Diospyros kaki L. (Persimmon)

Subjects: Food Science & Technology | Nutrition & Dietetics

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Persimmon (*Diospyros kaki* L.) is a member of the Ebenaceae family and is a very popular and important fruit in East Asian countries, being widely produced in China, South Korea, and Japan. The name "persimmon" (Diospyros) originates from the Greek *dióspuron*, which means "food of Zeus", while "kaki" comes from the Japanese kaki (柿).

Keywords: Diospyros kaki L. ; phenolic compounds ; proanthocyanidins ; antioxidant ; sustainability ; new products ; food crisis

1. Introduction

Recently, persimmon's popularity has grown outside its traditional region of production (China, Japan, and Korea), growing into an encouraging crop in Brazil and in some Mediterranean countries such as Italy, Spain, and Portugal. The cultivation of persimmon in Europe is limited to the proximity to the Mediterranean Sea [1]. China is the largest persimmon producer, producing around 3.03 million tons, followed by Spain with 400,000 tons, South Korea with 300,000 tons, Japan with 225,000 tons, and Brazil with 182,000 tons. In Portugal, for example, there are some dedicated orchards in the south of the country such as in the Algarve region, although most persimmons come from trees scattered throughout the central and northern regions of country. The world production of persimmon is around five million tons, corresponding to 0.75% of total fruit production [2].

The persimmon tree belongs to the genus Diospyros, Ebenaceae family, and has four commercially important species, of which the most representative is *Diospyros kaki* (Japanese persimmon) having, however, other equally relevant species such as *Diospyros virginiana*, *Diospyros oleifera*, and *Diospyros lotus* [3][4].

Persimmon is a spherical fruit with a color that ranges from reddish to yellow according to carotene content, the pulp is a viscous orange-red and somewhat rough, depending on the content of tannins. The pulp, regardless of the variety, consists mainly of mucilage and pectin, which is responsible for its characteristic appearance [5].

Persimmon is a seasonal fruit: it is only available in its fresh form for a short-time window throughout the year. In Europe, persimmons can be purchased in late autumn and early winter, from September to early December [6][7].

In several studies, it has been described that the concentration of nutrients and other functional components of persimmon is higher in the skin than in the pulp [8]. However, the skin of the fruit is typically discarded when it is consumed with a spoon (Figure 1) when it is very ripe, or during the drying process of the persimmon [9]. This process of fruit preservation is widely used in China and Japan, given the large quantities produced, its usage in a high number of culinary recipes, and the need to preserve it in significant quantities in a long-lasting and safe way [10].

Figure 1. Persimmon, *Diospyros kaki* L. fruit from Algarve, Portugal.

Persimmon, in addition to its nutritional value, has been used in traditional Chinese medicine for its beneficial effects in health, namely against hypertension, hemorrhages [11], in maintaining body temperature, and slowing oxidative processes in general [12][13], due to their diuretic effect, in diabetes, and atherosclerosis [14]. It has also been used to improve the function of the lungs, stomach, spleen, and intestines and used in the prevention and treatment of diseases such as sore throat, thrush, and insomnia [15].

Several studies have shown that persimmon has anti-tumor properties [16][17], prevents dyslipidemia [18], has anti-hypercholesterolemic, antioxidant effects [19][20], and antidiabetic effects [21]. These health benefits have been associated with its richness in antioxidants including vitamins, phenolic compounds, and carotenoids [15][22].

The EAT-*Lancet* Commission gathered all accessible nutritional and environmental data to build the first global benchmark diet able to sustain health and protect the planet [23]. The intersection of nutrition and sustainability is the key idea behind the EAT-*Lancet* diet. This report supports the concept of building a diet that could improve human health and decrease the global impact of food-related health conditions such as cancer, heart disease, diabetes, and obesity. The EAT-*Lancet* commission finally recommended a ‘flexitarian’ diet that covers a range of food groups, even though it also suggested vegan and vegetarian options. Plants shape the substance of the commission’s flexitarian diet, which suggests the daily consumption of about 230 g of whole grains, 200 g of fruit, 300 g of vegetables, and 125 g of plant-based protein-rich foods such as nuts, dry beans, and lentils [24][25]. Existing diets diverge considerably from the EAT-*Lancet* targets [23].

2. Nutritional Characterization

Persimmon has a pretty good nutritional value: it contains many compounds such as different sugars, starch, organic acids and amino acids, proanthocyanidins (PACs), flavonoids, carotenoids, triterpenoids and fatty acids [26][27][28][29][30], proteins, and vitamins A, B6, B12, C, and D [31].

According to some authors, persimmons contain around 80.3% water, 0.58% protein, 0.19% total lipids, 18.6% total carbohydrates and some minerals (calcium, potassium, magnesium, sodium, iron, zinc, copper, manganese, phosphorus, selenium), up to 1.48 g of total dietary fiber, and 7.5 mg of ascorbic acid [32][33].

In the following table (Table 1), the general nutritional composition of persimmon is presented.

Table 1. Generic nutritional composition of persimmon [34][35].

Parameters	100 g of the Edible Part
Energy (Kcal)	**71.50**
Proteins (g)	**0.64**
Total lipids (g)	**0.25**
Carbohydrates (g)	**17.30**
Fibers (g)	**2.60**
Water (g)	**80.86**
Calcium (mg)	**8.00**
Iron (mg)	**0.20**
Magnesium (mg)	**9.25**
Zinc (mg)	**0.11**
Sodium (mg)	**2.50**
Potassium (mg)	**230.00**
Phosphorus (mg)	**19.50**
Selenium (µg)	**0.60**
Thiamine (mg)	**0.03**
Riboflavin (mg)	**0.03**
Niacin equivalents (mg)	**0.20**
Vitamin B6 (mg)	**0.10**
Vitamin C (mg)	**11.75**
Total Vitamin A (retinol equivalents) (µg)	**177.00**
Folate (µg)	**7.00**

It is documented that persimmons have a content in the order of 12.5 g of sugar per 100 g of fruit, with fructose, glucose, and sucrose present in greater quantities [26][36][37][38][39], and containing smaller quantities of maltose, xylose, arabinose, and glucuronic acid [40]. The amounts of these sugars may, however, vary significantly between cultivars and their degree of ripeness [40][41]. In the study performed by Ryu et al. on the composition of the persimmon, where they used various techniques combined with NMR, it was possible to demonstrate that glucose and fructose are present in the aqueous extract of the fruit juice in much greater quantity than sucrose [42]. According to Giordani et al., extraction methods significantly affect the sugar composition of the extracts obtained due to the activity of invertase, which degrades sucrose during extraction [43]. The low percentage of sucrose observed by Ryu et al. [42] may in fact be due to the invertase activity in the pulp of the persimmon.

Having an important mineral composition, consumption of one piece of this fruit (200–400 g) can provide 1–10% of the recommended daily allowance (RDA) for calcium, 1–30% for copper and potassium, 1–15% for iron and magnesium, up to 1% sodium, and up to 4% zinc [44].

Persimmons are a good source of carotenoids, which even though they are mostly found in the skin [45], the pulp still contains large amounts of these compounds, responsible for the color of the fruits and whose amount increases as the fruit ripens [26][46]. Persimmons have 2 mg of carotenoids/100 g of fresh fruit (FF) [47], which corresponds to 22% of the RDA of vitamin A [35]. This group of compounds has been implicated in the reduction in degenerative diseases in humans due to their antioxidant capacity and free radical uptake properties [48][49][50]. Since its main carotenoids are β-cryptoxanthin (193 µg/100 g), β,β-carotene (113 µg/100 g FF), and β-carotene (30 µg/100 g FF) [43], it is generally β-cryptoxanthin that is found in greatest quantity [51].

Esters of carotenoid fatty acids (*Diospyros kaki* THUNB.), lycopene, β-carotene, ester of zeaxanthin di-myristic acid, and mono-myristic acid ester of β-cryptoxanthin have all been characterized in the persimmon peel, while a small quantity of palmitoleic acid in the fatty acid and oleanolic acid fraction was found [52][53].

With regard to vitamin C, the broad variations in its content present in persimmons as reported [43][54] can be explained through environmental factors, by the fruit's inherent qualities, by its time of harvest, and the general conditions of the crop. These elements have an impact on the daily reference intake of vitamin C (80 mg/day), which covers the eating of this fruit. As such, one unit of persimmon fruit (average weight = 263.32 g) can satisfy anywhere between 15.21% and 33.74% of the daily reference intake of vitamin C [55], or as demonstrated by Rao and colleagues, a persimmon can supply around 46% of this vitamin's daily requirements [56].

The levels of vitamin C in cultivars that are non-astringent are considerably greater (10 times) than in cultivars that are astringent [43]. It should be referenced that persimmon fruit has two types of vitamin C: L-ascorbic acid and its oxidized product, L-dehydroascorbic acid. Although both chemical species are important compounds thanks to their antioxidant activities, they do not have the same activity, since L-ascorbic acid is more active than the oxidized form [57]. About 2/3 of the total vitamin C in the persimmon is available as L-ascorbic acid [43].

In persimmon extracts, organic acids (malic, oxoglutamic, citric, succinic, and aspartic), amino acids (gamma-aminobutyric acid (GABA), alanine, arginine, valine, leucine, and isoleucine), fatty acids (palmitoleic acid methyl ester, myristic acid, and linoleic acid) [40][52], vitamins (trigonelline and ascorbic acid), α-tocopherol, oleanolic acid, betulinic acid, β-sitosterol, and uridine have also been identified [40].

It is also known that organic acids occur naturally in food as a result of metabolic processes, namely in the metabolism of abscisic acid, and are related to the tolerance to environmental stress in plants [58], the main ones in persimmon being malic and citric acids [42][59]. In the studies by Senter et al. with persimmons, these acids were quantified, where malic acid was the predominant acid in all cultivars studied by the authors, followed by citric [60]. The amounts of malic acid increased with maturation and those of citric decreased [41].

The amino acid *L*-tryptophan has been identified in recent studies in the aqueous extract of persimmon when analyzed based on NMR techniques [42]. With HPLC-DAD-ESI-TOF/MS technology applied to persimmon juice, the precursor ion m/z 203 was also identified as the amino acid *L*-tryptophan [38]. In studies on the characterization of persimmon juices using HPLC-DAD-ESI-TOF/MS methodology by Jiménez-Sánchez et al., various proteins and derivatives were detected. Precursor ions with m/z 164, 180, and, 203 were identified as *L*-tyrosine, *L*-phenylalanine, and *L*-tryptophan. These authors reported the detection of precursor ions m/z 395 and 383, which they considered as peptides, with the possibility of being *L*-lysine, *L*-serine, *L*-tyrosine/*L*-serine, *L*-proline, for the first and *L*-lysine, *L*-trionine, and *L*-histidine for the second [38][59].

Domínguez Díaz and colleagues characterized the 'Rojo Brillante' persimmons (*Diospyros kaki* L.), Protected Designation of Origin (PDO) 'Ribera del Xúquer' with regard to the existence of fiber with a total content of 2.38–4.99 g/100 g FW (vaguely greater for soluble fiber); vitamin C in the range of 4.62–10.25 g/100 g FW (primarily as dehydroascorbic acid); carotenoids (with lycopene as primary, in 26.76–51.10 µg/100 g FW, followed by β-carotene, in 10.07–20.50 µg/100 g FW, and neoxanthin, violaxanthin and β-cryptoxanthin as minor compounds); and mineral elements (Ca, Cu, Fe, K, Mg, Mn, Na, and Zn). With this information in mind and taking into consideration the scientific results surrounding this fruit showing the richness of persimmon fruit in bioactive compounds such as carotenoids, fiber, and vitamin C, not to mention the micro- and macro-minerals with significant health-furthering properties, the authors propose that the use of persimmon fruit and its bioactive components may be a solid approach to improving the population's health level globally. However, even though the consumption of persimmons brings important health benefits, to date, there are no specific health claims authorized for this fruit. As such, Domínguez Díaz and co-authors suggested that Persimon® (the registered trademark for the 'Rojo Brillante' variety) fruit is in theory capable of demonstrating two nutrition allegations: "sodium-free or salt-free" and "source of fiber". Persimon® fruit ought to have 3 g at a minimum of total dietary fiber/100 g of edible portion or at least 1.5 g per 100 kcal for the use of the "source of fiber" nutrition assertion. Given that the total dietary fiber mean values of all analyzed batches (2017 and 2018 seasons) were greater than the necessity of 1.5 g of fiber/100 kcal, it could be feasible to present the nutrition assertion "source of fiber" for Persimon® fruits. The nutrition claim "sodium-free or salt-free" might also be used for Persimon® given that its sodium content is inferior to the requirement of 0.005 g of sodium. These results may prepare the conditions for considering natural food products as candidates for the use of approved nutrition claims such as those used for this or other persimmon varieties [61], similarly to what has also been described for raspberry fruit (*Rubus idaeus* L.) [62]. It should also be noted that it has also been explained that the recommended daily intake of fresh persimmon should be around 100–150 g [43].

3. Phenolic Compounds

Phenolic compounds (PCs) can be found in a variety of foods available to the human diet including vegetables, fruits, beverages, herbs, and spices, many of which have been used empirically by humanity for centuries, namely in traditional medicine [63]. Fruits and vegetables, and their products, are among the foods richest in these compounds.

The persimmon is rich in phenolic compounds already identified as bioactive [36][37][40]. Much like carotenoids, PCs are also more abundant in the peel when compared to the pulp [64].

There is an interest in these compounds, which is mainly due to their antioxidant capacity (reaction with free radicals and chelation of metals) and possible beneficial implications for human health such as prevention and co-adjuvants in the treatment of various types of cancer, cardiovascular diseases, and other pathologies [65][66][67]. In addition to their antioxidant capacity, phenolic compounds have many other characteristics such as anti-atherogenic, anti-tumor, and anti-inflammatory effects, which cannot be described based only on their antioxidant properties [68].

Persimmons are rich in flavonoids, terpenoids, naphthoquinones, saponins, and condensed tannins [69]. In addition to the low molecular weight phenols present in the edible part of the fruit, there are phenolic acids such as gallic acid and its glycoside and acyl derivatives, glycosides of p-coumaric and vanillic acid, caffeic, chlorogenic acids, and several different di-C-hexoxide flavones [70]. It is worth noting that the following flavan-3-ol monomers were detected in persimmons: catechin, epicatechin, and epigallocatechin [71]. It was also through the combination of several analytical techniques that it was possible to identify myricetin as the terminal unit of the most common flava-3-ois (catechin and epigallocatechin-3-*O*-gall) [72].

In their work, Chen, Fan, and colleagues determined the content of individual and total phenols (epigallocatechin, epicatechin, catechin, chlorogenic acid, gallic acid, and caffeic acid) and compared them with those of other fruits such as apples, grapes, and tomatoes. They then concluded that persimmon was the fruit with a higher content of total phenolic compounds (about 170 mg/100 g dry weight) when compared to grapes (about 100 mg/100 g dry weight), apple (about 40 mg/100 g dry weight), and tomato (about 20 mg/100 dry weight) [15]. The content of total phenolic compounds in persimmons was eight times greater than that of tomatoes, which is in line with the high antioxidant capacity of the persimmon extract [15]. Gorinstein and colleagues also obtained similar results, showing that the content of total phenolic compounds in persimmons was greater than that of apples [8].

Total phenolic content dosages in persimmons as reported by available literature differed extensively. Total phenolic compounds were registered to be in the range of 12.7 and 29.5 mg of GAE/100 g of fresh weight (FW) [26]. Other researchers have registered soluble polyphenol concentrations to vary in the range of 1.3 mg to 1.550 mg/100 g FW of total phenolic compounds as well for the same astringent Triumph cultivar [8][73]. As a matter of fact, if we consider the work done by Jang and co-authors performed on homogeneous samples of the non-astringent cultivar Fuyu, the smallest concentration of soluble polyphenols was 454 mg GAE/100 g FW with ethanol extraction, about half the maximum concentration determined through extraction with water (860 mg GAE/100 g FW) [37]. Denev and colleagues determined 916.8 mg GAE/100 g FW [74], and Direito and colleagues determined 641 ± 51.96 mg GAE/100 g FW [75]. The inconsistency detected in these assays can be illuminated by considering the edaphoclimatic conditions, analysis of distinct opossum cultivars, and maturation phases, even when the fruit is more suitable for eating. Additionally, the various extraction methods that were used as well as the analytical methods of the protocols may have had an impact on the results [43].

Through an improved extraction procedure, together with an ultraperformance liquid chromatography coupled with Q-TOF mass spectrometry (UPLC-Q-TOF-MS) platform, Esteban-Muñoz and colleagues characterized the PC composition of the two varieties of persimmon, Rojo Brillante and Triumph. The phenolic composition of the pulp of these two varieties was shown to have hydroxycinnamic and hydroxybenzoic acids, tyrosols, dihydrochalcones, hydroxybenzaldehydes, flavonols, flavanols, and flavanones. According to this team's work, an overall amount of 31 compounds were detected, while 17 compounds were quantified. The prevalent phenolic compound observed in the Rojo Brillante type (0.953 mg/100 g fruit pulp) was gallic acid, while the concentration of p-hydroxybenzoic acid was greater in the Triumph variety (0.119 mg/100 g fruit pulp). The results demonstrated that the Rojo Brillante type had greater amounts of PCs than the Triumph type [20]. The concentrations of the phenolic compounds (caffeic acid, catechin, chlorogenic acid, epicatechin, fisetin, ferulic acid, gallic acid, p-coumaric acid, and protocatechuic acid) were determined by the ultra-high performance liquid chromatography (UHPLC-DAD) method (**Table 2**). In an aqueous persimmon fruit extract, gallic acid was found to be the most plentiful phenolic compound (2.794 ± 0.263 mg/100 g FW) detected [75], which is also in accordance with Pu and colleagues who found a concentration of 2.789 mg/100 g FW in the variety *D. kaki var. silvestris* M [76]. Nevertheless, Veberic and co-authors reported 2.43 ± 0.215 mg/100 g FW [26]. According to the work undertaken by Esteban-Muñoz et al., caffeic acid was the second most profuse hydroxycinnamic PC with 0.078 and 0.046 mg/100 g for the Triumph and Rojo Brillante varieties, respectively, levels that are consistent with those determined in other varieties of persimmon [76][77]. The concentrations of the three hydroxycinnamic acids (caffeic acid, ferulic acid, and chlorogenic acid) in the study done by Direito and colleagues were below 0.1 mg/100 g FW, except for the chlorogenic acid content, as was illustrated by Pu and colleagues [76]. The chlorogenic acid concentration in the work presented by these authors was 0.171 ± 0.016 mg/100 g FW *D. kaki* extract [75]. Published results of 0.274 mg/100 g FW in the variety of *D. kaki var. silvestris* M and 0.145 mg/100 g FW in the variety of *D. kaki cv.* Xingyangshuishi have also been found [76]. These same authors were not able to discover p-coumaric acid in five out of the six genotypes that were evaluated. The only genotype where p-coumaric acid was found was in *D. kaki var. silvestris* M, with a value of 0.048 ± 0.004 mg/100 g FW [76], roughly less than twice the concentration reported by Direito and colleagues of 0.097 ± 0.004 mg/100 g FW [75], in accordance with the concentration reported by Esteban-Muñoz and colleagues, where p-coumaric acid was the hydroxycinnamic acid with the greatest levels in both persimmon varieties (not statistically different) with ranges from 0.088 to 0.113 mg/100 g FW [20]. According to these authors' work, protocatechuic acid had a concentration of 0.013 ± 0.010 mg/100 g in the Rojo Brillante variety, which was greater than those attained for the Triumph sample (0.004 mg/100 g), which is in agreement with the concentration reported by Direito and colleagues (0.005 mg/100 g FW) [75]. Greater concentrations were observed in various persimmon extracts acquired with various solvents [77], but the use of a HPLC equipped with ECD (electron capture detector) detection might overemphasize the concentration, and lower concentrations have also been described [75]. Esteban-Muñoz et al. identified ellagic acid for the first time in persimmon fruit in the Rojo Brillante variety (0.327 ± 0.173 mg/100 g fruit pulp), the variety of persimmons that had a greater concentration of ferulic acid than that found in the Triumph variety (0.011 vs. 0.008 mg/100 g). These concentrations are consistent with (or slightly lower than) those described for different persimmon varieties by other authors [75][76][78].

Table 2. Main phenolic compounds from persimmon fruits quantified and identified.

Phenolic Compounds (PCs)	**Quantification and Reference**			
Gallic acid (mg/100 g FW)	**0.953 ± 0.344 [20]**	**2.794 ± 0.263 [75]**	**2.789 ± 0.003 [76]**	**2.43 ± 0.215 [26]**
Caffeic acid (mg/100 g FW)	**0.078 ± 0.001 [76][77]**	**0.1 ± 0.001 [75][76]**		
P-coumaric (mg/100 g FW)	**0.048 ± 0.004 [76]**	**0.097 ± 0.004 [75]**	**0.088 ± 0.046; 0.113 ± 0.055 [20]**	
Ferulic acid (mg/100 g FW)	**0.1 ± 0.001 [75][76]**	**0.008 ± 0.003 [20]**		
Chlorogenic acid (mg/100 g FW)	**0.171 ± 0.016 [75]**	**0.274 ± 0.003 [76]**		
Protocatechuic acid (mg/100 g FW)	**0.013 ± 0.010; 0.004 ± 0.002 [20]**	**0.005 ± 0.000 [75]**		
Ellagic acid (mg/100 g FW)	**0.327 ± 0.173 [20]**			
Quercetin (mg/100 g FW)	**0.224 ± 0.002;0.812 ± 0.006 [76]**			
Proanthocyanins (mg/100 g FW)	**540.2 ± 0.000 [74]**	**744 ± 8.6 [75]**		
Identifications				
(Epi)catechin and (epi)gallocatechin	**[13][59][70][71][72][79]**			
Quercetin 3--2″-galloylglucoside), quercetin 3-*O*-glucoside and isomer and aglycone	**[59]**			
Kaempferol-3-*O*-glucoside, kaempferol 3-(2″-galloylglucoside)	**[59]**			
2-Methoxy-1, 4-benzoquinone	**[59]**			

Compared with hydroxycinnamic acids, the extent of hydroxybenzoic acids was higher [20][75], but the (+)-catechin and (−)-epicatechin contents reported by Direito et al. were lower than previously reported values [80][81]. The same situation occurred for the concentration of the flavone fisetin [72]. Nevertheless, the various stages of maturation and the various cultivars may possibly lead to a variability in the results [43]. The diversity of small phenols in pulp extracts reported to date is, however, surprisingly scarce, being normally restricted to three to ten components (derived mainly from cinnamic acid), depending on the variety being assayed [43]. Thus, it can be concluded that the profile of low molecular weight phenols, for example, in the pulp of the persimmon, still remains to be determined [20][70].

Catechins (flavan-3-ol) are the main flavonoids found in persimmons, which can offer potential benefits to human health, given that they are related to several physiological functions including a protective role against diseases associated with oxidative stress and have antimutagenic and anticarcinogenic capabilities [71]. Persimmon extracts also showed apoptosis-inducing activity of Molt 4B leukemic cells [82].

Procyanidins consisting of (epi)catechin and (epi)gallocatechin together with free phenolic acids in extracts of different varieties of Japanese persimmon have been reported in the literature [71]. However, Sentandreu and colleagues found no evidence of their presence in their tested samples [70]. Zang and colleagues described the presence of the precursor ion m/z 289, which may be -(−)epicatechin [79] and with a fragmentation spectrum characteristic of this type of compound (m/z 109, 123, 125, 205, and 245) [38]. Epicatechin and flavone di-C-hexoside were, however, identified by Maulidiani and colleagues [59].

Quercetin was measured in comparable quantities in the Triumph and Rojo Brillante varieties in the range of 0.005–0.007 mg/100 g fruit pulp. Even though these values are lower than those described for other varieties of persimmon [76], some authors did not find any quercetin in persimmons [78]. Maulidiani and colleagues identified quercetin and kaempferol derivatives as the major flavonoids in persimmon where the four derivatives of quercetin including quercetin 3-(2″-galloylglucoside), quercetin 3-*O*-glucoside and its isomer and quercetin aglycone were also identified. Kaempferol-3-*O*-glucoside and its isomer, kaempferol aglycone and kaempferol 3-(2″-galloylglucoside) were likewise also identified [59].

Persimmons accumulate a large amount of condensed tannins (or proanthocyanidins, PACs) in vacuoles of specific cells called “tannin cells” during the development of the fruits, which are responsible for the astringency, which is a sensation of dryness or “tie the mouth” due to the clotting of oral proteins [83]. As maturation progresses, tannin content decreases and the risk of bitter taste of astringent varieties also decreases [84]. However, the greater or lesser astringency of all cultivars decreases during ripening, not only because of the decrease in tannin content, but because the soluble tannins turn into insoluble forms [85]. Astringent cultivars continue to have a significant amount of soluble tannins even when ripe [51].

Gu and colleagues used the HPLC method coupled with electrospray ionization mass spectrometry (ESI-MS) to determine the fractions of condensed tannins of high molecular weight that constitute the persimmon, which permitted them to verify that the antioxidant activity of high molecular weight tannin fractions was significantly higher than that of low molecular weight tannins and that of proanthocyanidins in grape seeds. This led the author to consider that condensed high molecular weight tannins were the largest antioxidant present in persimmon pulp [13]. As studied by Suzuki and colleagues, the highest proanthocyanidin content was found in astringent varieties [71]. Proanthocyanins diminished proportionately throughout maturation from 540.2 mg CE/100 g FW to 90.2 mg CE/100 g FW [74]. In the study by Direito and colleagues, proanthocyanidin content was 744 ± 8.6 mg CE/100 g FW [54].

In the study of the structure of the proanthocyanidins present in the persimmon, it was found that they consist essentially of (epi)gallocatechin-3-*O*-gallate, (epi)catechin-3-*O*-gallate, and epicatechin [13][72]. The molecular weight distribution of the condensed tannins of high molecular weight was determined as being in an interval between 1.16×10^4 Da and 1.54×10^4 Da [13], and Li and colleagues described between 7 and 20 kDa (degree of polymerization 19–47), but sizes estimated by gel permeation chromatography were 50–70% smaller [72].

Tyrosol was found at similar levels in both varieties of persimmon (Rojo Brillante and Triumph), 0.020 ± 0.017 mg/100 g fruit pulp for Triumph and 0.038 ± 0.021 mg/100 g fruit pulp for Rojo Brillante studied by Esteban-Muñoz and colleagues, but no other studies discussing tyrosol have been found to date [20].

Triterpene and fatty acids are detected in different amounts in all cultivars: Fuyu, Triumph, Krembo, Jiro, Romang, and Taishu. Spathodic acid, a pentacyclic triterpenoid, rotungenic acid, and oleanolic acid were identified based on the molecular ion at m/z 455.3532 [59]. Spathodic, barbinervic, and rotungenic acids, which were only found in Krembo, can be considered as the chemical markers of the Krembo cultivar. L-malic and citric acids were also found in all cultivars. Interestingly, pantothenic acid was only detected in the Krembo persimmon. According to analyses, monogalloyl-hexoside was only found in Krembo and Triumph, while gallic acid was found in Krembo, Triumph, and Jiro cultivars. Quercetin and kaempferol were found in the Fu and Ji varieties, while its glycosidic forms were mostly found in Fuyu, Krembo, Triumph, and Jiro. Fructose was found in all cultivars, while glucuronic acid was found in the Krembo variety and had 23 unique compounds, while Fuyu and Taishu varieties had only eight and two unique compounds, respectively. All three cultivars shared the same 15 compounds, which were mostly sugars, amino acids, and fatty acids [59].

Two benzoquinone derivatives were also identified based on their molecular ions at m/z 137.0233 and 293.1760, the 2-methoxy-1, 4-benzoquinone, and embelin, respectively. Embelin is a dihydroxy-1,4-benzoquinone that has an undecyl group substitution at position C3 [59].

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