Phytochemicals: Sources, Chemical structure and Health benefits

Dr. Gargee Yadav

Associate Professor
Department of Chemistry,
S.N.Sen B.V.P.G.College, Kanpur

Abstract: Phytochemicals are chemical compounds produced by plants, to help them resist fungi, bacteria, and plant virus infections, and consumption by insects and other animals. Eating a diet high in fruits, vegetables, grains, legumes, and plant-based beverages has long-term health benefits. Which is due to presence of certain bioactive compounds termed as phytochemicals. Few examples of well-known phytochemicals are the flavonoids, phenolic acids, isoflavones, curcumin, isothiocyanates, and carotenoids

They are used as neuroprotective, antioxidant, antiulcer, antimicrobial, hypolipidemic, estrogenic, and in the treatment of atherosclerosis, cardiovascular disease, stroke, cancer, diabetes, and menopausal symptoms in women.

***IndexTerms* - Phytochemicals, Fruits, Vegetables, Neuroprotective, Antioxidants Atherosclerosis, Cardiovascular diseases.**

INTRODUCTION

Consuming plants for their presumed health benefits has occurred since early civilizations. Phytochemicals are found in various plants that are frequently included in the human diet and are thought to be safe for consumption because they are produced naturally. These are chemicals that are found in plants that protect them against bacteria, viruses, and fungi. Phytochemicals cannot be found in supplements and can only be obtained from common plant foods, herbs, and spices. A few examples of well-known phytochemicals are the flavonoids, phenolic acids, isoflavones, curcumin, isothiocyanates, and carotenoids.

They are found to be potentially beneficial for humans. These are present in fruits, vegetables and many other plants and are consumed or used as herbal remedies or dietary supplements for perceived health benefits [1].

In India, phytochemicals have been the most abundant source of health care and life improvement since ages. They cannot be found in supplements and can only be obtained from common plant foods, herbs, and spices. In this article, sources, structure and beneficial effects of some common phytochemicals have been discussed.

SOURCES & STRUCTURE OF PHYTOCHEMICALS.

There are several types of phytochemicals. Each one helps the body in a different way.

They are grouped into two main categories namely primary constituents which includes amino acids, common sugars, proteins, and chlorophyll etc., and secondary constituents consisting of alkaloids, essential oils, flavonoids, tannins, terpenoids, saponins, phenolic compounds etc.

Foods high in phytochemicals include the

*Red, orange, and yellow vegetables and fruit (such as tomatoes, carrots, peppers, squash, sweet potatoes, peaches, mangos, melons, citrus fruits, and berries)

*Dark green leafy vegetables (such as spinach, kale, bok choy, broccoli, Swiss chard, and romaine lettuce)

*Garlic, onions, chives, and leeks

*Whole grain products (such as brown rice, wild rice, quinoa, barley, wheat berries, and whole wheat whole grain breads and whole grain cereals)

*Nuts and seeds (such as walnuts, almonds, sunflower, sesame, and flax seeds)

*Legumes (such as dried beans, peas, lentils, soybeans and soy products)

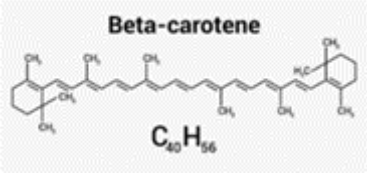
*Tea and coffee (such as green tea, black tea, and other herbal teas)

*Dark chocolate to name a few [2].

CAROTENOIDS

Carotenoids are a chemically diverse group (with more than 600 different compounds) of yellow to red colored polyenes consisting of 3–13 conjugates double bonds and in some cases, six carbon hydroxylated ring structures at one or both ends of the molecule. beta-carotene, lutein, and zeaxanthin are all types of carotenoids One of the more common phytochemicals is lycopene which is responsible for tomatoes' red color. It acts as an antioxidant in body protecting from cell damage. Lycopene may protect against cancer, especially prostate cancer, heart disease in diabetics, inflammation, infections, arteriosclerosis, and toxins. Grapefruit, watermelon, and red oranges are also good sources of lycopene. Egg yolk is a highly bioavailable source of lutein and zeaxanthin. Carotenoids inhibit cancer growth, improve immunity, support vision, and promote skin health. They are found in broccoli, carrots, cooked tomatoes, leafy greens, sweet potatoes, winter squash, apricots, cantaloupe, oranges, and watermelons.

Another example of carotenoids is beta carotene,

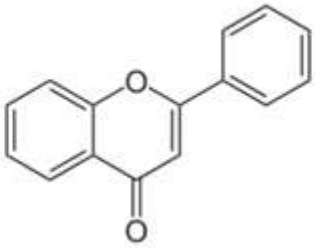


Structure of beta Carotene

It is the most abundant form of carotenoid and
is a precursor of the vitamin A. The presence of long chains of conjugated double bonds imparts beta-carotene with specific colors. Carotenoids are natural pigments responsible for colors ranging from yellow through orange to red [3].

FLAVONOIDS

Flavonoids consist of a large group of polyphenolic compounds having a basic benzo-□-pyrone structure.

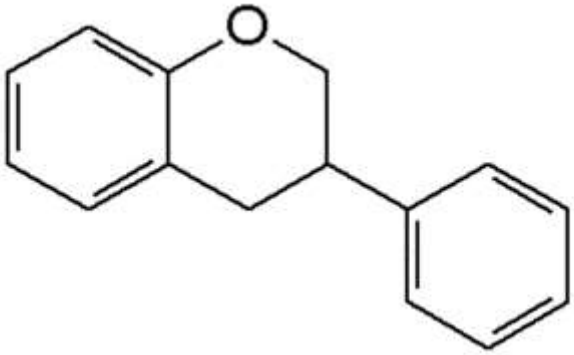


Flavone backbone
(2-phenylchromen-4-one.)

Flavonoids have the general structure of a 15-carbon skeleton, which consists of two phenyl rings (A and B) and a heterocyclic ring (C, the ring containing the embedded oxygen) [4]. Anthocyanins, quercetin and catechins are all types of flavonoids. They inhibit tumor growth, reduce inflammation and boost immunity. Apples, onions, soybeans, coffee, tea and citrus fruits like oranges and lemons are all sources of flavonoids. Fruits, tea, wine and soybeans all contain phytochemicals from the flavonoids group. Flavonoids are responsible for giving fruit their color. These phytochemicals act as an antioxidant in the body, protecting cells from damage. They have beneficial anti-inflammatory effects and protect the cells from oxidative damage that can lead to disease. The flavonoids found in tea may help lower triglycerides and blood cholesterol level. Soybean flavonoids can lower cholesterol levels as well but are also used to ease symptoms related to menopause. The phytochemical anthocyanins give red, blue and purple fruits and vegetables their color. Cherries, acai, blueberries, purple corn, blackcurrants and red grapes have the highest content of anthocyanins. While anthocyanins do act as an antioxidant, they are known more for their protection against atherosclerosis, inhibiting tumor growth and their role as an anti-inflammatory [5].

ISOFLAVONES

Isoflavones are substituted derivatives of isoflavone, a type of naturally occurring isoflavonoids, many of which act as phytoestrogens in mammals. Isoflavones are quite same as flavonoids except their difference in being exclusively present in the members of the bean family. In plants, some isoflavones have antimicrobial activity and are synthesized in response to attacks by bacteria or fungi. Structurally, isoflavones have the 3-phenylchromen-4-one backbone in their chemical structure.

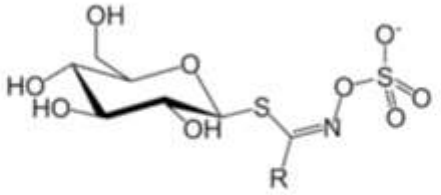


Isoflavones backbone
(3-phenylchromen-4-one backbone)

isoflavones inhibit tumor growth and limit the production of cancer-related hormones [6].

GLUCOSINOLATES

Glucosinolates, like other phytochemicals, are known to prevent tumor growth and decrease production of cancer-related hormones. Glucosinolates can be hydrolyzed by myrosinase (an enzyme that catalyzes the hydrolysis of glucosinolates) to produce D-glucose and various other degradation products like isothiocyanates. They are known for their fungicidal, bactericidal, nematicidal properties and cancer chemo-protective attributes. Iso-thiocyanates, one of the hydrolyzed products, show best anti-carcinogenic activity. They are found in broccoli, cabbage, kale, cauliflower, and Brussels sprouts [7]. Glucosinolates constitute a natural class of organic compounds that contain Sulphur and nitrogen and are derived from glucose and an amino acid. They are water-soluble anions and belong to the glucosides

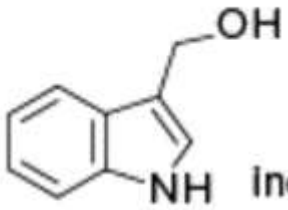


Glucosinolate structure; side group *R* varies

Every glucosinolate contains a central carbon atom, which is bound to the Sulphur atom of the thioglucose group, and via a nitrogen atom to a sulfate group (making a sulfated aldoxime). In addition, the central carbon is bound to a side group; different glucosinolates have different side groups, and it is variation in the side group that is responsible for the difference in properties [8].

INDOLES

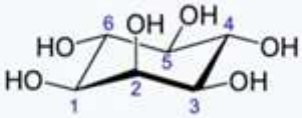
ndole-3-carbinol (I3C) is derived from the breakdown of glucobrassicin, a compound found in cruciferous vegetables. They function as stimulators for detoxifying enzymes in the intestine and liver, balance hormones, promote the action of chemotherapeutic drugs and has shown inhibitory effects in human breast and ovarian cancers growth. Indole derived phytochemicals function as antidepressants also [9].



Indole-3-carbinol

INOSITOLS

Inositols, is a group of nine different stereoisomers. Among these, however, the term inositol is generally used to refer to the most bioavailable type, myo-inositol. Inositols prevent cell damage and is found in bran from corn, oats, rice, rye and wheat, as well as nuts and soybeans.



Inositol structure

Inositol, is a carbocyclic sugar. The IUPAC name for inositol is 1,2,3,5/4,6-cyclohexanehexol. They are polyols having six-carbon ring structure where each carbon is hydroxylated. A number of these sugar-alcohol isomers are biologically active, of which myo-inositol (MI) is the most common [10].

Inositol might balance certain chemicals in the body to help with mental conditions such as panic disorder, depression, and obsessive-compulsive disorder. It might also help insulin work better. It is used for metabolic syndrome, polycystic ovary syndrome (PCOS), and for reducing the risk of preterm birth [11].

POLYPHENOLS

Polyphenols are one of the most important and certainly the most numerous among the groups of phytochemicals present in the plant kingdom.

They can prevent cancer formation and inflammation. They are typically found in green tea, grapes, wine, berries, citrus fruits, apples, whole grains, and peanuts. Red wine or a cup of coffee or tea contains about 100 mg polyphenols [12].

The major sources of dietary polyphenols are cereals, legumes (barley, corn, nuts, oats, rice, sorghum, wheat, beans, and pulses), oilseeds (rapeseed, canola, flaxseed, and olive seeds), fruits, vegetables, and beverages (fruit juices, tea, coffee, cocoa, beer, and wine) [13].
Although polyphenols are chemically characterized as compounds with phenolic structural features, this group of natural products is highly diverse and contains several sub-groups of phenolic compounds. Most polyphenols contain repeating phenolic moieties of pyrocatechol, resorcinol, pyrogallol, and phloroglucinol connected by esters (hydrolyzable tannins) or more stable C-C bonds (nonhydrolyzable condensed tannins). Polyphenols may be classified into different groups as a function of the number of phenol rings that they contain and based on structural elements that bind these rings to one another. The main classes include phenolic acids, flavonoids, stilbenes and lignans.
Phenolic acids are found abundantly in foods and divided into two classes: derivatives of benzoic acid and derivatives of cinnamic acid. Stilbenes contain two phenyl moieties connected by a two-carbon methylene bridge [14].

ISOLATION

Chemical methods
This extraction method is based on the type of functional groups possessed by a compound in the given mixture. Separation or purification can be achieved by chemical reactions using appropriate reagents [15].
Fractionation and purification of phytochemical substances are achieved through application of various chromatographic techniques such as paper chromatography, thin-layer chromatography, gas chromatography, and high-performance liquid chromatography [16].
Physical methods used in separation of compounds from mixtures include separation funnel method [17]. Chromatographic techniques, fractional distillation, fractional crystallization, fractional liberation, and sublimation [18].

IDENTIFICATION TECHNIQUES

Several methods were used in the identification of compounds from medicinal plant extracts. It comprised of detection of functional group, presence of multiple bonds and rings, hydrogen, and carbon arrangement as well as full structural elucidation. The techniques used include mass spectroscopy (MS), ultraviolet spectroscopy (UV), nuclear magnetic resonance spectroscopy (NMR), and infrared spectroscopy (IR) [19].

BENEFICIAL EFFECTS

Phytochemicals are a plant's way of protecting itself. They help shield tender buds and sprouts from predators, the elements, and pollution. These protective compounds are passed along to humans when they eat plant foods [20].
Phytochemicals have significant physiological effects in the body. Whether they are acting as antioxidants, mimicking hormones, stimulating enzymes, interfering with DNA replication, destroying bacteria, or binding to cell walls, they seem to work to curb the onset of diseases such as cancer and heart disease.
Number of studies has demonstrated that consumption of polyphenols limits the incidence of coronary heart diseases [21]. They are useful in neurotraumatic and neurodegenerative diseases [22].
Polyphenols show antithrombotic effects by means of inhibiting platelet aggregation [23].
Curcuminoids, the polyphenolic
phytochemicals, acts as an anti-inflammatory and cancer preventive drug. Carotenoids are beneficial antioxidants that can protect from disease, enhance immune system as well as eye health and reduce the risk of skin cancer. They are known to reduce inflammation, prevent DNA damage and regulate hormones and also prevent damaged cells from reproducing [24].
phytoestrogens are effective in maintaining bone mineral density (BMD) in postmenopausal women and to alleviate the osteoporosis and associated disorders. Phytoestrogens can produce estrogenic effects in the postmenopausal women, thus reducing post-menopausal ailments. Isoflavonoids can lower total and LDL cholesterols and raise HDL cholesterol resulting in reduced risk of CVDs [25].
Indole 3- carbinol, has been shown to exhibit potent anticarcinogenic properties in a wide range of cancers such as lung, liver, colon, cervical, endometrial, prostate, and breast cancer
The biological activity of these phytochemicals is related to the to the chemical structure of these compounds lending them the necessary beneficial properties [26].

CONCLUSION

Phytochemicals are highly beneficial for our body, the key is to get them from whole foods, not in the form of supplements. The structure of a molecule contains the features responsible for its physical, chemical, and biological properties. Thus, the beneficial properties of the phytochemicals responsible for their therapeutic importance can be related to the chemical structure which can be explored further for development of novel compounds having bioactivity as well as healing effects at par with these natural compounds.
They are found to be more effective in treating diseases as they have less side effects than the modern-days medication. The only way to increase the intake of phytochemicals is to eat more plant foods. Dietary recommendations of diets high in fruits and vegetables are advised.

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