Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi ISSN:1300-9362
Journal of Agricultural Faculty of Mustafa Kemal University 23(1):12-23 (2018)
Araştırma Makalesi | *Research Article*
Geliş Tarihi: 07.09.2017 Kabul Tarihi: 29.05.2018

Changes in Sugars Content and Some Biochemical Substances during Fruit Development in Different Persimmon Cultivars

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Abstract

The seasonal changes in the some biochemical substances in fruits of ten persimmon cultivars (PCNA cultivars such as 'O'Gosho', 'Fuyu', 'Hana Fuyu' and 'Jiro', and non-PCNA cultivars such as 'Vainiglia', 'Hachiya', 'Kaki Tipo', 'Eylül', 'Amankaki' and 'Harbiye') were determined in Dörtyol-Hatay (Turkey) in the 12th and 13th year after planting (YAP). All results were expressed on a fresh weight basis. The fructose and glucose were the predominant soluble sugar in different persimmon cultivars, and the amounts of fructose and glucose in persimmon fruits showed an apparent increase during fruit development. The total phenolics (TP), total flavonoids (TF) and soluble tannins (ST) concentration in fruits showed a continuous decrease from July to consumption maturity. The TP, TF and ST amounts of non-PCNA group fruits in tree maturity were higher more about 3.6, 4.9 and 5.6 fold than those of the PCNA group fruits, respectively. In consumption maturity, the highest TP content of non-PCNA group fruits was found in 'Eylül' (131.3 mg/100 g) and 'Hachiya' (128.5 mg/100 g) cultivars. The fruits of non-PCNA cultivars had 2.3 and 1.9 fold more total antioxidant capacity (TAC) than those of PCNA cultivars according to FRAP and TEAC, respectively. In addition, the results indicated that a good correlation between the TP content and TAC of persimmon cultivars ($r = 0.98$, at $p < 0.05$).

Key words: Persimmon, Cultivar, Biochemical substances, Antioxidant capacity

Farklı Trabzon Hurması Çeşitlerinde Meyve Gelişim Sürecindeki Şeker İçerikleri ile bazı Biyokimyasal Özelliklerin Değişimi

Özet

Çalışmada, Dörtyol/Hatay'da yetiştirilen 12-13 yaşlı 10 farklı Trabzon hurması çeşidinin ('O'Gosho', 'Fuyu', 'Hana Fuyu', 'Jiro', 'Vainiglia', 'Hachiya', 'Kaki Tipo', 'Eylül', 'Amankaki' ve 'Harbiye') meyvelerindeki bazı biyokimyasal maddelerin mevsimsel değişimleri incelenmiştir. Çalışmadaki tüm sonuçlar taze ağırlık üzerinden değerlendirilmiştir. Trabzon hurması çeşitlerinde hakim indirgen şekerin fruktoz ve glikoz olduğu ve bu şeker fraksiyonlarının meyve gelişim süresince belirgin bir artış gösterdiği saptanmıştır. Meyvelerdeki toplam fenolik (TFM), toplam flavonoid (TF) ve çözünebilir tanen (ÇT) konsantrasyonları, temmuz ayından itibaren yeme olumuna kadar düşüş göstermiştir. Derim olumu dönemindeki non-PCNA grubunda yer alan çeşitlere ait meyvelerin PCNA grubuna ait çeşitlerin meyvelerine göre TFM, TF ve ÇT içeriklerinin sırasıyla 3.6, 4.9 ve 5.6 kat daha yüksek olduğu belirlenmiştir. Yeme olumu döneminde, en yüksek TFM içeriği non-PCNA grubunda yer alan çeşitlerden 'Eylül' (131.3 mg/100 g) ve 'Hachiya' (128.5 mg/100 g) çeşitlerinde belirlenmiştir. Non-PCNA grubunda yer alan çeşitlere ait meyvelerde PCNA grubuna ait çeşitlerin meyvelerine göre FRAP ve TEAC yöntemlerine göre belirlenen toplam antioksidan kapasitenin (TAK) sırasıyla 2.3 ve 1.9 kat daha yüksek olduğu tespit edilmiştir. Çalışma sonuçları Trabzon hurması çeşitlerinde meyvelerin

içerdiği toplam fenolik madde ve toplam antioksidan kapasitesi arasında pozitif bir korelasyonun olduğunu göstermiştir ($r = 0.98$, $p < 0.05$).
Anahtar kelimeler: Trabzon hurması, Çeşit, Biyokimyasal özellikler, Antioksidan kapasite

Introduction

The persimmon (*Diospyros kaki* Thunb.) is a commercially important fruit crop, particularly widespread in Asian countries. In Europe the persimmon is much less widespread even though production is now increasing because of the characteristics of the Mediterranean climate, suitable for growing most of the persimmon cultivars. The persimmon industry in Turkey has been expanding due to domestic demand and export market opportunities for persimmon fruits. In Turkey which the commercially to be grown astringent variety, the main producer areas are located on the eastern part of the Mediterranean Region (Candir et al., 2009). *Diospyros kaki* (Thunb.) is classified into four types depending on the effect of pollination on the flesh colour, the presence of seeds and their pattern of astringency loss: pollination-constant non-astringent (PCNA), pollination variant non-astringent (PVNA), pollination-variant astringent (PVA), and pollination-constant astringent (PCA) (Yonemori et al., 2000).

Regular consumption of fruit and vegetables containing natural antioxidants is correlated with the decreased risk of diseases such as cancer, cardiovascular diseases, and so on (Temple, 2000). These beneficial properties are considered to be related to the various antioxidants, including vitamins, phenolic compounds, and carotenoids, contained in this kind of fruit. Consumers today are not only searching for a sweet tasting cultivar but also health-promoting compounds in fruit, such as polyphenols and carotenoids, which are equally important. Persimmon, among colourful fruits, is popularly consumed in the human diet as both fresh and processed forms (Jung et al., 2005). Studies have shown that persimmon is one of the most bioactive fruits (George and Redpath, 2008). Persimmon fruit contains different nutrients and phytochemicals such as carbohydrates, organic acids, vitamins, tannins, polyphenols, dietary fibers and carotenoids etc., which play important roles in the flavor, color, nutritive and pharmaceutical value of the fruit (Celik and Ercisli, 2008). The content varies greatly amongst cultivars; comparatively non-astringent cultivars of persimmon appear to have far less polyphenols, catechins and tannins (lower antioxidant potential) than the astringent types (Chen et al., 2008). The fruit is characterized by its high level of tannic acid (tannins), which disappears when the fruits are very ripe. Persimmon is also rich in antioxidant phenolic compounds other than tannins, and it has been demonstrated that these compounds may reduce the risk of chronic diseases by protecting tissues against free radical-mediated damage (Gorinstein et al., 1994). Moreover, tannins have been described to have antimutagenic, anticarcinogenic and antioxidant activities (Gali et al., 1992).

Persimmon fruits show significant differences among varieties in terms of color and astringency (Ito, 1980). Astringent varieties of persimmon have a limited consumption; therefore, improvement of their features with some technological processes is necessary. This fruit must be consumed completely ripe to avoid the astringent taste and, because of this, large production losses take place due to handling of overly soft products. The use of ethylene, carbondioxide, and other chemicals remove the astringency while the fruit is still unripe (Palmer-Wright and Kader, 1997). At harvest, astringent varieties of persimmon fruit contain approximately 2% of soluble tannins. Soluble tannins are responsible for an astringent taste, and contain catehin-3-gallat, galocatahin and galocatahin-3-gallat (Vidrih et al., 1994).

Maturity is important for the quality of any fresh fruit, and the ability to measure its

accuracy is essential for efficient marketing and consumer satisfaction. Various maturity indices of changes in biochemical properties have been used to monitor fruit development (Candir et al., 2009; Del-Bubba et al., 2009). However, there are limited studies on biochemical characteristics of persimmon cultivars grown in the Mediterranean Region. Determining the bioactive compounds in different persimmon fruits in different growing regions is crucial for future plant-breeding programmers.

The aim of this study was to investigate some biochemical characteristics of 10 astringent and non-astringent persimmon cultivars grown in the eastern Mediterranean region. To investigate changes during growth and maturation, the fruits were analyzed at different development stages for concentrations of sugar, total phenolics, total flavonoids and soluble tannin, as well as for their antioxidant capacity based on the TEAC (Trolox equivalent antioxidant capacity) and FRAP (Ferric reducing antioxidant power).

Material and Method

Plant Material and Sampling

The experiment was carried out in Mustafa Kemal University experimental farm in Dörtyol, Hatay, Turkey (Longitude, 36° 09' E; Latitude, 36° 51' N; Elevation: 9 m above sea level) in the eastern Mediterranean Region of Turkey. The experimental design was a completely randomized with three replications and a single tree per plot. 'O'Gosho', 'Fuyu', 'Hana Fuyu', 'Jiro' (PCNA group), 'Vainiglia', 'Hachiya', 'Kaki Tipo', 'Eylül', 'Amankaki' and 'Harbiye' (non-PCNA group), grafted on *Diospyros lotus* (L.) seedling in 1997 with 5 m x 6 m spacing at the Research Station. Fruits were collected in early July, August, September, October, and their tree maturity (Table 1) and consumption maturity for non-PCNA cultivars (keeping at room temperature prior to analysis). Ten fruits per tree were collected for each cultivar and sampling time in three replicates.

For the biochemical analyses, triplicate 10 number lots of persimmon fruits were homogenized in a blender at room temperature. Sample of each homogenate or fruit juice was separately transferred to polypropylene tubes to be determined for their sugars, total phenolic content, total flavonoid content, soluble tannin content, and total antioxidant capacity. Then all triplicates were frozen and stored at -20 ºC until analyzed.

Table 1. Harvest time and chromatographic parameters of fruit skin of 10 persimmon cultivars
Çizelge 1. 10 farklı Trabzon hurması çeşidinde hasat zamanı ile meyve kabuk rengi parametreleri

Cultivars	Year after planting (YAP)					
	12th			13th		
	Harvest time	L*	hº	Harvest time	L*	hº
O'Gosho	01 November	64.20	76.44	06 November	60.69	83.35
Fuyu	28 October	61.28	69.99	19 October	63.65	82.15
Hana Fuyu	28 October	66.20	74.54	19 October	62.18	79.16
Jiro	01 November	66.51	76.40	06 November	65.41	76.04
Vainiglia	15 November	72.36	84.35	06 November	68.63	67.63
Hachiya	01 November	61.35	69.61	19 October	60.22	78.83
Kaki Tipo	07 November	68.33	88.97	06 November	63.52	85.42
Eylül	15 October	62.86	67.07	09 October	63.79	72.92
Amankaki	01 November	63.89	74.83	09 October	65.67	85.33
Harbiye	10 November	72.75	83.04	06 November	64.23	84.82
HSD (5%)		2.56	3.53		3.74	6.34

Sugar Composition

Contents of individual sugars (fructose, glucose and sucrose) were determined with the similar procedure described by Claessens et al. (1996). Five grams of mashed fruit were mixed with 10 mL of distilled water. The one gram sample which was taken from this mixture was completed to 5 mL of distilled water, and homogenized during two minutes and later kept for 30 min at room temperature with occasional stirring. The extracted sample was filtered through Whatman No. 42 filter paper under a vacuum. The supernatant was then filtered through 0.45 mm membrane filters (Millipore, USA) prior to high-performance liquid chromatography (HPLC) analysis. Mobile-phase solvents were degassed before use. HPLC analyses of sugars were performed on LC-10A equipment consisting of LC-10AD pumps, in-line degasser, a CTO-10A column oven, a SCL-10A system controller, and a refractive index detector, and operated by LC solution software (Shimadzu, Japan).

Sugars were separated on EC 250/4 Nucleosil C18 carbohydrate column (250 mm – 4.0 mm i.d.) (Macherey–Nagel, USA) at 25 ºC. The mobile phase was acetonitrile:water (80:20, v/v) at a flow rate of 2 mL min^{-1}. The sugars were detected using a refractive index detector and quantified by the external standard method. The results were expressed as a fresh weight basis (%).

Total Phenolics (TP)

TP contents were determined by using the Folin–Ciocalteu phenol reagent method (Slinkard and Singleton, 1977). The extract samples (100 µL) were mixed with 0.75 mL Folin-Ciocalteau reagent, and incubated for five minutes at room temperature, followed by the addition of 0.75 mL of 60 g L^{-1} sodium carbonate. The absorbance of reaction was measured at 725 nm using a spectrophotometer (Shimadzu UV-1208, Japan) after 90 min of incubation at room temperature. Results were expressed as ferulic acid equivalents (FAE) on a fresh weight (FW) basis (mg FAE/100 g FW).

Total Flavonoids (TF)

TF contents were determined by a colorimetric assay (Shin et al., 2007). Briefly, 1mL fruit extract was added to a 15 mL tube containing 4 mL of deionized water. Then 0.3 mL of 5% sodium nitrate ($NaNO_2$) was added to this mixture, which was allowed to stand for 5 min at room temperature, and 0.3 mL of 10% aluminum chloride ($AlCl_3 \cdot 6H_2O$) was added. The mixture was allowed to stand for 6 min at room temperature, and 2 mL of 1 mol L^{-1} sodium hydroxide (NaOH) was added, and the total was made up to 10 mL with deionized water. The absorbance of the solution versus a blank at 510 nm was measured immediately. Total flavonoid contents were calculated as catechin from a calibration curve. Results were expressed as catechin on a fresh weight (FW) basis (mg catechin/100 g FW).

Soluble Tannins (ST)

ST contents were determined spectrophotometrically according to the Folin–Denis method. To measure the tannin content, 1 mL of fruit juice was homogenized with 5 mL distilled water. The homogenate was centrifuged at 3600 g for 5 min. The 1 mL of supernatant was made up to 5 mL of solution A and 10 mL of solution B, all made up to 100 mL with distilled water. The absorbance at 750 nm was read after 30 min on a spectrophotometer (Shimadzu UV-1208, Japan) against a blank and compared with a tannic acid standard solution on a FW basis (Jowkar et al., 2006). Solution A consisted of 100 g $Na_2WO_4.2H_2O$ (Merck Co., Germany) and 20 g phosphomolybdic acid [$H_3(PMO_3O_{10}).XH_2O$] (Merck Co., Germany) added into 750 mL distilled water. The solution was made up to 1:l with distilled water and stirred for 2 hours on a hot plate until the reagents dissolved. Solution B was saturated sodium carbonate (Merck Co., Germany).

Total Antioxidant Capacity (TAC)

TAC was estimated by two standard procedures FRAP (Ferric reducing antioxidant power) and TEAC (Trolox equivalent

antioxidant capacity) assays as suggested by Ozgen et al. (2006).

To conduct the FRAP assay, 2.95 mL aliquot of FRAP reagent (a mixture of 0.1 mol/L acetate buffer, 10 mmol/L TPTZ [2,4,6-tris(2-pyridyl)-1,3,5-triazine], and 20 mmol/L ferric chloride (10:1:1 v/v/v)) was combined with 50 µL of acetone fruit extract prepared by the protocol above. These solutions were prepared and stored in darkness under refrigeration. The samples were incubated at 37 ºC for 30 min, and the absorbance of the reaction mixture at 593 nm was determined on a spectrophotometer (Shimadzu UV-1208, Japan). To determine the antioxidant capacity of samples, absorbance values were compared with those obtained from standard curves of $FeSO_4$ x $7H_2O$ (10–100 µM). Antioxidant capacity values were expressed as Fe^{2+} equivalents mmol/kg fruit weight (FW).

For the standard TEAC assay, ABTS (2,2'-Azino-bis 3-ethylbenzothiazoline–6-sulfonic acid) was dissolved in acetate buffer and prepared with potassium persulfate. The mixture was diluted in acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm for longer stability. For the spectrophotometric assay, 2.95 mL of the ABTS+ solution and 50 µL of fruit extract were mixed and incubated in 10 min and the absorbance was determined at 734 nm by a spectrophotometer (Shimadzu UV-1208, Japan). The absorbance values were compared with those obtained from standard curves of Trolox (10–100 µM). Antioxidant capacity values were expressed as trolox equivalents mmol/kg fruit weight (FW).

Statistical Analysis

Data were analyzed using GLM procedure of SAS software (SAS Institute Inc., North Carolina, USA). Means and standard deviations were calculated using PROC TABULATE. The mean separations were carried out by the Tukey's Honestly Significant Difference (HSD) and assessed at 5% significance level.

Results

All results were expressed on a fresh weight basis. The fructose, glucose and sucrose contents during fruit development in the different persimmon cultivars were given in Figure 1. The fructose and glucose were the predominant soluble sugar in different persimmon cultivars. The amounts of fructose and glucose in persimmon fruits showed an apparent increase during this period, while the sucrose content remained low level. The contents both fructose and glucose in non-PCNA cultivars were higher than those of PCNA cultivars from in the all sampling dates, except first sampling. The fructose and glucose levels of PCNA cultivars (5.61% and 6.09%, respectively) were lower than those of non-PCNA cultivars (6.84% and 7.00%, respectively) in tree maturity. The amounts of fructose and glucose in non-PCNA fruits in consumption maturity increased as compared to tree maturity (about 16% and 12%, respectively).

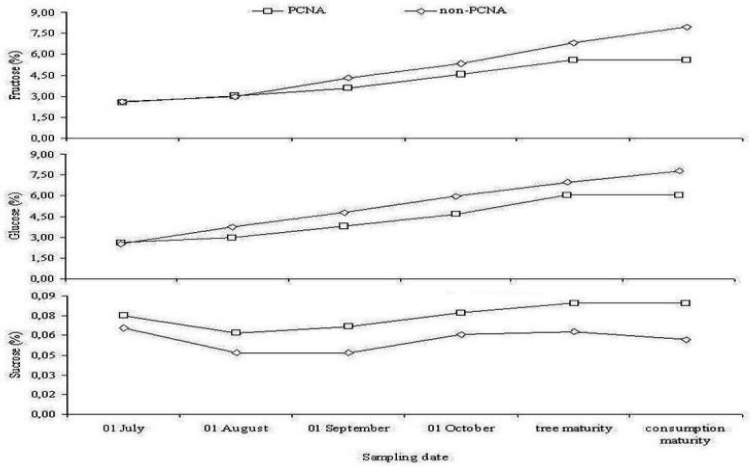

Figure 1. Seasonal variation in soluble sugar content of fruits in different persimmon cultivars
Şekil 1. Farklı Trabzon hurması çeşitlerinde meyvelerin çözünebilir şeker içeriklerinin mevsimsel değişimi

The concentration of TP in fruits of different persimmon cultivars decreased throughout fruit development (Table 2). The TP amounts of non-PCNA group fruits in tree maturity were higher more about 3.6 fold than those of the PCNA group fruits. TP contents of non-PCNA group fruits in consumption maturity declined by 80.0% as compared to tree maturity. The TP concentration of PCNA group fruits in tree maturity was in the range from 18.5 (Jiro) to 26.3 (Hana Fuyu) mg FAE/100 g FW. In consumption maturity, whereas the highest TP content of non-PCNA group fruits was found in 'Eylül' and 'Hachiya' cultivars, 'Kaki Tipo' was the lowest, followed by 'Vainiglia'.

The TF and ST concentration in fruits showed a continuous decrease from July to consumption maturity (Figures 2 and 3). The amounts of TP and ST at the tree maturity in PCNA group fruits were about 4.9 and 5.6 times lower than those of the non-PCNA group fruits. At the consumption maturity, the fruits of non-PCNA cultivars had approximately 2.8 fold more TP and ST than those of PCNA cultivars. In non-PCNA group cultivars, the Hachiya, Eylül and Amankaki cultivars had the highest TF content with 65.1, 59.7 and 53.0 mg catechin/100 g FW in consumption maturity, whereas the highest ST amount was determined in Eylül (30.7 mg tannin/100 ml), followed by Amankaki and Hachiya cultivars. The TF and ST concentration of PCNA group fruits was in the range from 10.8 to 17.9 mg catechin/100 g FW, and from 8.4 to 12.0 mg tannin/100 ml, respectively.

TAC was estimated by two standard procedures (FRAP and TEAC) in tree maturity for PCNA group cultivars, and in consumption maturity for non-PCNA group cultivars, and these procedures showed compatible results with each other (Table 3). 'Eylül' had the highest FRAP and TEAC, followed by Hachiya. The lowest FRAP and TEAC was in Hana Fuyu (1.20 mmol Fe^{2+}/kg FW and 1.78 mmol Trolox/kg FW, respectively). The fruits of non-PCNA cultivars had 2.3 and 1.9 fold more TAC than those of PCNA cultivars according to FRAP and TEAC, respectively. When comparing the results of FRAP and TEAC, a good correlation between the two can be observed ($r = 0.99$, $P < 0.05$), suggesting that all extracts have almost identical ability to scavenge both FRAP and TEAC radicals.

Table 2. Seasonal variation in total phenolics of fruits in different persimmon cultivars (mg FAE/100 g FW)

Çizelge 2. Farklı Trabzon hurması çeşitlerinde meyvelerin toplam fenolik içeriklerinin mevsimsel değişimi (mg FAE/100 g Taze Ağırlık)

Cultivars		01 July	01 August	01 September	01 Ocrober	Tree maturity	Consumption maturity
PCNA	O'Gosho	99.4	77.6	64.9	36.1	22.8	22.8
	Fuyu	89.7	59.7	56.9	49.8	19.0	19.0
	Hana Fuyu	105.5	82.6	59.1	41.5	26.3	26.3
	Jiro	83.5	42.2	30.1	29.3	18.5	18.5
non-PCNA	Vainiglia	347.1	308.9	254.1	104.4	39.4	37.4
	Hachiya	483.1	456.0	361.6	311.8	207.4	128.5
	Kaki Tipo	267.2	271.3	235.2	134.7	68.8	27.9
	Eylül	576.7	445.5	419.5	243.0	235.4	131.3
	Amankaki	414.9	363.7	346.0	216.9	178.6	96.6
	Harbiye	249.1	244.5	234.5	146.8	119.6	49.9
	HSD (5%)	24.41	17.35	28.23	20.92	20.47	10.33
Mean (PCNA)		94.5	65.5	52.8	39.2	21.6	21.6
Mean (non-PCNA)		389.7	348.3	308.5	192.9	141.5	78.6

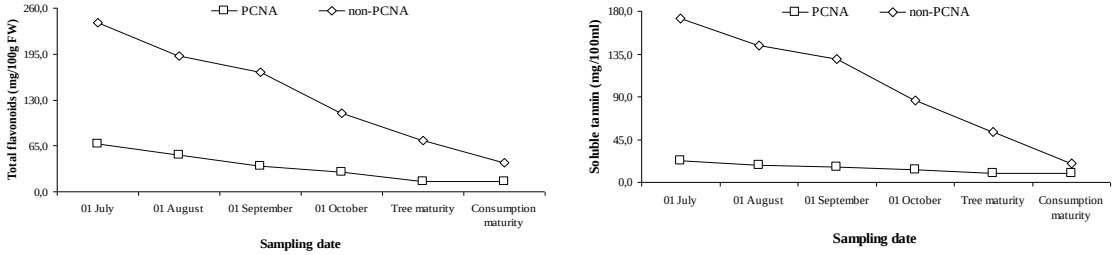

Figure 2. Seasonal variation in total flavonoids (left) and soluble tannin (right) of fruits in different persimmon cultivars

Şekil 2. Farklı Trabzon hurması çeşitlerinde meyvelerin toplam flavonoid (solda) ve çözünebilir tanen (sağda) içeriklerinin mevsimsel değişimi

Table 3. Total antioxidant capacity of different persimmon fruits in consumption maturity

Çizelge 3. Yeme olgunluğundaki farklı Trabzon hurması çeşitlerinde meyvelerin toplam antioksaidant kapasitesi

Cultivars		FRAP (mmol Fe^{2+}/kg FW)	TEAC (mmol Trolox/kg FW)
PCNA	O'Gosho	2.15	2.71
	Fuyu	1.43	2.46
	Hana Fuyu	1.20	1.78
	Jiro	1.70	2.75
Non-PCNA	Vainiglia	2.42	2.90
	Hachiya	5.25	6.71
	Kaki Tipo	1.40	2.23
	Eylül	5.88	6.94
	Amankaki	4.61	5.38
	Harbiye	2.75	3.82
	HSD (5%)	0.40	0.50
Mean (PCNA)		1.6	2.4
Mean (non-PCNA)		3.7	4.7

The relationships between TP and TAC and among these traits with other biochemical characteristics were investigated by correlation analysis (Table 4). Fructose and gluctose were significantly correlated with the coefficient of 0.88. These results indicate a good correlation between the TP content and TAC of persimmon cultivars ($r = 0.98$, at $p < 0.05$), which supports the observation that the TAC of persimmon fruit is strongly dependent on the TP. In addition, the TP concentaration is positively related to TF and ST content in persimmon cultivars. The sucrose and fruit skin hue° value were not correlated with other biochemical characteristics.

Discussion

The sugars and polyphenols such as secondary metabolites can contribute to sweet, bitter or astringent flavours of fruit, while they can also contribute to aroma (Tomas-Barberan and Espin, 2001). A number of studies have shown that the presence of polyphenols in fruits can be particularly important for consumers, because of their beneficial health properties (Stoclet et al., 2004; Butkhup and Samappito, 2011). The soluble sugar contents clearly increased throughout the fruit development (Figure 1). This finding was in agreement with others reporting the seasonal changes of this carbohydrate fraction in different persimmon cultivars (Candir et al., 2009; Del-Bubba et al., 2009; Novillo et al., 2016). Glucose and fructose are generally considered the main sugars, while sucrose is present as a minor component in mature persimmon fruits (Veberic et al., 2010; Baltacioglu and Artik, 2013). The ratio of 1 : 1 was determined for glucose : fructose in this stduy. This ratio is evidence of the presence of very active invertase, and it is believed that the presence of such an active enzyme may explain the absence of sucrose (Del-Bubba et al., 2009). Veberic et al. (2010) reported that the fructose and glucose content of different persimmon fruits range from 38.0 to 77.8 g/kg FW, and from 47.8 to 87.9 g/kg FW, respectively. In agreement with our results, authors found that the lowest content of individual sugars was measured in PCNA cultivars, such as 'O'Gosho', 'Cal Fuyu' and 'Hana Fuyu'. On the other hand, Giordani et al. (2011) reported that there was no statistically significant differences between glucose and fructose were found in the fruits of astringent cultivars compared to nonastringent types.

Table 4. Correlation coefficients (r) of some biochemical characteristics for persimmon cultivars

Çizelge 4. Trabzon hurması çeşitlerinin meyvelerinde bazı biyokimyasal özellikler arasındaki korelasyon

Source	Glucose	Sucrose	TP	TF	ST	TAC (FRAP)	TAC (TEAC)	Hue
Fructose	0,88*	-0,33	0,47	0,46	0,56	0,47	0,46	-0,33
Glucose		-0,32	0,61	0,64	0,62	0,58	0,58	-0,14
Sucrose			-0,25	-0,23	-0,48	-0,26	-0,17	-0,30
TP				0,99*	0,93*	0,98*	0,98*	-0,47
TF					0,91*	0,97*	0,96*	-0,45
ST						0,96*	0,93*	-0,42
TAC (FRAP)							0,99*	-0,49
TAC (TEAC)								-0,48

Abbreviation: TP, total phenolics; TF, total flavonoids; ST, soluble tannin; TAC, total antioxidant capacity.
* $P < 0.05$.

The decrease in polyphenol content of fruits causes a loss in astringency and bitterness during ripening (Butkhup and Samappito, 2011). The TP levels have been

found to decrease during persimmon fruits maturation (Baltacioglu and Artik, 2013). This decline was postulated by Kadioglu and Yavru (1998) to be due to the cessation of synthesis and conversion of other o-diphenols to other compounds. The TP content in fruits of our persimmon cultivars was within the range reported in other persimmon cultivars (Gorinstein et al., 2001; Veberic et al., 2010), but lower than those reported by Chen et al. (2008) and Pu et al. (2013). It has been reported that the content of total phenolics may vary in different persimmon varieties, different extraction procedures, and analysis methods used (Gorinstein et al., 2001). Most studies in the persimmon fruits showed that the total phenolic content is higher in astringent persimmons than in nonastringent persimmon (Jang et al., 2011; Li et al., 2011). The results obtained regarding the TP content are in agreement with Suzuki et al. (2005), who reported that fruits of PCNA cultivars had 4-6 fold less the TP content than those of non-PCNA cultivars. On the other hand, Veberic et al. (2010) mentioned that PCNA and non-PCNA cultivars did not produced standard results in the TP content. The TP content of fruits depend on the genetic differences, cultural practices, geographic origin, growing season, the degree of maturity at harvest (Deshmukh et al., 2011).

Flavonoids are important for healthy nutrition because of their antioxidant activities. They also can inhibit the low-density lipoprotein oxidation and impart the cardio protective effects (George and Redpath, 2008). Generally, there was a sharp decline in the TF and ST contents of fruits non-PCNA group cultivars throughout fruit development. Similar TF observations were reported in apple (Awad et al., 2001) and plum (Zhang et al., 2004). In addition, our ST results (Figure 3) agreed with those reported by Candir et al. (2009), Ikegami et al. (2009) and Novillo et al. (2016) who found that the ST content decreased from early fruit development to ripening. Taira et al. (1998) reported that soluble tannins were synthesized and had accumulated in the fruits of all persimmon cultivars by the second growth stage, but a portion of insoluble tannins in PCNA group fruits remained after the second growth stage. Also, authors suggested that soluble tannins in PCNA group fruits tend to polymerize into the insoluble form more than those in non-PCNA group fruits. Our results supplied from different persimmon cultivars are in agreement with those of Akagi et al. (2009), reporting that ST content in non-PCNA group fruits at one month before full maturation were about 4.0 times higher than those of PCNA group fruits. Soluble tannin concentration in consumption maturity decreased to the level of 0.03% (30 mg/100 ml), at which time fruits became non-astringent based on the scale suggested by Candir et al. (2009).

The assessment of the total antioxidant capacity of fruits and vegetables cannot be fulfilled correctly by single way, due to the complex nature of the phytochemicals. Many methods have been suggested to evaluate the antioxidant potential of fruits, vegetables, and other plant products. Use of at least two of these methods is necessary in order to evaluate the total antioxidant capacity of the products (Meng et al., 2011). In this study, the 2 antioxidant assays, such as FRAP and TEAC, were applied to evaluate the antioxidant capacity of the different persimmon cultivars (Table 3). The biological activity of compounds contributes to the various beneficial physiological effects associated with customer preferences of persimmon fruits. Chen et al. (2008), Ercisli et al. (2008) and Pu et al. (2013) reported that the extracts of persimmon had strong antioxidant activity.

Although many other natural compounds, including carotenoids, vitamin E, and vitamin C, may also contribute to the radical scavenging activity of vegetables and fruits, the present results suggest that the total phenolics are mainly responsible for the observed antioxidant activities (Gorinstein et al., 2001; Chen et al., 2008). In addition, authors reported that individial phenolic compounds, such as catechin, epicatechin, epigallocatechin, chlorogenic acid, caffeic

acid, and gallic acid, were found to be positively correlated with TAC. Similar to our results, a strong correlation between the TP and TAC of persimmon has been previously reported (Jung et al., 2005; Pu et al., 2013). Many authors have studied the correlation between bioactive compounds and antioxidant capacity in various fruits (Fernandez-Orozco et al., 2011; Miletić et al., 2012).

Conclusions

The changes in phytochemical properties and concentrations of polyphenol compounds within the persimmon fruits are important for their beneficial effects and quality. There are significant differences in the levels of soluble sugar, TP, TF and ST of persimmon fruits during development and ripening. The bioactive compounds determined in persimmon fruits in the present study represent important variable genotypic effects on the composition of the fruits. Plant phenolics constitute one of the major groups of compounds acting as primary antioxidants or free radical terminators. The differences reported may also very crucial for future breeding studies to select a plant that can be combined with more bioactive compounds in its fruits. The great differences among genotype compositions also show the potential of obtaining forms for the raw material for different purposes. The results for total phenolics and antioxidant activity clearly suggest that persimmon is one of the richest natural antioxidant sources among fruit species. Thus, non-PCNA cultivars, especially Hachiya and Eylül could be used as a bioactive food due to its strong antioxidant activity.

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