective natural remedies.

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