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Review Article

Chemistry and Functionality of Bioactive Compounds Present in Persimmon

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Extensive research has related the consumption of persimmon with the reduced risk of various diseases and particularly highlighted the presence of bioactive phenolic compounds for their therapeutic properties. Major phenolic compounds present in persimmon are ferulic acid, *p*-coumaric acid, and gallic acid. β-Cryptoxanthin, lycopene, β-carotene, zeaxanthin, and lutein are important carotenoids having antioxidant potential. They are important to prevent oxidation of low-density lipoproteins, safeguard beta cells of the pancreas, and reduce cardiovascular diseases, cancer, diabetes mellitus, and damage caused by chronic alcohol consumption. In this paper, the chemistry and health benefits of bioactive compounds present in persimmon are reviewed to encourage impending applications and to facilitate further research activities.

1. Introduction

Scientific research-based knowledge regarding the impact of food on human health has steered to substantial nutritional discoveries, product innovations, and mass production on an unprecedented scale [1]. The starring role of food for improving health by decreasing the risk of illness and disease has highlighted a new class of foods, now known as functional foods [1, 2]. Functional foods and therapeutic agents are obtained either directly or indirectly from different natural sources. The therapeutic value of functional foods depends upon the presence of biologically active compounds (bioactive compounds). These bioactive compounds can offer various health benefits beyond the basic nutritional value of a food product [3–6].

Recently, natural bioactive compounds have been acknowledged with greater consideration [3]. Fruits and vegetables are vital parts of the diet and a rich source of bioactive compounds including dietary fiber, natural antioxidants, and various phytochemicals [3, 4, 7]. The individual phytochemicals that have been recognized are about 5000 in number, but large numbers of them are still unknown or unidentified [8]. Most bioactive compounds (phytochemicals, phenolics, and carotenoids) are nonnutritive but effective against different diseases [9, 10] as they play important roles as chemopreventive or chemotherapeutic agents [11].

Among the fruits, persimmon (*Diospyros kaki*) is a popular and widespread fruit that is enriched with many bioactive compounds, including polyphenols, terpenoids, steroids, flavonoids, carotenoids, minerals, and dietary fiber [6, 12]. Some components like phenolics, antioxidants, sterols, and flavonoids have a beneficial effect on human health owing to their ability to prevent or control various ailments [6, 9]. These bioactive components play an important role in reducing arterial stiffness and prevent oxidation of low-density lipoproteins (LDL) thus resulting in the prevention of atherosclerotic plaque formation [13]. Many phytochemicals also possess antimutagenic effects and regulate and trigger the immune system, thus resulting in the normal functioning of metabolism [14]. A number of them also serve as chemopreventive [15], anticancer, anti-inflammatory, and immunomodulatory agents [16, 17]. Hence, persimmon, like other fruits, contains a number of functional compounds which are useful in promoting human health. This paper is aimed at appraising the chemical profile of persimmon fruit with reference to prospective bioactive components and at

exploring their functionality and potential applications in disease prevention.

2. Persimmon Origin and Production

The *Diospyros* genus belongs to the Ebenaceae family and has more than 350 known species [12]. *Diospyros kaki* (persimmon) also known as Japanese or oriental persimmon is a deciduous fruit originated in Eastern Asia [18]. The regions with relatively mild summer and moderate winter are the most suitable for its growth. It is widespread in China, Japan, and Korea, where it is traditionally used for medicinal purposes [6]. Persimmon production is expanding at a rate of 5.76% annually, which makes it the 5th fastest developing fruit crop in the world with a current annual production of 3.63 million metric tons [19]. China is ranked first in persimmon production in the world, with an annual production of 1.65 million metric tons [6].

Persimmon fruits are climacteric and ethylene regulates their process of ripening. Therefore, the shelf life of persimmon fruits can be increased by slowing the ripening process by inhibiting ethylene biosynthesis or its action, hence enhancing their storage life [20, 21]. Persimmon is eaten as fresh or dried fruits. During drying, persimmon peel is removed; otherwise it produces bitter taste because of its astringency. Usually whole fruit and slices are dried to make dried persimmon products. Juices, sherbet, or puree is prepared from peeled persimmon pulp. However, unpeeled whole persimmon fruit can be used for persimmon vinegar and wine production [22].

3. Physical Attributes

The persimmon fruit looks like an orange red tomato with a pointed end. The whole fruit is edible, with the exemption of its seed and calyx. The color of the fruit varies from yellow or orange to deep red [23] depending upon the concentration of carotenoid contents [24]. Hence, higher carotenoid contents are imperative to get maximum market value of the fruit [25, 26].

4. Classification Based on Taste

The persimmon fruits are usually classified into astringent (A) and nonastringent (NA) varieties depending upon their taste. In the early stages of development, persimmon fruits accumulate large amounts of proanthocyanidins (PAs) in specialized tannin cells [27]. In both types of varieties, astringency decreases with maturation, resulting in about 70–90% decline in the total polyphenolic components like tannins [28]. Antioxidant activities of astringent persimmon are higher as compared to nonastringent varieties [29]. Astringent (A) type fruits remain rich in soluble PAs even after they reach the full-mature stage, whereas nonastringent (NA) type fruits lose these compounds before full maturation [30].

4.1. Astringent Persimmon. The astringency among different varieties of persimmon mainly depends on the concentration of water soluble tannins [19, 31] that are present in large tannin cells [32] in fruit flesh and peel and the level decreases as the fruit matures [31].

Among different varieties Mopan (*Diospyros kaki* L. cv. Mopan) is the main cultivar of astringent persimmon produced in Northern China [33] especially around Beijing [34–36]. Hachiya is another variety of persimmon that cannot be consumed until being fully ripened because of its astringency. During the course of ripening, soluble tannins polymerize into insoluble ones resulting in reduced astringency [37]. Immature persimmon has proanthocyanidins (PAs) which are about 25% (dry basis) of the fruit weight [27]. However, on maturation, this level drops below 1% [38], resulting in reduced antioxidant activity [39].

Moreover, on maturation, the fruit peel becomes thin and waxy, having thick jellylike pulpy flesh in it [40]. Large production losses take place during handling of too much soft fruits. To avoid these postharvest losses and to reduce the level of astringency, the use of ethylene or carbon dioxide, and so forth, along with the selection of appropriate cultivars, has been recommended [41]. The effectiveness of CO_2 treatment to remove astringency is based on the insolubilization of tannins by the acetaldehyde generated during anaerobic respiration, which is triggered when fruit is exposed to a high CO_2 atmosphere [42]. However, these treatments (ethylene, carbon dioxide) can generate undesirable changes, especially a characteristic yellow-orange color, due to changes in carotenoids contents. Novillo et al. [42] also identified a new disorder, known as "pinkish-bruising," in astringent persimmon that is associated with mechanical damage during the postharvest handling.

4.2. Nonastringent Persimmon. Nonastringent varieties include Lzu, 20th century, Fuyu (flat), Maekawa Jiro, and Fuyu Hana (pomelo). These are sweet in taste and must be eaten before full maturation; otherwise they become too soft to eat. In nonastringent types of persimmon, water soluble tannins completely disappear at maturity [31]. Their flesh is dark in color due to higher levels of β-cryptoxanthin and total carotenoids [43]. The level of these carotenoid contents increases up to 5.54 times from the first to the last stage of maturity during fruit development. According to findings by Zhao et al. [12] the level of carotenoid contents is higher (more than double) in nonastringent persimmons than astringent ones at each stage of development before ripening.

Fuyu is the most important nonastringent cultivar grown in Japan. They have a firm peel enclosing orange-yellow flesh and have a good (sweet) taste [44].

5. Compositional Profile

5.1. Persimmon Fruit. Persimmon fruit contains 79% water, 0.7% pectin, 0.4% protein, and crude fiber [31]. It is rich in vitamin A (217 RE) compared to apple (5 RE). Vitamin C contents vary from 7.5 to 70 mg per 100 g of the fruit flesh depending upon the variety [39]. Some varieties are as rich as satsuma mandarin and strawberry in their vitamin C contents [25]. It also contains various bioactive substances (Table 1)

Table 1: Nutritional value[a] per 100 g (3.5 oz) of persimmon fruit (*Diospyros kaki*, raw).

Energy	293 kJ (70 kcal)
Carbohydrates	18.59 g
Sugars	12.53 g
Dietary fiber	3.6 g
Fat	0.19 g
Saturated	0.02 g
Protein	0.58 g
Riboflavin (Vit. B_2)	2.5 mg (208%)
Folate (Vit. B_9)	8 μg (2%)
Vitamin C	7.5 mg (9%)
Calcium	8 mg (1%)
Iron	0.15 mg (1%)
Sodium	1 mg (0%)

[a]Percentages are relative to US recommendations for adults (Source: [45]).

like vitamins (A, B complex, C, E, and K) and minerals (zinc, copper, iron, magnesium, calcium, and phosphorus) that are valuable for the proper physiology of human health [45]. Proanthocyanidins (PAs) are potent antioxidants and show 20 and 50 times more activity than vitamins C and E, respectively [46].

5.2. Persimmon Peel. The external layers of a fruit such as peel, shell, and hull that shield the inside materials generally contain enormous quantities of functional compounds [2]. Regarding the persimmon peel, it is considered as waste, yet it is receiving much attention because of its chemical composition [47, 48]. The main constituent of peel is dietary fiber (40.35% w/w). In addition, high levels of antioxidants, including vitamin C, total phenolics, and total carotenoids, are also present [49]. Among the phenolic compounds, caffeic acid, *p*-coumaric acid, ferulic acid, and gallic acid (Figure 1) are present in large quantities [50, 51]. Proanthocyanidins (PAs) are condensed tannins that exhibit powerful antioxidant activities. These are largely present in the peel as compared to pulp [52]. The level of total carotenoids in persimmon peel is very high (about 340 mg/100 g of dried peels as β-carotene equivalents) as compared to the peels of other fruits like banana [53] and apple [54]. Among the carotenoids, β-cryptoxanthin is the highest (about 42%), followed by zeaxanthin, lutein, and β-carotene (Figure 2) [55]. The quantity of bioactive compounds (biologically active components), especially carotenoids and polyphenols, is greater in the peel compared to the pulp [50]. Hence, persimmon peel should be consumed by individuals and used for industrial processing [47].

5.3. Persimmon Fruit Pulp. Persimmon pulp is rich in nutrients such as vitamin C (70 mg/100 g), vitamin A (65 mg/100 g), calcium (9 mg/100 g), and iron (0.2 mg/100 g) [56]. In the edible part (pulp) of the persimmon, the major phenolic acids are ferulic acid, *p*-coumaric acid, and gallic acid, and the antioxidant activity of these phenolic acids is affected by their chemical structures (number of hydroxyl groups attached).

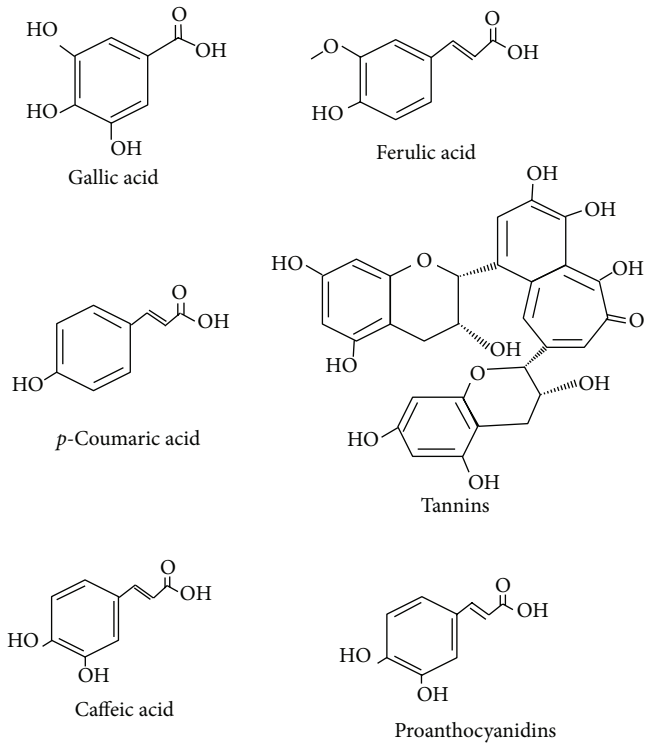

Figure 1: Chemical structures of common phenolics in persimmon.

Carotenoids are the major pigment present in persimmon. They contribute to both color and nutritional value [57–59]. Carotenoid contents rapidly increase as green mature fruit changes to soft mature persimmon, except for lutein and lycopene that decrease during fruit maturation [60]. Among them β-cryptoxanthin content is the highest (50%), followed by lycopene (10%), β-carotene (10%), zeaxanthin (5%), and lutein (5%) [59]. They are all excellent lipid-soluble antioxidants, especially lutein, astaxanthin, and zeaxanthin, having the ability to scavenge free radicals in a lipid-soluble environment and thus preventing the oxidation of lipids. The final composition and concentration of carotenoid contents are properly regulated to some extent by the different developmental stages of plant tissues [61]. Carotenoids identified in persimmon fruits are *cis*-mutatoxanthin, antheraxanthin, zeaxanthin, neolutein, cryptoxanthins, α-carotene, and β-carotene and also fatty acid esters of β-cryptoxanthin and zeaxanthin [62].

5.4. Persimmon Seeds. Palmitic acid, oleic acid, and linoleic acid are the major fatty acids found in persimmon seeds, ranging from 70.4% to 78.3% of total fatty acids [63]. Among the fatty acids, oleic acid plays a role in cancer prevention. The effect of oleic acid on the same lines of breast cancer cells was examined and it supported the theory that oleic acid is chemopreventative [64]. Moreover, omega-6 fatty acid (linoleic acid) diminishes the risk of cardiovascular diseases [65].

5.5. Persimmon Leaves. Persimmon leaves contain 4 flavonols [66]. The leaves of persimmon have been reported to

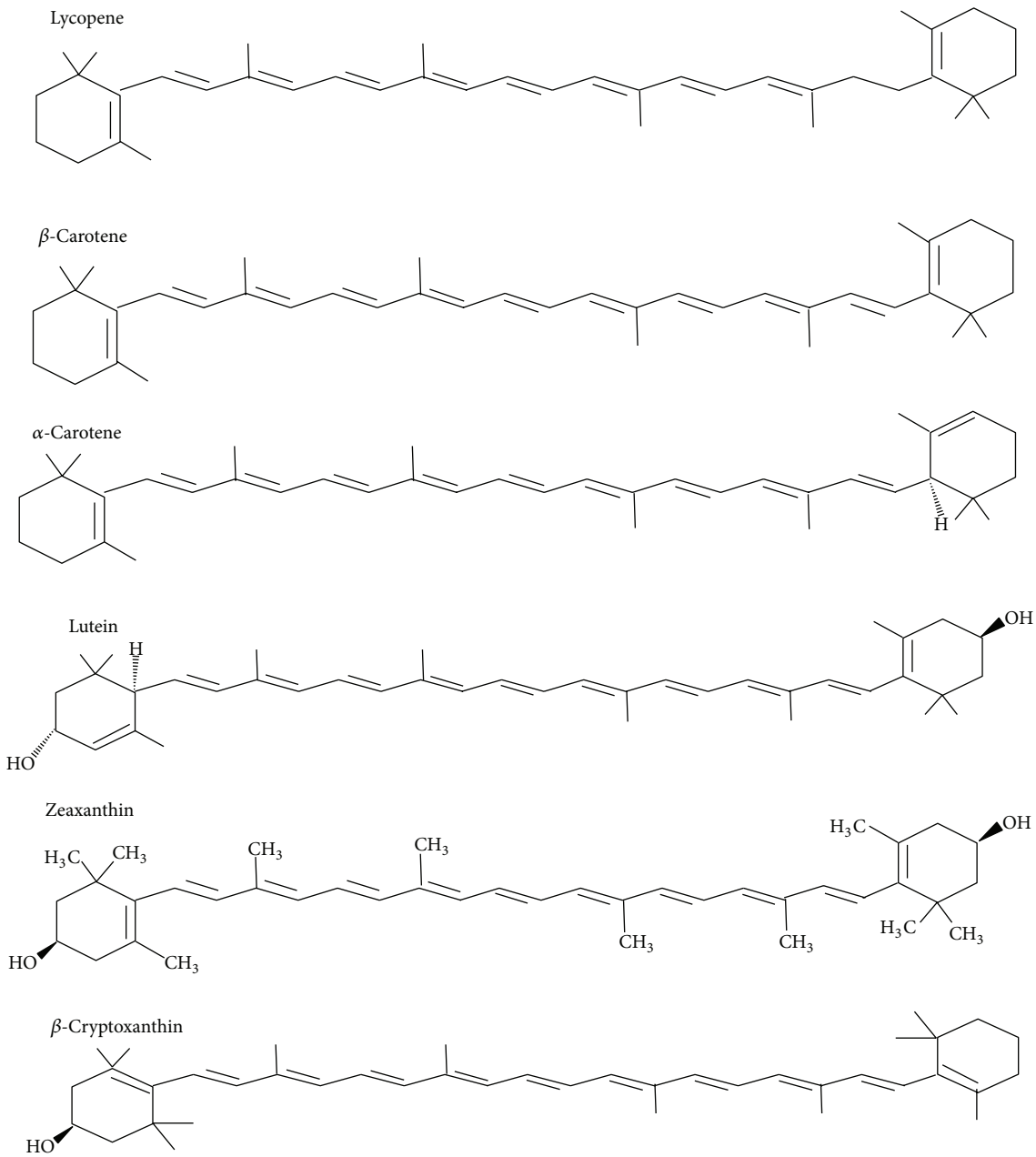

Figure 2: Chemical structures of common carotenoids in persimmon.

contain the following compounds: 40-dihydroxy-a-truxillic acid, tatarine C, myricetin, annulatin, trifolin, astragalin, hyperin, isoquercetin, rutin, quercetin, kampferol, kakispyrone, and kaki saponin [67]. Leaves have been used for tea in Korea, since they were was thought to be effective against hypertension [68].

6. Persimmon Bioactive Compounds

Persimmon fruit is a good source of polyphenols [69]. The term "polyphenols" includes a large group of substances, and they all have more than one phenolic hydroxyl group bound to one or more benzene ring systems [70]. The phenolic compounds are secondary metabolites of plants [71, 72] and found in free and bound forms in persimmon fruit [73].

Persimmon phenols can be grouped as a function of their molecular complexity/weight. Thus, free phenolic acids, catechins, and hydrolyzable tannins are included in low-molecular weight phenols while high-molecular weight phenols which are also called as condensed tannins or proanthocyanidins (PAs) are large polymers of catechins with or without galloylation [74]. One of the major components of condensed tannin in persimmon fruit was identified by Akagi et al. [75] during compositional study of persimmon

with phloroglucinol. They characterized this component as novel epigallocatechin-3-O-gallate-phloroglucinol (EGCG-P) adduct. Li et al. [76] also reported that the persimmon pulp is comprised of flavan-3-O-galloylated extenders, flavan-3-ol and flavonol terminal units, and A-type interflavan linkages which are condensed tannins with high-molecular weight.

Structurally, phenols contain an aromatic ring having hydroxyl substituents, ranging from simple to highly polymerized compounds [77]. The naturally present compounds form linkages with saccharides and might be functional derivatives like esters and methyl esters. Hence, the extensive variety of phenolic compounds occurring in nature is the result of this structural assortment. These compounds are categorized in several groups. Out of them, phenolic acids, flavonoids, and tannins are considered as the main dietary components [78].

Phenolic acids are non-flavonoid polyphenolic compounds comprised of 2 subgroups: hydroxybenzoic and hydroxycinnamic acids. Hydroxybenzoic acids contain gallic, *p*-hydroxybenzoic, protocatechuic, vanillic, and syringic acids, in which they all have the C6–C1 structure. Hydroxycinnamic acids, instead, are aromatic compounds like caffeic, ferulic, *p*-coumaric, and sinapic acids with a 3-carbon (C6–C3) side chain [78]. The structure of phenolic compounds is a vital factor affecting radical-scavenging and metal chelating activities and, hence, it is referred to as having a structure–activity relationship. In the case of phenolic acids, the antioxidant activity is influenced by the numbers and positions of the hydroxyl groups with respect to the carboxyl functional group [47]. Hence, they give their hydrogen atoms to scavenge free radicals as shown in Figure 1.

Flavonoids have the C6–C3–C6 general structural backbone in which the two C6 units (Ring A and Ring B) are of phenolic nature. Flavonoids can be further divided into different subgroups on basis of variations in chromane ring and hydroxylation pattern. Flavonoids can be further divided into different subgroups such as anthocyanins, flavan-3-ols, flavones, flavanones, and flavonols. While the vast majority of the flavonoids have their Ring B attached to the C2 position of Ring C; these basic structures of flavonoids are aglycones; however, in plants, most of these compounds exist as glycosides. Biological activities of these compounds, including antioxidant activity, depend on both the structural variation and the glycosylation patterns [79].

Tannins, the third important group of phenolics, are segmented as hydrolysable and condensed tannins, which are esters of gallic acid and polymers of polyhydroxyflavan-3-ol monomers, respectively. The third segment, phlorotannins comprised of phloroglucinol, is found in brown algae. However, these are insignificant regarding human diet [75, 76]. Tannins are present in persimmon prolonged life and reduced the incidence of stroke in hypertensive rats [80, 81]. This effect was attributed to the fact that persimmon tannins are 20 times more potent than antioxidant vitamin E [82]. The persimmon tannin is composed mostly of epicatechin, epicatechin-3-O-gallate, epigallocatechin, and epigallocatechin-3-O-gallate [83].

7. Therapeutic Effects of Persimmon

Persimmon has been used for various medicinal purposes (Table 2) owing to the therapeutic properties such as diuretic effect, blood pressure-lowering capability and the cough treatment, viral and bacterial infectious diseases [84], and dental caries [85]. Various bioactive compounds including polyphenols, carotenoids, vitamins, and dietary fiber in the fruit are responsible for beneficial properties [49]. Subagio et al. [52] reported the protective effect of proanthocyanidin from persimmon peel against DNA damage and SIRT expression in the aging process.

The persimmon leaves are a good source of antioxidants [102] while the seed extracts have a strong radical-scavenging activity [104]. The fruits are a rich source of dietary carotenoids (â-carotene, â-cryptoxanthin, zeaxanthin, lutein, and lycopene), which have been implicated in the reduction of degenerative human diseases [91]. The concentration of â-carotene and â-cryptoxanthin is so high that 100 g of pulp provides 10% of the recommend daily allowance provitamin A [105].

Persimmon fruit can be used in the manufacturing of products with functional characteristics because of its bioactive properties. It is an excellent source of ascorbic acid, tannins, and carotenoids, having healthy aspects owing to their antioxidant and other health protecting activities [6].

7.1. Diabetes. Diabetes mellitus is a chronic disease and the reason behind that is inherited and/or acquired insufficient insulin production by the pancreas, or by the incompetence of the insulin produced. Such a deficiency results in raised concentrations of glucose in the blood, which sequentially damage many of the body's systems, particularly the blood vessels and nerves [106]. When body's defense systems neither detoxify the reactive intermediates nor repair the resulting damage from reactive oxygen species (ROS), then such an imbalance condition is known as oxidative stress, responsible for diabetes mellitus and related complications [107].

Along with insulin, many other agents like sulfonylurea and biguanide can be used to reduce blood glucose level in order to treat diabetes. These hypoglycemic agents have considerable side effects [108]. In chronic diabetes, these hypoglycemic agents sometimes become ineffective [109]. Therefore, the demand of such hypoglycemic agents which have side effects and are either made artificially or from natural source is decreasing day by day [110]. Hence, there is need of natural agents like plant and plant based materials which can show more potential for control and treatment of diabetes and its complications with no side effects [111]. Since several years, herbal remedies including different medicinal plants or their extracts have been taken orally in order to treat diabetes. The search for effective natural hypoglycemic agent is under consideration as recommended by WHO [112]. Recently great attention has been paid to a number of nonvitamin antioxidants, widely distributed in natural sources like fruit, vegetables, and spices, having the ability to enhance the antioxidative defense mechanism at cellular level without side effects [113]. The main group of compounds that act primarily as free radical terminator or antioxidants is plant phenolics.

Table 2: Various bioactive compounds present in persimmon and their functional properties.

Source	Health benefits	Reference
Extracted polyphenol		
p-Coumaric	Prevention of oxidative stress related diseases including diabetes	[86]
Tannins	Scavenging action against active oxygen free radicals	[82, 87, 88]
Tannin	Assists the neuronal degeneration and karyopyknosis in cells, reduction of thickness of skin epidermis	[89]
Flavonoids	Scavenging action against active oxygen free radicals	[82, 87, 88]
Persimmon fruit		
Whole fruit	Possesses antitumor effects due to betulinic acid	[47, 90]
	Blood pressure-lowering and diuretic effects, also effective for coughs treatment	[91]
	Has antioxidative potentials due to compounds like vitamin A, beta-carotene, lycopene, lutein, zeaxanthin, and cryptoxanthin	[92]
	Exhibits hypolipidemic and antioxidant properties	[50, 82]
	Contains nutritional antioxidant vitamins, polyphenols, and dietary fiber	[93, 94]
	Reduction of patches of pigmentation on skin	[95]
	Has ability to dilate the blood vessels near the surface of the skin, thereby allowing more blood to flow through the skin, where it can be cooled by the air (antifebrile)	[96]
	Reduction of degenerative disease in human beings	[91, 97–99]
Fruit peel powder	Pharmacological potential such as antioxidant and hypocholesterolemic	[51, 95, 100]
Water-soluble polysaccharides extracted from persimmon fruits	Have ability to alter or regulate immune functions (immunomodulatory activity)	[85]
Persimmon vinegar	Has antitumor and antioxidative effects and also prevents metabolic disorder induced by chronic alcohol administration	[101]
Plant and leaf extracts		
Persimmon leaf tea	Prevents hardening of the arteries which ultimately lowers the blood pressure	[95]
	Good source of natural antioxidants	[102]
Persimmon plant extracts	Contain antitumor and multidrug resistance-reversing agents Stop oxidative damage of DNA	[47]
Persimmon calyx extracts	Anticonvulsants	[103]
Persimmon plant supplemented to a diet	Hypocholesterolemic and antioxidative effects	[82]
Persimmon seeds	Contain omega 6 fatty acids like palmitic acid, oleic acid, and linoleic acid	[63]
	Radical-scavenging activity	[104]

Among fruits, persimmon is comprised of a large number of biologically active polyphenols like tannins and flavonoids having good antioxidant potential. These polyphenols prevent the diabetes resulting from oxidative stress [86], since these work as antioxidants preventing the peroxidation of lipids by the donation of a hydrogen atom from hydroxyl group attached to their chemical structure rapidly and form peroxyl radical (ROO) that ultimately leads to the formation of alkyl (aryl) hydroperoxide (ROOH), as shown in the following reaction:

$$\mathrm{ROO}^{-} + \mathrm{PPH} \longrightarrow \mathrm{ROOH} + \mathrm{PP}^{-} \quad (1)$$

The phenolic antioxidant (PPH) itself changes into polyphenol phenoxyl radical (PP), which becomes stable after donating a hydrogen atom, by conversion into quinines, and it hinders the initiation of new chain reaction by reacting with another radical in which another phenoxyl radical is also included [114, 115].

Gorinstein et al. [49] reported that a 2-week intake of persimmon peel supplemented diet considerably reduces food intake, blood glucose, total cholesterol, and plasma triglycerides level in diabetics. The researchers concluded that persimmon peel rich in high level of antioxidant and dietary fiber with antidiabetic properties may be characterized as a possible nutritional supplement for improving diabetic complications and hyperglycemia.

In fresh persimmon leaves most of the polyphenols are found to be water soluble. The chief components in persimmon leaf tea are unique proanthocyanidin oligomers and oral administration of this tea along with starch resulted in a dose-dependent decline in the blood glucose level in Wistar rats [116].

7.2. Atherosclerosis. Inflammation and high levels of oxidative stress are a major initiator of cardiovascular diseases like atherosclerosis that ultimately leads to coronary artery

disease (CAD). In such condition, the oxidative stress is characterized by the accumulation of metabolites (from the oxidation of proteins and lipids) and macrophages. According to the hypothesis of oxidative modification, the early event which initiates the development of atherogenesis (development of atheromatous plaques) is the oxidative breakdown of low-density lipoproteins. Reactive oxygen species in the vessel wall have been considered to be one of the most important causes of vascular dysfunction [117].

Dietary components having antioxidant properties as the polyphenols are receiving a lot of attention because of their ability to reduce cardiovascular diseases [118, 119]. When diet rich in fiber is largely consumed, it results in prevention and treatment of diverticular and coronary heart diseases [120]. Coronary atherosclerosis, especially, is inhibited by preventing oxidation of low-density lipoprotein (LDL) and by nutritional antioxidants like phenolics [121] and vitamins A, C, and E [122].

Hence, many reports have shown that if intake of vegetables and fruits is increased in diet, then chances of coronary heart diseases could greatly be reduced [123]. According to Hertog et al. [124] if 100 g of persimmon is consumed regularly, then it will be sufficient to inhibit occlusion of arteries. In young fruits of persimmon (*Diospyros kaki*) tannin is found to have the ability of bonding bile acid [83].

It has been established that addition of persimmon in the diet hinders the increase in plasma lipid level and hence works as antiatherosclerosis [80, 124], which reduces the chances of mortality by the action of polyphenols [125]. Matsumoto et al. [82] also reported that the persimmon peel supplemented diet shows hypocholesterolemic and antioxidative effect.

Total dietary fibers including soluble and insoluble, total phenolics including epicatechin, gallic, and *p*-coumaric acids, and concentrations of minerals like Na, K, Mg, Ca, Fe, and Mn are high in peel, pulp, and whole persimmon fruit compared to apple [50]. Hence, persimmon must be given preference over apples and some other fruits in selecting an antiatherosclerotic diet. Liu [126] reported decline in blood triglyceride and total cholesterol contents after intake of persimmon vinegar (PV) for 6 weeks.

7.3. Cancer. In recent years, persimmon has been the focus of attention for potential medicinal applications for prevention of cancer [47]. Carotenoids are nature's most widespread pigments and have also received substantial attention because of both their provitamin and antioxidant roles [127]. Carotenoids possess antioxidant properties that have been associated with cellular protection [128], regulation of cell growth, differentiation, and apoptosis [129].

Not only are the carotenoid contents responsible for the superficial appearance (color) and nutritional quality of fruit [130] but also they provide potential health benefits and disease prevention by quenching singlet oxygen and scavenging free radicals [131]. Chemoprotective effects of persimmon against various forms of cancer are due to the carotenoid contents [132, 133]. Persimmon was shown to be effective in the treatment of prostate and breast cancers [134], oral carcinoma cells [47], human lymphoid leukemia cells [135], and precancerous colon polyps in women [136]. The bioactive compounds in persimmon may also affect multidrug resistant (MDR) inhibiting activity. It enhances the accumulation of cancer cells due to the reduced activity of efflux pumps. MDR inhibitors from persimmon may help to treat noncurable cancer because of the modulating effects [47]. The calyx (persimmon) extracts act as anticonvulsants and may alleviate the side effects of barbituric acid compounds [103].

8. Other Health Promoting Properties

Dried persimmon snacks were found to be effective in reducing the concentration of alcohol in the blood [55]. Similarly, Matsuno [137] observed that kaki-tannin found in persimmon fruit flesh and leaves was soluble in artificial stomach liquid and reduced blood alcohol (40%) and acetaldehyde contents (30%). Dietary intake of persimmon tannin was found to prevent hypercholesterolemia in some animal models and humans [138].

Some carotenoids present in persimmon are precursors of vitamin A [139] and also have immunoregulatory [140] and antiaging effects [141]. Carotenoids are inversely linked with inflammation, atherosclerosis, cardiovascular diseases, sarcopenia, and mortality. Carotenoid supplementation improves the antioxidant status and reduces lipid peroxidation.

Carotenoids like β-carotene, α-carotene, β-cryptoxanthin, lycopene, and lutein (Figure 2) have been found to be associated with inflammation and mortality risks [142]. In addition, lutein (carotenoids) present in persimmon peel can help protect eye vision [143].

9. Persimmon Leaves and Health

Persimmon leaves and extracts are being used as a green tea, oriental medicines, deodorants, antiallergic substrates, and cosmetics (especially for dermatitis) as they prevent skin problems and have an antiwrinkle effect [68, 143] and skin whitening effect [72]. The leaves are brewed into a beverage to release their antioxidant activity and antitumor effects and to inhibit angiotensin converting enzymes as well as alpha amylase [66]. The leaves of persimmon possess antithrombotic activity. Arakawa et al. [144] demonstrated that a 10,000 D anticoagulant fraction has been purified from the leaves that inhibited thrombin-catalyzed fibrin formation with a competitive inhibition pattern. Based on their antimicrobial properties, persimmon leaf-based products have been incorporated into athlete's foot socks and soaps, and persimmon leaves have been used as a sushi ingredient [145].

10. Unripen Persimmons and Health Issues

Bezoars are thick hard masses formed in gastrointestinal tract usually the stomach [146]. Patients who have undergone stomach surgery and have delayed gastric emptying are often more prone to the development of bezoars [147]. Phytobezoars are the most common types of bezoars and

these are composed of skins, seeds, and vegetative matter including lignin, cellulose, hemicelluloses, tannins, and other nondigestible matter from fruits and vegetables ingested. Diospyrobezoars are a type of phytobezoars related to the consumption of persimmon fruit and are common worldwide. These are more difficult to treat because of their hard consistency [146, 148, 149]. Most bezoars in animals are caused by hairs.

When unripe astringent persimmon, having a high level of tannin, is ingested, a coagulum is formed in the stomach due to the contact of tannin and shibuol with hydrochloric acid that accumulates cellulose, hemicellulose, and protein [150]. Phytobezoars may require surgical removal or endoscopic treatment as they are usually resistant to drug treatment [151]. Han et al. [152] suggested a nonsurgical approach for cases of persimmon phytobezoar small intestinal obstruction with its partial dissolution of a bezoar by performing oral and injected Coca-Cola therapy.

11. Conclusion

Bioactive compounds particularly phenolics (ferulic, *p*-coumaric, and gallic acids) and carotenoids (β-cryptoxanthin, lycopene, β-carotene, and lutein) are of major interests in persimmon fruit. These valued bioactive components have strong antioxidant potential which relates to the variety, stage of maturity, and fruit parts. These functional compounds can play a significant role in preventing and curing various ailments like diabetes, hypercholesterolemia, and cancer. Hence, the known impact of natural bioactive compounds to improve human health, has introduced a substantial area of research resulting in extensive advances in biochemical and nutritional sciences.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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