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HEALTH BENEFITS OF POLYPHENOLIC COMPOUNDS

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Abstract:
"Plant phenolics" and "polyphenols" are secondary natural metabolites arising biogenetically from either the shikimate/phenylpropanoid pathway. Higher plants synthesize several thousand known different phenolic compounds. The ability to synthesize phenolic compounds has been selected throughout the course of evolution in different plant lineages, thus permitting plants to cope with the constantly changing environmental challenges over evolutionary time. Plant phenolics are considered to have a key role as defense compounds when environmental stresses, such as high light, low temperatures, pathogen infection, herbivores, and nutrient deficiency, can lead to an increased production of free radicals and other oxidative species in plants. Both biotic and abiotic stresses stimulate carbon fluxes from the primary to the secondary metabolic pathways, thus including a shift of the available resources in favour of the synthesis of secondary products. An interesting link between primary and secondary metabolism couples the accumulation of the stress metabolite proline with the energy transfer toward phenylpropanoid biosynthesis via the oxidative pentose phosphate pathway. The alternating oxidation of NADPH by proline synthesis and reduction of NADP+ by the two oxidative steps of the oxidative pentose phosphate pathway lead to the simultaneous accumulation of phenolic compounds.

Key words: *Phenol, nyctinasty,acetophenones, Xanthones, Stilbenes*

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INTRODUCTION:

There are approximately 300,000 documented species of higher plants on the planet, which synthesize an enormous number of chemicals of diverse structure and class. These compounds can be further divided into primary and secondary metabolites. The primary metabolites include metabolites such as sugars, fatty acids, amino, and nucleic acids, as well as chemicals considered ubiquitous to all plants for growth and development. Secondary metabolites are structurally and chemically much more diverse than the primary metabolites and refer to compounds present in specialized cells that are not directly essential for basic photosynthetic or respiratory metabolism but are thought to be required for plants' survival in the environment. Secondary metabolites apparently act as defence (against herbivores, microbes, viruses, or competing plants) and signal compounds (to attract pollinating or seed dispersing animals), as well as protecting the plant from ultra violet radiation and oxidants.

Phenolic compounds are the most widely distributed secondary metabolites, ubiquitously present in the plant kingdom, even if the type of compound present varies according to the phylum under consideration. Phenolics are uncommon in bacteria, fungi, and algae. Bryophytes are regular producers of polyphenols including flavonoids. Leaves of vascular plants contain ester; amides and glycosides of hydroxycinnamic acids; glycosylated flavanoids, especially flavanols; and proanthocyanidins and their relatives. Lignin, suberin and pollen sporopollerin are examples of phenolic-containing polymers.Broadly, as far as the definition of plant phenolics is concerned, the term'phenol' is a chemical term that defines a phenyl ring bearing one or more hydroxyl substituents. The term 'polyphenol' could thus be used to define natural product featuring at least two phenyl rings bearing one or more hydroxyl substituents, including their functional derivatives (e.g., esters and glycosides). The terms phenolic compounds should be strictly used to refer secondary natural metabolites arising biogenetically from the shikimate/phenylpropanoid pathway, which directly provides, phenylpropanoids or the 'polyketide'acetate/malonate pathway, and which fulfill a very broad range of physiological roles in plants. Several classes of phenolics have been categorized on the basis of their basic skeleton: C6 (simplephenol, benzoquinones), C6—C1 (phenolic acid), C6—C2 (acetophenone,phenylacetic acid), C6—C3 (hydroxycinnamic acid, coumarin, phenylpropanes,chromones), C6—C4 (naphthoquinones), C6—C1—C6 (xanthones), C6—C2—C6(stilbenes, anthraquinones), C6—C3—C6 (flavonoids, isoflavonoids, neoflavonoids),(C6—C3—C6)2,3 (bi-, triflavonoids), (C6—C3)2 (lignans, neolignans), (C6—C3)n (lignins), (C6)n (catechol melanins), and (C6—C3—C6)n (condensed tannins). Lowmolecular-weight phenolics occur universally in higher plants.

CLASSIFICATION

Sl;no	No;of carbon atom	No;of phenolic ring	Skeleton	Classification	Example
1	6	1	C6	Smiple phenols	Catachol hydroquinone
2	7	1	C6-C1	Acetophenones	Gallic acid
3	8	1	C6-C2	Phenylacetic acid	Homogentisic acid
4	9	1	C6-C3	Hydroxycinnamic acid Coumarin	p-Coumaric acid Esculetin
5	10	1	C6-C4	Naphthoquinone	Plumbagin
6	13	2	C6-C1-C6	Xanthones	Mangiferin
7	14	2	C6-C2-C6	Stilbenes	Emodin,Resveratrol
8	15	2	C6-C3-C6	Flavanoids	Quercetin,Cyanidin
9	16	2	C6-C4-C6	Haloginated algal phenolic compound	Kaviol A,Copol
10	18	2	(C6-C3)2	Lignins Neolignans	Pinoresinol
11	30	4	(C6-C3-C6)2	Biflavanoids	Amentoflavone
12	many	Ngreater than 12	(C6-C3)2 (C6)2 (C6-C3-C6)2	Lignins Melanins	Tannic acid

1.SIMPLE PHENOLS

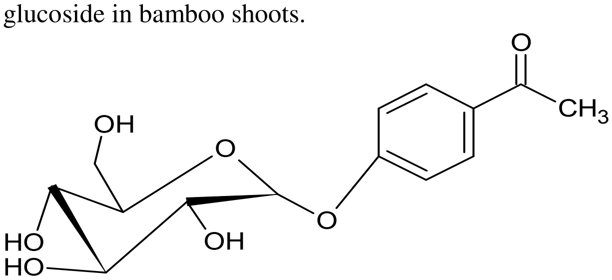
Simple phenols (C6) include catechol and phloroglucinol. Although most of the more complex plant polyphenols contain these two simple phenols as a parts of their structures, catechol and phloroglucinol are uncommon in plant tissues.

2.PHENOLIC ACID

Phenolic acids are usually present in the bound soluble form conjugated with sugars or organic acids and are typically components of complex structures such as lignins and hydrolyzable tannins. Gallicacid is the base unit of gallotannins, whereas gallic acid and hexahydroxydiphenoyl moieties are both subunits of the ellagitannins, which are classified as hydrolyzable tannins.

3.PHENYLACETIC ACID

Phenolic ketones(C6-C2) have occasionally been found as plant constituents. Picein the main component of all investigated spruce needles . p-Hydroxy phenylacetic acid occurs free and as a glucoside in bamboo shoots.

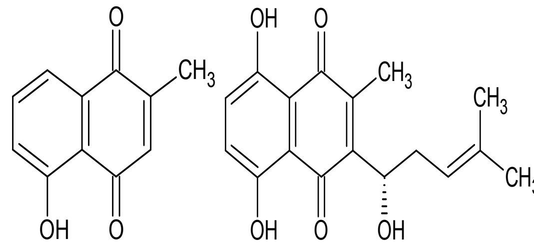


4.HYDROXYCINNAMIC ACID

The most widely distributed hydroxycinnamates (C6—C3) are p-coumaric, caffeic, ferulic, and sinapic acids, which usually occur in various conjugated forms and are seldom found in the free state except as artifact due to chemical or enzymic hydrolysis during tissue extraction. The p-coumaric moiety is an important unit in the structure of flavonoids, stilbenoids, and xanthones. Coumarins, which are also C6—C3 derivatives,are benzo-a-pyrones (lactones) formally derived from o-hydroxycinnamic acids by cyclization and ring closure between the o-hydroxy and carboxyl groups.

5.NAPHTHOQUINONES

Naphthoquinones (C6—C4) represent a class of quinone pigment widespread in nature. The most important higher plant families containing naphtha quinine are Avicenniaceae, Bignoniaceae, Boraginaceae, Droseraceae, Ebenaceae Juglandaceae, Nepenthaceae, and Plumbaginaceae. They are biosynthesized via a variety of pathways including polyketide pathway (plumbagin) shikimate/ succinyl-CoA combined pathway [lawsone (2-hydroxy-1,4-naphthoquinone)], and shikimate/mevalonate pathway.

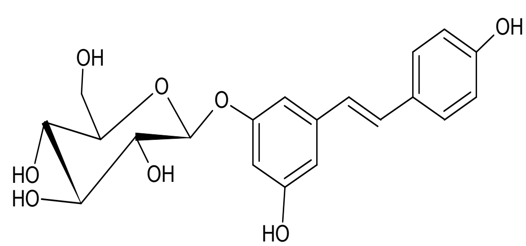


6.XANTHONES

Xanthones (C6—C1—C6) are a class of plant phenolics occurring in a few higher plant families (Gentianaceae, Guttiferae, Loganiaceae, Podostemaceae, and Polygalaceae). The majority of natural xanthones have been found in just two families of higher plants, Guttiferae and Gentianaceae. Xanthones may be classified into five major groups: simple oxygenated xanthones (this group can further be subdivides into six groups according to the degree of oxygenation), xanthone glycosides, prenylated andrelated xanthones, xanthonolignoids, and miscellaneous. Mangiferin is unique among the natural xanthonesin having a much wider natural occurrence than that of any of the others.

7.STILBENE

The stilbene family have the C6—C2—C6 structure and are widely distributed in the plant kingdom, although some structures are characteristic of particular plant families.These stilbene phytoalexins include resveratrol and its derivatives.



8. FLAVANOIDS

Flavonoids and their conjugates form a very large group of natural products; over 8,000 different flavonoids have been identified. They are found in many plant tissues, where they are present inside the cells or on the surfaces of different plant organs. The chemical structures of this class of compounds are based on a C6—C3—C6 skeleton. Depending on the position of the linkage of the aromatic ring to the benzopyrano (chromano) moiety, this group of natural products may be divided into three classes:

the flavonoids (2-phenylbenzopyrans), the isoflavonoids (3-benzopyrans), and the neoflavonoids (4-benzopyrans).

9.LIGNANS AND NEOLIGNANS

Lignans and neolignans (C6—C3)2 are a large and varied group of plant phenolics produced by the oxidative dimerization of two phenylpropanoidunits, which occur in a wide range of plant species. When the two C6—C3 units are linked by a b,b0-bond (or 8,80-bond), the parent structure lignane is used as the basis fornaming the lignan. If the two C6—C3 units are linked by a bond other than a b,b0-bond, the parent structure, neolignane, is used as the basis for naming the neolignan (+)-Pinoresinol , for example, is a lignin derived by a tail-to-tail linkage in the b-position of two coniferyl alcohol residues, which has been extracted from various plant sources such as Saussurea medusa, Pinus, and Picea. Related dimers, called neolignans, can be formed by other condensations between two C6—C3 units, for example, joining head-to-tailinstead of tail-to-tail. One example of dimer formed by other condensations between two C6—C3 units, for example, joining head-to-tail instead of tail-to tail is eusiderin. This and related structures occur in heartwoods of Magnoliaceae, Piperaceae, and Lauraceae

10.TANNINS

The plant tannins are a unique group of phenolic compounds of relatively high molecular weight which have the ability to complex strongly with carbohydrates and proteins. In higher plants, tannins consist of two major groups of metabolites: the hydrolyzable tannins and condensed tannins. Hydrolyzable tannins are split by acids, bases, and in some cases by hydrolytic enzymes (tannase) into sugars (usually D-glucose) or related polyols and a phenolic acid. Phlorotannins consist of phloroglucinol units linked to each other in various ways and are of wide occurrence among marine organisms, especially brown and red algae. Based on the means of linkage, phlorotannins can be classified into four subclasses, namely, phlorotannins (i) with an ether linkage (fuhalols and phlorethols), (ii) with a phenyl linkage (fucols), (iii) with an ether and a phenyl linkage (Fucophlorethols), and (iv) with a dibenzodioxin linkage (eckols and carmalols).3-Phloroeckol isolated from Eisenia arborea, is an example of phlorotannins with a dibenzodioxin linkage

11.LIGNIN AND MELANINS

Lignin (Latin: lignum ¼ wood) [(C6—C3)n], the essential structural polymer of wood and second only to cellulose as the most abundant organic substance in plants, is found as an integral cell wall constituent of all vascular plants including herbaceous species. Gymnosperm lignins are primarily derived from coniferyl alcohol. As a biomacromolecule, lignin is unusual in having a complex network-type structure that at a first glance appears chaotic. In fact, it is optically inactive.

Melanins are pigments of high molecular weight formed by the oxidative polymerization of phenolic compounds and usually are dark brown or black. They are widely distributed in the living world. In general, they are conjugated polymers of ortho-dihydroxyphenols. The individual residues of polymeric melanin likewise contain two ortho oxygens. Melanins are among the most stable, insoluble, and resistant biochemical materials, and they enhance the survival and competitive abilities of organism in certain environments. Melanins constitute a mechanism of defense and resistance to stress such as UV radiations, free radicals, gamma rays, dehydration, and extreme temperatures and contribute to the fungal cell wall resistance against hydrolytic enzymes in avoiding cellular lysis.

They are three types:

1. Eumelanins (black or brown) that are produced in the course of oxidation of tyrosine (and/or phenylalanine) to 3,4-dihydroxyphenylalanine (DOPA) and dopaquinone, which further undergoes cyclization to 5,6-dihydroxyindole or5,6-dihydroxyindole- 2-carboxylic acid.
2. Pheomelanins (yellow, red, or brown) that are initially synthesized just like eumelanins, but DOPA undergo cysteinylation, directly or by the mediation of glutathione, then polymerizes.
3. Allomelanins (black), the most heterogeneous group of polymers, which emerge through oxidation /polymerization of dihydroxynaphthalene or tetrahydroxynaphthalene, homogentisic acid, g-glutaminyl-4-hydroxybenzene, 4-hydroxyphenylacetic acid, as well as of catechols.

The eumelanins and pheomelanins are found mainly in animal species, whereas the allomelanins are found in plants.

PHYSIOLOGICAL AND ECOLOGICAL ROLE OF PLANT PHENOLICS

1.KEY ROLE IN DEFENSE MECHANISAM

Plant phenolics are considered to have a key role as defense compounds when environmental stresses, such as high light, low temperatures, pathogen infection, herbivores, and nutrient deficiency, can lead to increased production of free radicals and other oxidative species in plants. The accumulation of phenolics in plant tissues is considered a common adaptive response of plants to adverse environmental conditions, therefore increasing evolutionary fitness.

2.ROLE IN DECOMPOSITION AND NUTRIENT CYCLING

Polyphenols, which enter the soil mainly as leachates from above- and below ground parts of plants and/or within above- and belowground plant litter, have been recognized as regulators of soil processes, where it has been suggested that they could control the pool and the form of nutrients available for plants and/or microbes. For example, phenolic compounds can directly affect the composition and activity of decomposer communities, thus influencing the rates of decomposition and nutrient cycling.

3.ROLE IN NYCTINASTY

Some plants are known to open their leaves in the daytime and "sleep" at night with their leaves folded. This circadian rhythmic leaf movement known as nyctinasty. Nyctinastic leaf movement is induced by the swelling and shrinking of motor cells in the pulvinus. A flux of potassium ions across the plasma membranes of the motor cells is followed by a massive water flux, which results in the swelling and shrinking of these cells. This prosses are under the metabolic control. All the leaf-opening factors have a common structural feature, the p-coumaroyl moiety, and this result suggests that this structural feature would be deeply involved in the common mechanism for leaf-opening.

4.ROLE IN FLOWERS AND FRUIT COLOURING

Anthocyanins represent a class of flavonoidcence that are abouts providing the red and blue/purple colors familiar in many flowers and fruits. Anthocyanins are also the pigments responsible for spectacular displays of variable red to reddish-orange color in the leaves of deciduous trees. Thus, red is produced actively in autumn and is not simply the side effect of leaf senescence. Red may protect the leaf from the damaging effects of light at low temperatures (photoinhibition andphotooxidation), allowing a more efficient resorption of nutrients, especiallynitrogen.

5.ROLE IN PROTECTING THE PLANTS FROM PATHOGENS

In an environment rich in potentially harmful microbes, plant survival depends on an efficient microbe perception and fast defense responses. Plant immunity relieson the ability of each cell to recognize pathogens. A first level of microbe recognition is performed by membrane proteins termed pattern recognition receptors (PRRs), which perceive the molecular signatures characteristic of a whole class of microbes, termed pathogen-associated molecular patterns (PAMPs). Phenolics are synthesized when plant PRRs recognize potential pathogens by conserved PAMPs, leading to a PAMP-triggered immunity. The plant's recognition of pathogens induces its endogenous multicomponent defense system.

6.ROLE IN PROTECTING THE PLANT FROM INSECTS

The ecological relationship between plants and insects is a complex one with physical as well as chemical interactions. This relationship is also affected by plant factors, insect factors, and by some insect–plant factors, including hypersensitive reaction and plant resistance to insect-borne diseases. Plant constituents that make unpalatable a host are secondary metabolites in sufficient concentration to exert an undesirable physiological effect. It is now generally accepted that plant phenolics play a role in protecting plants from insects.

Tannins, also, may affect the growth of insects in three main ways: they have an astringent taste which affects palatability and decreases feed consumption; they combine with proteins to form complexes of reduced digestibility; and they act as enzyme inactivators.

CONCLUSION:

Natural phenolic compounds play an important role in cancer prevention and treatment. Phenolic compounds from medicinal herbs and dietary plants include phenolic acids, flavonoids, tannins, stilbenes, curcuminoids, coumarins, lignans, quinones, and others. Various bioactivities of phenolic compounds are responsible for their chemopreventive properties (e.g., antioxidant, anticarcinogenic, or antimutagenic and anti-inflammatory effects) and also contribute to their inducing apoptosis by arresting cell cycle, regulating carcinogen metabolism and ontogenesis expression, inhibiting DNA binding and cell adhesion, migration, proliferation or differentiation, and blocking signaling pathways. This review covers the most recent literature to summarize structural categories and molecular anticancer mechanisms of phenolic compounds from medicinal herbs and dietary plants.

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