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A Critical Study on Chemistry and Distribution of Phenolic Compounds in Plants, and Their Role in Human Health

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Abstract: *Phytochemicals are the secondary metabolites synthesized in different parts of the plants. They have the remarkable ability to influence various body processes and functions. So they are taken in the form of food supplements, tonics, dietary plants and medicines. Such natural products of the plants attribute to their therapeutic and medicinal values. Phenolic compounds are the most important group of bioactive constituents of the medicinal plants and human diet. Some of the important ones are simple phenols, phenolic acids, flavonoids and phenyl-propanoids. They act as antioxidants and free radical scavengers, and hence function to decrease oxidative stress and their harmful effects. Thus, phenols help in prevention and control of many dreadful diseases and early ageing. Phenols are also responsible for anti-inflammatory, anti-biotic and anti-septic properties. The unique molecular structure of these phytochemicals, with specific position of hydroxyl groups, owes to their powerful bioactivities. The present work reviews the critical study on the chemistry, distribution and role of some phenolic compounds in promoting health-benefits.*

Key words: *Antibiotic, Antiseptic, Antioxidants, , Oxidative Stress, phenolic acids, Phenyl propanoids , Simple phenols,.*

I. Introduction

Many plants and herbs consumed by humans are known to contain rich amounts of phenolic compounds and flavonoids. These compounds are currently of great interest due to their antioxidative, anti-inflammatory and pharmacological activities. They are the good sources of natural antioxidants in human diets (Kim *et al.,* 2003). Phenolics have the ability to scavenge free radicals, and protect cells from the damages of oxidative stress. Their contribution in providing security against diseases, alongwith the activity of antioxidant vitamins and enzymes indicate their therapeutic potentials. Plant extracts rich in phenolics are of great interest in food industry because they inhibit the oxidative degradation of lipids, and thereby improve the nutritional value of food. Alongwith flavonoids, the phenols show antioxidant and inhibition properties , affecting hydrolytic and oxidative reactions (Patel *et al.,* 2010).

II. Chemistry and distribution of Phenolic compounds

Phenolic compounds comprises of all the phytochemicals of the plant which possess in common an aromatic ring bearing one or more hydroxyl substituents. They frequently occur in combined states with sugar or glycosides, hence tend to be water soluble. Among the natural phenolic compounds, the simplest are phenols, and flavonoids form the largest group. Simple monocyclic phenols, phenyl propanoids and phenolic quinines also exist considerably. Other important polyphenolics present in plants are lignins, melanins and tannins.

Simple phenols include three dihydroxylbenzenes, *viz.*, hydroquinone, catechol and resorcinol. The three trihydroxylbenzenes of the simple phenols are benzenitrol, pyrogallol and phloroglucinol. Hydroxyl set in phenol molecule imparts the nature of alcohol and this enables the categorization of phenols as tertiary alcohols. All phenol by-products are basically polycyclic molecules changing their basic features. When fundamental elements are replaced by one or more hydrogen, it leads to the formation of simple phenols. Naturally occurring phenolic acid contain two distinctive carbon structures, *viz.*, the hydroxycinnamic and hydrobenzoic structures. Phenolic acids are the phenols with functionality of one carboxylic acid. Plant phenolic compounds are recognized by unusual molecular structure, characterized by hydroxylated aromatic rings (Mandal *et al.,* 2010). Phenyl propanoids are naturally occurring phenolic compounds which have an aromatic ring to which a three-carbon side-chain is attached. They contain one or more C_6-C_3 residues, and are derived from the aromatic

protein amino acid, phenyl alanine. The important phenyl-propanoids are hydroxycinnamic acids, hydroxycoumarins, phenyl-propanes and lignans.**(Table PH-1)**

Phenolic compounds and simple phenols are usually located in plant tissues. Soluble phenolics are concentrated in the cell vacuoles, whereas the insoluble phenolics are found in cell walls (Towers & Harborne, 1964). Phenols have the ability to form complex with protein. Phenolic acids are universal in distribution, and are either associated with lignin or present in the alcohol – insoluble fraction of the leaf. *ρ*-hydroxybenzoic acid, protocatechuic acid, vanillic acid, gallic acid and syringic acid are also widely distributed. Free phenols are relatively rare in plants. Hydroquinone is the most widespread phenol. Catechol, orcinol, phloroglucinol and pyrogallol are comparatively less in presence. Plant melanins are the natural phenolic polymers, that are known to yield simple phenols. The commonly distributed phenyl-propanoids are lignans, coumarin and eugenol. Lignans are mainly found in heartwoods. Coumarin occurs in many varieties of grass and fodder crops. Eugenol is the distinctive component of oil of cloves.

III. Role of Phenolic compounds in Human health

The different molecular frameworks of plant phenolic compounds attribute to their properties of protection against oxidative damage. The higher levels of ROS (Reactive Oxygen Species) leading to various degenerative diseases such as cardiovascular diseases, cancer and ageing are thus controlled by phenolic compounds (Battisi *et al.,* 2008). Plant tissues containing phenols act as stimulant agents of leucocyte. Hydroquinone, the simple phenol, is usually used as urinary antiseptic. It also acts as the skin lightening mediator, and reduces the formation of melanin in the skin. Hydroquinone forms an important part of the effective medicine used for curing age spots, murky skin and freckles.

Hydroxycinnamic acids help in growth regulation and disease resistance. Other phenyl-propanes, such as eugenol and thymol also exhibit medicinal properties. Eugenol, besides its multiple use, is known to be used as local antiseptic and anesthetic. Zinc-oxide eugenol is used for interim filling and cementing decayed teeth. It also has unique antibacterial properties. Thymol has its uses as antiseptics, preservatives and as cooling agents. Thymol is obtained from the oil of thyme (*Thymus vulgaris*), and is used externally only. It is an useful antifungal negotiator, and an efficient anthelmintic agent. The phenols and phenolic acids function against oxidative stress to decline the incidences of dreadful diseases. Salicylic acid is another important phenolic acid, removed from willow bark in the form of bitter powder. It is used to cure pains and reduce temperature in fevers. Salicylates help in increasing blood flow. Their strong antipyretic nature increase sweat formation. It is the best used medicine for curing nausea, gastric disorders, and skin problems, *viz.*, acne, corns, calluses and warts. Thus, the phenolic compounds are not only known for antioxidant activities, but also are effective antibiotic and best used remedies for inflammatory diseases.

Table PH-1 showing the common categories and examples of some of the important phenolic compounds

Simple Phenols	Phenolic acids	Phenolics	Phenylpropenes / Phenyl propanoids
Orcinol Resorcinol Catechol Hydroquinone 4-Methylresorcinol 2-Methylresorcinol Pyrogallol Phloroglucinol	Gallic acid Gentisic acid Protocatechuic acid *ρ*-Hydroxybenzoic acid Syringic acid Vanillic acid Salicylic acid	Phenol *o*-Cresol *m*-Cresol *ρ*-Cresol Guaiacol Catechol 4-Methylcatechol Hydroquinone	Safrole Anethole Estragole Myristicin Thymol Eugenol Isoeugenol Methyleugenol Elemicin Apiole

IV. Discussion

Phenolic compounds, the natural antioxidants, are the phytochemicals produced by plants for their sustenance (Apka *et al.,* 2007). They are widely distributed in the Plant kingdom. Phenolic acids such as protocatechuic acid and pyrocatechol, and phenylacetic and phenylpyruvic acids, are found in many mushroom species (Barros *et al.,* 2009). Lichens and algae are reported to produce phenolic acids, *viz.,* ρ-coumaric,

cinnamic and salicyclic acids (Babu & Wu, 2008 ; Osofrejova *et al.,* 2010). The occurrence of phenols in land plants is universal. Important phenolic compounds have been identified in vascular plants, such as, pteridophytes, gymnosperms and angiosperms (Canachan *et al.,* 2000). Hypogallic and caffeic acids have been isolated from the fresh water fern, *Salvinia molesta.* Phenols are concentrated in abundant amounts in parenchyma cells in the phloem of all conifers (Krokene *et al.,* 2008). Aquatic vascular plants produce ellagic, gallic and pyrogallic acids (Nakai, 2000). Phenolic compounds are also found significantly in monocotyledons, such as cereals. The occurrence of phenolics in non-vascular plants, i.e., bryophytes is also quite common. Some phenolics like rosmarinic acid are reported from mosses (Vigeslang *et al.,* 2005).

Phenolic compounds play an important role in prevention of chronic diseases, and thus prove beneficial to human health. These phytochemicals not only participate in many physiological processes, but most importantly act as the powerful antioxidants. The antioxidant property of the phenols enable them to reduce the harmful effects of the hazardous free radicals and oxidative stress. Researchers have shown that the antioxidants of plant origin with free radical scavenging properties function as therapeutic agents against diseases caused due to oxidative stress (Ramchoun *et al.,* 2009). Atoui *et al.,* 2005 reported that the compounds with potent antioxidant activity from natural sources include carotenoids, curcumin, and significantly, flavonoids and phenolic acids. Phenolic compounds have been reported as the antioxidants more effective than vitamin C,E and carotenoids (Dai *et al.,* 2010). They are known to protect the biological systems against ROS (Reactive Oxygen Species) and the oxidative damages caused by them (Kim *et al.,* 1993). Many of the phenolic acids, like the derivatives of cinnamic and benzoic acid exist in all plants and plant derived foods, such as fruits, vegetables and grains (Shahidi and Nacsk, 1995). They help in many functions including photosynthesis, protein synthesis and enzyme activity. The development of dreadful diseases, such as cancer, inflammatory bowel syndrome and cardiovascular disorders, is delayed by the consumption of phenolic antioxidants (Bodekar *et al.,* 2000).

Besides being the important boosters of the antioxidant defense systems, the phenolic compounds act as protective agents and inhibitors. They are natural animal toxicants and pesticides against invading organisms and pathogens. Phenols contribute a lot in human metabolism too. After ingestion through vegetables, fruits or spices, natural phenols become part of the xenobiotic metabolism. Bioavailability of phenolic acids is of great interest. It emphasizes its direct intake through food consumption, and indirectly by gastric, intestinal and hepatic metabolism (Lafay *et al.,* 2008). The role of phenols in metabolism and antioxidant activities depends upon the number of free hydroxyl groups in their molecular structures.

V. Conclusion

Phenolic compounds are known not only for their antioxidant property, but also exert other remarkable activities, such as cytotoxic, antimicrobial, anti-inflammatory and anti-tumoric. All biological actions of phenolic compounds is attributed to their antioxidant activity. Apart from strengthening the defense systems of the human body, phenolic compounds exhibit positive effects in improving health. So, suitable sources of natural phenols may be included in human nutrition, *viz.,* fruits, vegetables, herbs, spices, berries and tea. Organically grown fruits and leafy vegetables, rich in phenols, are also advantageous in providing antioxidant protection against acute ailments. The therapeutic and health-promoting actions of the phenolics is quite remarkable. Their structural diversity owes to the dietary and medicinal values of phenolic compounds, and to their role in delaying the development of chronic diseases.

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