

Review Article

Importance of Polyphenols in Food and its Health Benefits

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Abstract: Polyphenols are widely available in different plant-based food sources, and recent studies have found the relationship between decreased rates of chronic diseases with higher intake of food rich in polyphenols, i.e. cardiovascular diseases. Polyphenolic compounds have antioxidant properties and helps in the prevention of diseases like heart disease and cancer. Polyphenolic compounds are basically any organic compounds which contain a benzene ring with one or more hydroxyl groups. Sensory attributes of foods like appearances, taste, colour, odour etc., are greatly affected by the presence of phenolic compounds. This review paper aims to provide a brief overview about the importance of consumption of phenols present in foods and its well-established health benefits.

Key words: Polyphenols, Health Benefits, Anti-carcinogenic Properties, Antioxidants, Therapeutic Benefits

1. INTRODUCTION

Food contains essential nutrients, which plays important role in maintaining healthy body, providing energy for day to day work and other essential roles. Nowadays, consumers being more educated regarding what they consume, have become more aware of consumption of health-promoting foods. Recent studies have revealed that various bioactive compounds and phytonutrients present in foods, has a wide role in the prevention of various diseases [10,15, 26,40].

Among the bioactive compounds, polyphenols are a class of important naturally occurring compounds of plant kingdom, present in different kinds of fruits, vegetables, cereals, legumes, plantation crops (tea, coffee etc.), oilseeds (i.e. rapeseed, canola, flaxseed etc.) and even in chocolates

[15,25,28,45]. For example, fruits like apple, cherry, berries etc. contain 200-300 mg polyphenols/ 100 g fresh fruit whereas red wine or tea or coffee contains 100 mg polyphenol/ per serving [15,28,29].

In “plant source” foods, polyphenols are widely found occurring naturally which are classified under following categories [10,16,28,37,51]:

- Hydrobenzoic acid (Protocatechuic acid, Gallic acid)
- Hydroxycinnamic acids (Coumaric acid, Caffeic acid, Ferulic acid, Curcumin)
- Stilbenes (Resveratrol)
- Lignans (Secoisolariciresinol)
- Flavonoids (Flavonols, Flavones, Isoflavones, Flavanones, Anthocyanidins and Flavanols)

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Polyphenols present in plant world, serves a wide range of applications, i.e. pigmentation in flowers, fruits and seeds which attracts pollinators like insects and help in seed dispersion, regulates growth hormones, protects plants from ultraviolet ionizing radiation, prevents chances of microbial infection, important role in release of signalling molecules for ripening and plant growth [3,7,38].

Polyphenols play role in defining taste, colour and nutritional properties of fruits [7,25], i.e., red colour of red wine, with astringency and bitter taste are attributed to anthocyanidins and tannins (type of polyphenols) [27,52]. Polyphenols are known for their antioxidant property, which prevents LDL lipoprotein oxidation, platelet aggregation, red blood cells (RBC) damages [41]. Polyphenols are known for other important properties as listed below [43]:

- Metal chelating
- Anti-mutagenic
- Anti-carcinogenic
- Antimicrobial
- Clarifying agent

2. CARDIOVASCULAR HEALTH

Khurana *et al.* reviewed about the harmful effects of accumulated reactive oxygen species (ROS) due to oxidative stress resulting in harmful effects on cellular functioning, causing origin of a number of diseases which even includes cardiovascular diseases [23]. Further, it was reviewed about the therapeutic uses of antioxidants like polyphenols and their beneficial properties in maintaining cardiovascular health. It was further reviewed by Dell'Agli *et al.* that, intake of polyphenol-rich diets lowers the risk of cardiovascular diseases, due to the presence of polyphenol compounds like anthocyanosides (ACs), catechins, proanthocyanidins (PAs), stilbenes and other phenolics [8].

Fraga *et al.* studied about the potential polyphenolic compounds molecular interaction and biochemical mechanisms classified as specific and non-specific actions [13]. Evidence suggested that consumption of fruits and vegetables promotes health and prevents the occurrence of cardiovascular diseases. Effects of polyphenol rich food consumption reduce the chances of occurrence of following diseases [5,13]:

- Dyslipidaemia and atherosclerosis
- Endothelial dysfunction and hypertension
- Platelet activation and thrombosis
- Inflammation associated with the induction and

perpetuation of CVD

Vasodilator effects of polyphenols, improvement of lipid profile, reduction of oxidation of low-density lipoprotein, and anti-inflammatory effects help prevention of cardiovascular disease by consuming polyphenols rich foods [39]. Higher concentrations of the catechol amines 'epinephrine' were administered to experimental laboratory animals which were responsible for inducing myocellular mitochondrial swelling, myofibrillar disruption, plasma membrane blabbing, and myocardial necrosis. It was observed that these cardio-toxic effects were not from the catechol amines alone but also from the production of oxygen radical and H₂O₂ generated by a complicated series of reactions during the auto-oxidation of catechol amines. It was further reported that the vitamin-E deficient rats were sensitive to the cardiotoxicity effect of isoproterenol. Furthermore, vitamin-E supplemented diet reduced the myocardial damaged caused by synthetic catecholamine. These experiments demonstrate the protective action by antioxidants against catecholamine-induced myocardial necrosis [48].

Cardvedilol have potential antioxidant effects, which prevents the lipoperoxidation of mitochondrial membranes thereby contribute to mitochondrial cardioprotective function [33]. Facino *et al.* observed from the study that an identical cardioprotective effect is observed by antioxidant enzymes and agents having the capability to scavenge hydroxyl radicals but no potency scavenge super oxide anion produced [11]. Plant-derived compounds, for example, procyanidine from *Vitis vinifera L.*, resveratrol shows protective effects against ischemic injury [11]. Tea is a major source of flavonoids, its consumption is said to have stroke lowering effect [19,25].

3. ANTI-CARCINOGENIC EFFECTS OF POLYPHENOLS

Polyphenols are effective in reduction of tumours or their proliferation when subjected to human cancer cell lines [54]. This effect is observed at various sites of the human body like stomach, duodenum, liver, colon, skin, lung and mammary glands. Tests involving polyphenols such as quercetin, catechins, iso-flavones, lignans, flavanones, ellagic acid, red wine polyphenols, resveratrol and curcumin reveal that the protective effects of the compounds vary in their mode of action with different models. Development of cancer is said to have multi-stages; initiation, promotion and progression.

Polyphenols are capable of chemo-preventive properties. The mechanisms can be estrogenic or anti-estrogenic activity, prevention of oxidation, detoxifying enzymes, regulating host immune system, anti-inflammatory activity and several others

[20]. Polyphenols are believed to modulate the cytochrome P₄₅₀ activities, which are involved in the activation of carcinogen. Polyphenols intake can activate detoxification and boost defensive mechanism against toxic xenobiotics [50]. Khan and Mukhtar inferred that tea catechins consumed by men with high-grade prostate intraepithelial neoplasm (PIN), had shown anti-carcinogenic ability by suppressing transformation of PIN lesions into tumours [22]. Studies have shown that polyphenolic compounds present in black tea, i.e., theaflavins and thearubigins, have strong anti-carcinogenic properties by inhibiting proliferation and apoptosis of prostate cancer cells. Principle behind anti-carcinogenic properties of black tea polyphenols may be understood from the work reported by Sharma and Rao, where it was stated that black tea polyphenols block IGF-1 induced cells to transform into prostate carcinoma cells [47].

Studies on quercetin reveal that the compound has anticancer property against lung cancer induced by benzo (a) pyrene in mice models. This property can be attributed to free radical scavenging ability [21]. Resveratrol has the capacity to prevent all stages of cancer and particularly more effective on lung, co-rectal and breast cancer by suppressing angiogenesis and metastasis. Athar *et al.* reported anti-carcinogenic effects of resveratrol and association with its antioxidant activity by inhibiting cyclooxygenase, hydroperoxidase, protein kinase C, Bcl-2 phosphorylation, Akt, focal adhesion kinase, NFκB and cell cycle regulators [1].

4. NEURO-PROTECTIVE EFFECTS

Oxidative stress and brain macromolecules damage are major culprits in neurodegenerative disorders. It is believed that 18 million people are affected by neural disorders like Alzheimer's disease. Polyphenols being potent antioxidant in nature, consumption of these would decrease occurrence of such neurodegenerative disorders [49].

Resveratrol holds potency to inhibit nuclear factor κB (NF-κB) signalling and thereby protecting against microglia – dependent beta-amyloid toxicity in Alzheimer's disorder model. This activity can be correlated with activation of SIRT-1 [30]. Naturally available polyphenolic compounds, from fruits and vegetables have the vital role in neuro-protection by having the influencing capability of various cellular functions, i.e., proliferation, apoptosis, and Redox balance and cell differentiation.

Green tea consumption is linked to reducing risk of occurrence of Parkinson's disease. Epigallocatechin gallate (EGCG) shown protective role against neurotoxin MPTP (N-methyl-4-phenyl-1, 2, 3, 6-tetra hydropyridine) which is

believed to induce Parkinson's disease. Falany stated that EGCG also protects and facilitate neural cell survival by activating signalling pathways involving MAP kinases and also by chelating iron [12]. Barone *et al.* reviewed the potential of maize bran polyphenol, ferulic acid in reversing Alzheimer's disease by its virtue of antioxidant and anti-inflammatory properties [2].

5. ANTIOXIDANT ACTIVITY

During oxidative stress condition, imbalance occurring between free radicals and antioxidants, leads to the production of free radicals and reactive metabolites, which are known as reactive oxygen species (ROS) or oxidizing agents. The occurred imbalance leads to the damage of vital bio-molecules and cells affecting the overall equilibrium of living cell. Oxidative stress has detrimental effect on lipids, DNA, carbohydrates in functional cells, which also will leads to disorders like diabetes and neurodegenerative disorders. Polyphenols are known for their free radical scavenging activity involving metal chelation, suppressing free radical formation and enzyme regulation [13].

Nijveldt *et al.* reviewed that polyphenols exert scavenging effects on ROS, superoxide, hydrogen peroxide and hypochlorous acid. These have a detrimental effect on bio-molecules such as genetic material like DNA and multifunctional proteins [35]. Furthermore, polyphenols have the capability to indirectly interfere with the cellular detoxification mechanisms like super oxide dismutase (SOD), catalase or glutathione peroxidases. Polyphenols also are known for inhibiting enzymes responsible for the production of ROS like xanthine oxidase and Nicotinamide adenine dinucleotide phosphate (NADPH) oxidase [36]. Red wines have abundant phenolic acids like, resveratrol, flavanols and anthocyanins, which have huge antioxidant potency [14].

6. ANTI-DIABETIC EFFECT

Imbalanced and disturbed glucose metabolism leads to metabolic disorders including onset of physiological imbalance of higher sugar levels (hyperglycaemia) and subsequently giving rise to diabetes mellitus [42]. There are several complications associated with long-term diabetes leading to retinopathy, nephropathy, foot ulcers and sexual dysfunctions. Catechins present in tea, are known for their anti-diabetic ability [42]. Polyphenols act by inhibiting glucose absorption in the gut thereby inhibiting alpha-glucosidase in the gut mucosa. They are found to block glucose transporters and intestinal glycosidase [31]. Polyphenolic compounds such

as catechins, epicatechin gallate, epigallocatechin, isoflavones, tannic acid, glycyrrhizin and saponins are responsible for delay in glucose transport in intestine and intestinal absorption [9].

Chen *et al.* investigated that resveratrol inhibits diabetes-induced renal malfunction (Nephropathy) and recovery of renal malfunctioning and damage caused by oxidative stress in rat models [6]. Investigations reveal that resveratrol lowers insulin secretion and postpone insulin resistance. It is believed that polyphenols inhibit K⁺ATP and K⁺V channel in beta cell of the pancreas. Rizvi and Mishra investigated onion polyphenols, especially quercetin having strong diabetes prevention ability by regulating lipid peroxidation [44]. Phenolic compounds of *Hibiscus Sabdariffa* extract like phenolic acids, flavonoids, protocatechuic acid and anthocyanins diminishes diabetic nephropathy and serum lipid profile. Furthermore, Ferulic acid (FA) abundantly available in vegetables and fruits including maize bran known for antidiabetic effect by lowering glucose in blood and elevating plasma insulin [2].

7. ANTI-AGING EFFECT

Aging is the accreted effect of free radical and oxidative stress mechanism. With time, the cells and tissues undergo detrimental changes, which elevate the risk of disease and death [18]. Cao *et al.* investigated combined effects of anti-ageing for antioxidant or anti-inflammatory polyphenolic compounds, present in fruits and vegetables [4]. Seeram *et al.* reported the role of anthocyanins, which are responsible for colours in fruits/vegetables, to prevent lipid peroxidation and inflammatory components such as cyclo-oxygenase (COX) – 1 and 2 [46]. High antioxidant activity is observed in spinach, strawberries and blueberries having potential in reversing age-associated neural disorders in aged rats. Recent studies suggest that tea catechins may delay onset and symptoms associated with ageing. Food polyphenols protect against ageing brain as they have the ability to cross the blood-brain barrier (BBB) [32]. Harikumar *et al.* reported resveratrol as an anti-ageing component in grapes responsible for prolonging lifespan, due to mechanisms like caloric restriction or partial food deprivation mechanism [17].

8. OTHER THERAPEUTIC BENEFITS

Apart from above stated pathological events, polyphenols are known to exhibit various beneficial effects on health. For example, dietary polyphenols are known for their preventive effects they exert, in the treatment of asthma

[53]. Genistein, an soy-isoflavone, present in soybean, improves lungs functioning for asthmatic patients. Intake of polyphenols is also proclaimed as beneficial in osteoporosis patients. Dietetic supplemented with genistein, daidzein for few weeks prevents the loss of bone mineral density and trabecular volume caused by the ovariectomy. In this way, polyphenols consumption is beneficial for osteoporosis patients [34].

Kim *et al.* studied the protective effects of (–)-epigallocatechin-3-gallate (EGCG), which is a green tea catechin on guinea pigs, hairless mice and human dermal fibroblast cultures and concluded that UVA induced skin damages may be reduced by EGCG treatment and also reported about the reduction of dermal collagen in hairless mouse skin [24]. Black tea polyphenols are widely known for their therapeutic benefits, i.e., mineral absorption in the intestine and antiviral activity [47].

9. CONCLUSION

This review showcases a precise understanding of the beneficial biological effects of consumption of polyphenols and their various beneficial effects in maintaining good human health. Polyphenolic compounds rich prevents many chronic diseases like cancer, diabetes, cardiovascular problems, ageing and neural disorders and several others, although some studies suggested adverse effects on consumption of some polyphenols like tannin. More research work need to be done to study the specific roles of polyphenols in human health and their therapeutic effects. On basis of recent scientific understanding, polyphenols offer great hope for the prevention and delaying of human chronic diseases and overall wellness of humans provided a considerable amount of polyphenols are consumed in the diet. Bioavailability of consumed polyphenol and its studies on the absorption kinetics, its accumulation and its elimination in human body after consumption, needs to be taken up to have a better understanding about the beneficial mechanisms of polyphenols in human body.

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