Tarım Bilimleri Dergisi
Tar. Bil. Der.
Dergi web sayfası:
www.agri.ankara.edu.tr/dergi

Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 377-385

Comparison of Biochemical Parameters and Volatile Compounds of Some Hybrid Tomato Varieties

Meryem KARA[a, b], Hüseyin ŞAHİN[c], Saliha DİNÇ[b,d], Oktay YILDIZ[e], Zehra CAN[f], Fatih ER[d]

[a]*Selcuk University, Cumra Vocational High School, Konya, TURKEY*

[b]*Selcuk University, Advanced Technology Research and Application Center, Konya, TURKEY*

[c]*Giresun University, Espiye Vocational High School, Giresun, TURKEY*

[d]*Selcuk University, Cumra School of Applied Sciences, Konya, TURKEY*

[e]*Karadeniz Technical University, Maçka Vocational High School, Trabzon, TURKEY*

[f]*Giresun University, Sebinkarahisar Vocational High School, Giresun, TURKEY*

ARTICLE INFO
Research Article
Corresponding Author: Meryem KARA, E-mail: meryemkaram72@gmail.com, Tel: +90 (332) 241 21 43
Received: 25 February 2015, Received in Revised Form: 31 July 2015, Accepted: 08 November 2015

ABSTRACT

Evaluating morphological and quality parameters such as shape, colour, size and yield are all common practices when assessing the quality of fruit and vegetables. In recent times, however, consumer interest in foods with high levels of bioactive components, high mineral content and acceptable flavor has increased considerably. In order to make a contribution to the production of fruit and vegetables with excellent morphological properties and high levels of bioactive compounds, two different hybrid tomato varieties (Ege F1 and Alida F1) cultivated in Turkey were compared in terms of their biochemical parameters (phenolic compounds, ascorbic acid, β-carotene, lycopene, minerals) and volatiles. While the Alida F1 was rated the highest for lycopene and mineral values, the Ege F1 was outstanding in terms of phenolic compounds and volatiles. Ascorbic acid content of both cultivars ranged from 7.13 to 11.94 mg 100 g^{-1} fw. The quantity in the Ege hybrid was remarkable. Chlorogenic acid, caffeic acid, *p*-coumaric acid, rutin and *trans* ferulic acid were the main phenolic compounds in both cultivars. Potassium (K) (4.09%) was the most predominant mineral in both hybrid tomatoes. Hexenal had the highest concentration value among tested volatiles followed by 2-hexenal, (6-methyl)-*trans*-5-Hepten-2-one. Comparison of biochemical parameters and volatiles of both varieties will give breeders an opportunity to choose the desired traits of tomatoes to cultivate for both taste and nutritional value.

Keywords: *Lycopersicon esculentum* Mill.; Phenolic compounds; Lycopene

Bazı Hibrit Domates Çeşitlerinin Biyokimyasal Parametrelerinin ve Uçucu Bileşenlerinin Karşılaştırılması

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Meryem KARA, E-posta: meryemkaram72@gmail.com, Tel: +90 (332) 241 21 43
Geliş Tarihi: 25 Şubat 2015, Düzeltmelerin Gelişi: 31 Temmuz 2015, Kabul: 08 Kasım 2015

ÖZET

Meyve ve sebzelerin kalite değerlendirmelerinde genellikle şekil, renk, irilik ve verim gibi morfolojik ve kalite parametreleri dikkate alınmaktadır. Bununla birlikte son zamanlarda tüketicilerin yüksek oranda biyoaktif bileşenlere, minerallere ve kabul edilebilir aromaya sahip gıdalara olan ilgisi artmıştır. Hem düzgün morfolojik özelliklere sahip hem de yüksek oranda biyoaktif bileşenlere sahip meyve ve sebzelerin yetiştirilmesine katkıda bulunmak amacıyla Türkiye'de yetiştirilen iki hibrit domates çeşidinin (Ege F1 ve Alida F1) biyokimyasal parametreleri (fenolik bileşenler, askorbik asit, β-karoten, likopen, mineraller) ve uçucu bileşenleri açısından karşılaştırılmıştır. Alida F1 yüksek oranda likopen ve mineral değerlerine sahipken, Ege F1 fenolik bileşenler ve uçucu bileşenleri açısından dikkate değer bulunmuştur. Her iki çeşidin askorbik asit içerikleri 7.13-11.94 mg 100 g^{-1} fw arasında değişmiş ve Ege hibritinin askorbik asit değeri kayda değer bulunmuştur. Klorojenik asit, kafeik asit, *p*-kumarik asit, rutin ve *trans* ferulik asit her iki çeşitte bulunan ana fenolik bileşenlerdir. Potasyum (K) (% 4.09), her iki hibrit domateste bulunan baskın mineraldir. Hekzenal, test edilen uçucu aroma bileşenleri arasında en yüksek konsantrasyona sahip bileşen olup bunu 2-hekenal, (6-methyl)-*trans*-5-Hepten-2-one izlemiştir. İki çeşidin de biyokimyasal parametrelerinin ve uçucu aroma bileşenlerinin karşılaştırılması, yetiştiricilere istenen özelliklere ve besinsel değere sahip domateslerin yetiştirilmesi ve çeşit seçimine fırsat verecektir.

Anahtar Kelimeler: *Lycopersicon esculentum* Mill.; Fenolik bileşenler; Likopen

1. Introduction

As the scale of the relationship between diet and health has become better understood, consumers' interest in foods that affect their health has increased (De Souza et al 2012). Among the more popular food categories, vegetables are rich in nutrients including vitamins, trace minerals, dietary fiber and bioactive compounds (Singh et al 2008; Palafox-Carlos et al 2011). Tomato is one of the most-consumed vegetables providing a significant proportion of carotenoids in diet, which are able to reduce the risk of certain types of cancer, arteriosclerosis and cataract formation in human diet. Health stimulating effects of tomatoes have been attributed to lycopene, carotenoid, phenolics, ascorbic acid and vitamin E content of tomatoes. Tomatoes are also the main source of the lycopene, which has been shown to have strong antioxidant activity and to exhibit radical scavenging activity (Frusciante et al 2007). Carotenoids such as β-carotene, particularly non-provitamin lycopene, are responsible for the colour of tomatoes (Ristovska & Mirčeska 2011). Moreover, tomatoes are potential source of phenolic compounds, which exhibit strong antioxidant activity (Frusciante et al 2007). Although proper yield and fruit quality are important parameters in the selection of tomato cultivars to improve the economic efficiency of this vegetable, evaluation of bioactive compounds in tomatoes with enhanced nutritional value is also an important point in determining breeders' choices of cultivars (Fanasca et al 2006; Radzevičius et al 2009). Therefore, identification of tomato cultivars with high nutritive value will be a useful approach to select tomato cultivars with better health-promoting properties (Frusciante et al 2007). Furthermore, consumers generally complain about poor tomato flavour which are therefore another important attribute of the tomato from the consumers's point of view (Carbonell-Barrachina et al 2006). It has therefore become important to produce fruit and vegetables with both good flavor and high level of bioactive compounds. Although there has been much researches performed on the biochemical properties of tomatoes, there are no comprehensive reports dealing with health related compounds and volatile compounds of hybrid tomatoes cultivated in Turkey. This study therefore investigated two tomato hybrid varieties cultivated in the Cumra region, the first being Ege hybrid, and the second, Alida hybrid, in terms of phenolic compounds, β-carotene, lycopene, ascorbic acid, minerals and volatiles for the cultivar choices of local farmers in Turkey. Since both types of tomato varieties, Ege F1 and Alida F1, are preferred by a majority of farmers in Konya as well as in other cities, we chose to compare these varieties. Both varieties of tomatoes have an economic importance as table tomato varieties for the Turkish tomato industry. This study was thus the first research dealing with biochemical properties of tomato, including phenolic composition, β-carotene, lycopene, ascorbic acid, macro and micro nutrients and volatile compounds. The investigation of the combination of many biochemical parameters of hybrid tomatoes could be an advantageous tool for tomato breeders as well as farmers to cultivate healthier and better quality varieties.

2. Material and Methods

2.1. Chemicals

Phenolic standards (purity> 99%) Fluka, Ehrenstorfer GmbH, Alfa Aesar Analytik GmbH. Other chemicals were supplied by Merck (Darmstadt, Germany). Sigma-Aldrich (St. Louis, MO) and Fluka Chemie GmbH (Switzerland).

2.2. Sample preparation

Two varieties of hybrid tomatoes, Ege F1 and Alida F1, were used in this research. Ege F1 and Alida F1 are indeterminate, strong and early tomato plants with deep red colour, a high degree of firmness and a high fruit setting. Both cultivars are generally used as table tomatoes. Seedlings of hybrid varieties were supplied by the Cumra Tomato Producer's Cooperative, one of the major suppliers of tomatoes in the Cumra and Konya regions. Seedlings were planted in an experimental field located at latitude of 37° 33' 52'' and a longitude of 32° 45' 47'' in May 2012. The tomato seedlings were irrigated with drip irrigation and planted in an inter-row spacing of 140 cm and in an intra-row spacing of 45 cm.

During the growth and development phases of the tomatoes fertilizers were not used. Common practices, though, such as pest control, pruning and hoeing were applied. Average daytime temperatures ranged from 20-22 ºC during the growing period, and rain was rare during the summer. Tomatoes were harvested in August 2012 at a commercial stage of ripeness (red stage), according to the criteria used by the local cooperatives. After the tomatoes had been collected, the fruits were kept in a refrigerator at 4 ºC for 3-4 days until the analysis was performed. Six fruits from each of the hybrid varieties were crushed and lyophilized (Scanvac cool safe 110-4 Pro, Labogene, Denmark) under vacuum conditions. Methanolic extraction of 2.5 g of tomatoes for phenolic compounds was performed with 60 mL of methanol at room temperature for 24 hours in a reflux condenser. Next, liquid-liquid extraction was carried out with 3x3 mL diethyl ether and ethyl acetate consecutively. After the rotary evaporation stage, the dried extracts were dissolved in 2.5 mL methanol and used for further HPLC analyses. The extraction and determination of ascorbic acid was carried out as follows. A 5 g of lyophilized sample was placed into a beaker containing 50 mL 2% metaphosphoric acid and homogenized (11000 rpm) for 3 minute. After shaking for 15 minute, the mixture was filtered and the filtrate was then diluted to 50 mL with metaphosphoric acid 2% and kept at -18 ºC until the analysis was conducted. For the extraction of carotenoid, a common method that was developed by Olives Barba et al (2006) was used. For volatile compounds determination, tomatoes samples were homogenized and 5 g of purée was later weighed into 15 mL headspace vials in triplicate. 1 g NaCl was added to each vial to prevent enzymatic activity. Finally, the vials were vortexed, closed and kept at -20 ºC until further analyses (Viljanen et al 2011).

2.3. Determination of phenolic compounds, ascorbic acid, lycopene and β-carotene by HPLC

HPLC system (Shimadzu, Japan) (Model SPD-20A/20AV) equipped with a UV-Vis detector, C18 column (150 mm × 4.6 mm id, 5 mm particle; Fortis) was used for separation of biochemical parameters. For the separation of phenolic compounds 280 nm wavelength was applied and gradient elution was used modifying the method developed by Wen et al (2005). The separation of ascorbic acid was carried out on a 4.6 mm x 250 mm ODS 4 RP-C18 column with a particle diameter of 5 μm at wavelength of 278 nm. The method which originally developed by Sawant et al (2010) was modified and used for the separation of ascorbic acid. The carotenoids lycopene and β-carotene were estimated using A C18 column (250x4.6 I.D., 5 µm particle, Perkin Elmer). The mobile phase of A (acetonitrile-H_2O 9:1) and B (ethyl acetate) was used with the gradient elution (Mu-Lin et al 2007).

2.4. Analyses of minerals

Mineral elements content of tomato samples were determined in acid-digested extracts by using ICP-AES (Varian-Vista).

2.5. Analysis of volatile compounds

Briefly, 10 µL of 81 mg L^{-1} internal standard (2-methyl-3-heptanone) in methanol was added to each vial. Vials were sealed with a silicone septum and an aluminium cap. DVB/CAR/PDMS (divinylbenzene/carboxen/polydimethylsiloxane; 50/30 µm coating thickness; Supelco, Bellefonte, PA, USA) fiber was used for extraction of volatile compounds. Volatile compounds of tomatoes were identified and quantified with a GC (Agilent 7890A)-MS (Agilent 5975 detector) in splitless mode (Cakmakci & Hayaloglu 2011; Gokbulut & Karabulut 2012; Demir et al 2014).

2.6. Statistical analyses

For each variety, six tomatoes were combined and processed for the measurement of biochemical parameters. Three independent analyses were performed for the determination of each biochemical parameter. The values were averaged and reported along with the standard deviation (SD). The test was conducted using the SPSS statistical software version. 9.0 (SPSS Inc., Chicago, IL). $P<0.05$ were considered significant. The independent-samples "t test" was used to evaluate the differences between means of the two groups.

3. Results and Discussion

3.1. Concentrations of minerals

Tomato is a vegetable rich in macro (P, Mg, Fe and K) and microelements that are important elements in the human diet (Harmanescu 2007). In addition to antioxidant compounds and fiber, mineral intake is also significantly associated with tomato consumption (Erba et al 2013). It is therefore important to determine the mineral composition of tomatoes in order to select the cultivar with the richest mineral content. Macro and micro nutrients of hybrid tomatoes are presented in Table 1. There was a significant difference in macro (Ca, Mg, K and P) and micro elements (Fe, Cu, Mn and Zn) between the hybrid tomato cultivars. Among the determined macro elements K was predominant in both cultivars. The highest values for K, Mg, P and Ca were obtained from the Alida F1. The results for K, Ca and Mg agreed with the findings of other researchers (Fanasca et al 2006; Sánchez-Rodríguez et al 2012; Erba et al 2013). The highest microelement value was obtained for Fe, followed by Zn, Mn, and Cu in both tomato cultivars. The Zn, Mn and Cu levels in Ege F1 were lower than those in Alida F1. Zn and Mn values of our tested tomatoes were lower than those reported by Sánchez-Rodríguez et al (2012). The P content of the tomatoes was also higher than that of Sánchez-Rodríguez et al (2012). Some of our mineral findings are in agreement with those of other authors, while others are not. The variation in the mineral contents of tomatoes may be due to the environmental conditions, application of fertilizers and manure or the amount and type of nutrients taken from the growth medium (Carbonell-Barrachina et al 2006).

Table 1- Macro and micro nutrients (dry weight basis) of hybrid tomato cultivars (n= 3, mean±standard deviation)*

Nutrient	*Alida F1*	*Ege F1*
Ca, %	$0.37 \pm 0.04^{a*}$	0.22 ± 0.05^{b}
Mg, %	0.42 ± 0.06^{a}	0.25 ± 0.05^{b}
K, %	4.09 ± 0.40^{a}	3.04 ± 0.30^{b}
P, %	1.53 ± 0.25^{a}	1.32 ± 0.33^{a}
Fe, mg kg^{-1}	68.35 ± 6.23^{b}	84.63 ± 8.45^{a}
Cu, mg kg^{-1}	11.20 ± 1.58^{a}	5.32 ± 1.05^{b}
Mn, mg kg^{-1}	31.86 ± 3.20^{a}	14.23 ± 1.33^{b}
Zn, mg kg^{-1}	39.75 ± 3.62^{a}	38.76 ± 3.23^{a}

*, means followed by the same letter are not statistically different at $P<0.05$

3.2. Determination of lycopene and β-carotene

The lycopene and β-carotene contents of the tomato cultivars in this study are presented in Table 2. The lycopene content of Alida hybrid was considerably higher than that of Ege F1. However, the β-carotene content of the two cultivars were similar. Our findings for the lycopene content of tomatoes are consistent with those of reported by Olives Barba et al (2006) and Leonardi et al (2000), while our β-carotene results agree with those reported by Nour et al (2013).

Table 2- Biochemical parameters of the hybrid tomatoes (n= 3, mean±standard deviation)*

Parameter	*Alida hybrid*	*Ege hybrid*
Lycopene (mg 100 g^{-1} fw)	8.23±0.01[a*]	5.33±0.04[b]
β-Carotene (mg 100 g^{-1} fw)	2.72±0.16[a]	1.94±0.20[a]
Ascorbic acid (mg 100 g^{-1} fw)	7.13±0.08[b]	11.94±0.26[a]

*, means followed by the same letter are not statistically different at P<0.05

3.3. Ascorbic acid content

As a powerful water soluble antioxidant, ascorbic acid is of great importance in the human diet in terms of nutrition and health. Ascorbic acid results for tomatoes are provided in Table 2. A significant difference in ascorbic acid content was determined between the two cultivars. The amount of ascorbic acid quantity in Ege F1 was considerably higher than in Alida F1. Nour et al (2013) reported ascorbic acid contents between 9.19-32.97 mg 100 g^{-1} fw^{-1} in ten different tomato cultivars. Frusciante et al (2007) and Radzevičius et al (2009) reported ascorbic acid contents in the ranges of 8.00-16.30 mg 100 g^{-1} fw, 7.8-15.9 mg 100 g^{-1} fw and 25.65-46.32 mg 100 g^{-1} fw, respectively. The value for Ege hybrid was in agreement with those reported by Nour et al (2013), Frusciante et al (2007), and Radzevičius et al (2009). Variation in the ascorbic acid content of tomatoes may be attributed to environmental growing conditions, light, temperature and cultivar (Radzevičius et al 2009).

3.4. Determination of phenolic compounds

The most abundant polyphenols (chlorogenic acid, caffeic acid, syringic acid, *p*-coumaric acid, rutin, *trans*-ferulic acid, myricetin, protocatechuic acid, resveratrol, quercetin, naringenin and kaempferol) in tomato varieties investigated in our research are presented in Table 3. The main phenolic compounds in both varieties were chlorogenic acid, caffeic acid, *p*-coumaric acid, rutin and *trans*-ferulic acid, with levels ranging between 10.67 and 83.67 µg 100 g^{-1} fw. The variety with the highest phenolic compounds was Ege F1, which contained chlorogenic acid, caffeic acid, *p*-coumaric acid, rutin, *trans*-ferulic acid and quercetin. In Alida hybrid, myricetin and quercetin were below quantifiable limit. Syringic acid, resveratrol, naringenin and kaempferol were not detected in either variety.

Table 3- Phenolic compounds of the hybrid tomatoes (µg 100 g^{-1} fw; n= 3, mean±standard deviation)*

Phenolic compounds	*Alida F1*	*Ege F1*
Chlorogenic acid	11.00±0.00[a]	10.67±1.53[a]
Caffeic acid	45.33±1.15[b]	58.33±0.58[a]
Syringic acid	nd	nd
p-coumaric acid	15.00±1.00[b]	37.33±1.15[a]
Rutin	44.33±0.58[a]	53.00±3.46[a]
Trans-ferulic acid	51±0.00[b]	83.67±1.15[a]
Myricetin	LOQ	LOQ
Protocateuchuic acid	nd	LOQ
Resveratrol	nd	nd
Quarcetin	LOQ	38.67±0.58
Naringenin	nd	nd
Kaempferol	nd	nd

*, means followed by the same letter are not statistically different at P<0.05; nd, not detected; LOQ, under the limit of quantification

Caffeic, *p*-coumaric and *trans*-ferulic acid levels in the tomato samples tested in our study fell within the ranges reported by Barros et al (2012). Resveratrol's antioxidant properties play an important role in the prevention of atherosclerosis and carcinogenesis and in the inhibition of platelet aggregation (Ragab et al 2006). Resveratrol was not detected in either tomato variety. However, resveratrol has been found in tomato skins at different concentrations, from undetectable levels to 18.4 μg g^{-1} dw^{-1} (Ragab et al 2006). Naringenin and kaempferol levels were undetectable in both hybrids. This result was in agreement with Martinez-Valverde et al (2002) who also reported kaempferol levels were below detectable limits in the tomato varieties they tested Rambo, Senior, Liso, Canario, Durina, Daniella, and Remate.

A significant variation in levels of phenolic compounds was determined in our tested tomatoes. Therefore, and in agreement with the literature, we found that tomato varieties possess different levels of phenolic compounds. This may be attributed to genetic features, cultivation conditions, harvesting season, environmental stresses such as the amount of daylight and temperature, as well as soil and plant growth regulators (Barros et al 2012).

3.5. Volatile compounds

Volatile compounds exhibiting high impact on tomato flavour are *cis*-3-hexenal, *cis*-3-hexenol, hexanal, 1-penten-3-one, 3-methylbutanal, *trans*-2-hexenal, 6-methyl-5-hepten-2-one, methyl salicylate, 2-isobutylthiazole, and *β*-ionone (Heredia et al 2012). Acids, aldehydes, ketones, alcohols, furans, esters, terpenes are regarded as volatile, while sugars, organic acids, free amino acids and salts are regarded as non-volatile compounds (Yilmaz 2001). The flavor compounds in tomato samples were investigated using SPME/GC-MS. The 48 volatile compounds identified in tested tomatoes are presented in Table 4.

Seven miscellaneous compounds (acids, alcohols, aldehydes, ketones, esters, terpenes and, miscellaneous compounds) were also identified. Ege hybrid was the richer variety in terms of volatile compounds, at a level of 1115.12 μg kg^{-1} fw. Among the volatiles, 2-isobutylthiazole is described as having a mellow wine-like and slightly horseradish-type flavor in tomato. When added to tomato paste and juice in the range of 25-50 μg kg^{-1}, it strongly enhances aroma and flavor (Yilmaz 2001). In our study, 2-Isobutylthiazole levels in the Ege and Alida hybrids were 54.82 μg kg^{-1} and 43.37 μg kg^{-1}, respectively. The 36 μg kg^{-1} level previously reported

Table 4- Volatile compounds of Ege and Alida hybrids (μg kg^{-1} fw; n= 3, mean±standard deviation)*

Compound	*Cultivar*	
	Alida	*Ege*
Acids		
Hexanoic acid	-	4.24±0.97
Octanoic acid	8.77±7.42	-
Total acids	8.77^{b*}	4.24^{a}
Alcohols		
1-Pentanol	8.23±0.09^{a}	6.14±0.84^{b}
1-Hexanol	50.53±10.87^{b}	84.78±5.52^{a}
3-Hexen-1-ol	27.78±6.28^{b}	60.49±8.27^{a}
1-Octen-3-ol	-	6.13±0.24
6-Methyl-5-hepten-2-ol	28.17±0.49^{a}	13.49±0.44^{b}
2 Ethyl hexanol	29.14±45.39	-
1-Octanol	4.54±0.23^{a}	3.98±0.30^{b}
2-Octen-1-ol	48.66±0.91^{a}	4.88±0.70^{b}
2,4-Decadien-1-ol	16.94±2.89	-
Total alcohols	222.76^{a}	184.14^{b}
Aldehydes		
Hexanal	34.13±13.74^{b}	285.76±18.63^{a}
2-Hexenal	-	151.87±7.05
Octanal	-	5.46±0.67
2-Heptenal	15.96±3.52^{b}	33.70±0.29^{a}
Nonanal	2.28±0.00^{b}	6.95±0.00^{a}
2-Octenal	52.42±7.43^{b}	84.02±4.19^{a}
2,4-Heptadienal, (*trans, trans*)-	-	2.91±0.71
Benzaldehyde	3.42±0.00^{b}	8.92±0.43^{a}
cis-2-Nonenal	4.70±0.07^{a}	4.89±0.48^{a}
Β-Cyclocitral	2.93±0.13^{b}	3.81±0.05^{a}
2-Decenal, (*trans*)	-	3.24±0.13
2,4-Donadienal	-	2.93±0.17
2,4-Decadienal, (*trans, trans*)-	12.86±2.89^{b}	39.03±1.02^{a}
Total aldehydes	128.70^{b}	633.48^{a}
Ketones		
(6-methyl)-*trans*-5-Hepten-2-one	84.18±13.54^{b}	108.51±0.77^{a}
Phenylethanone	2.61±0.70	-
Geranylacetone	31.36±6.42^{b}	51.42±1.73^{a}
Β-ionone	2.42±0.00^{b}	3.94±0.55^{a}
Total ketones	120.58^{a}	163.88^{b}
Esters		
Hexyl Acetate	5.48±3.67	-
cis-3-Hexenyl Acetate	3.67±1.31	-
Methyl Octanoate	20.22±15.59^{a}	3.27±0.00^{b}
Ethyl Octanoate	8.53±0.00^{a}	2.95±0.00^{b}
Methyl Salicylate	—	12.80±0.60
Total esters	37.90^{a}	19.02^{b}
Terpenes		
α- Terpinolen	4.78±0.00	-
Limonene	7.06±2.21^{a}	9.25±1.38^{a}
Β-Phellandrene	10.18±2.28	-
cis- Citral	6.53±0.00^{b}	12.59±5.81^{a}
Geranial	7.01±1.14^{b}	10.42±0.32^{a}
Guaiacol	-	3.97±1.46
Eugenol	-	3.01±0.97
Total terpenes	35.56^{b}	39.24^{a}
Miscellaneous compounds		
p-Xylene	-	4.37±0.17
2-Pentylfuran	36.28±13.58	-
Styrene	13.81±13.76^{a}	5.13±0.06^{b}
2-Isobutylthiazole	43.37±4.00^{b}	54.82±2.48^{a}
1,3-Hexadiene 3-ethyl-2-methyl-, (*cis*)	5.95±0.71^{b}	7.39±0.52^{a}
1,2-Dichlorobenzene	2.52±0.12	-
Benzothiazole	3.33±1.09	-
Total miscellanous	109.64^{a}	71.11^{b}
Total all	663.90^{b}	1115.12^{a}

*, means followed by the same letter are not statistically different at $P<0.05$

for 2-isobutylthiazole in the literature is lower than that in our study (Buttery 1993). Terpenes identified in the tested tomatoes were *α*-Terpinolen, limonene, *B*-phellandrene, *cis*-citral, geranial, guaiacol, and eugenol. *cis*-citral was the predominant terpene in tomato cultivars at 12.59 µg kg^{-1}. The levels of limonene and *B*-cyclocitral, which bestow a fruity and particularly citrus flavour, were below 10 µg kg^{-1} in both cultivars. Total terpenoid level in Ege hybrid was close to that in Alida hybrid. 6-carbon aldehydes and alcohols have been identified as the most abundant volatiles in the tomatoes. In our study, 1-hexanol was the most abundant alcohol in the samples, and Alida hybrid had the highest amount of total alcohols. 1-Octen-3-ol was determined only in the Ege hybrid. 2-ethyl hexanol and 2,4-decadien-1-ol were detected mainly in Alida. The amount of 3-hexen-1-ol, which is formed in tomatoes via the reductase conversion pathway, in both tomato hybrids was similar to that reported by Vogel et al (2010). There was a significant difference in aldehydes between the two tomato hybrids. The total aldehyde content of Ege F1 was approximately five times higher than that of Alida F1. Hexenal, which is important for its impact on a fresh tomato flavour, is one of the major aldehydes in tomatoes and derived from the linoleic acid breakdown pathway. Hexenal, found at high levels in Ege hybrid (285.76 µg kg^{-1} fw) also represented the largest component among the total aldehydes in Ege hybrid. 2-Hexenal was detected at high levels only in Ege hybrid. Furthermore, after aldehydes and alcohols, the highest volatile compounds detected in tomato cultivars were ketones. Four different ketones, 6-methyl-*trans*-5-hepten-2-one, β-ionone, phenylethanone and geranyl acetone were identified in the tested tomatoes. Ketones found in tomatoes derive from the lipoxygenase pathway (Viljanen et al 2011). Of the ketones, the level of 6-methyl-*trans*-5-hepten-2-one, originating from lycopene, was higher in Ege hybrid. 6-methyl-*trans*-5-hepten-2-one and β-ionone are known to contribute a fruity and pungent aroma (Yilmaz 2001; Guler & Sekerli 2013). Esters so-called "green leaf volatiles" are formed by esterification of alcohols with carboxylic acids, and bestow a sweet, floral and fruity aroma (Gómez & Ledbetter 1997). Hexyl acetate is a particular contributor of fruity characteristics (Gokbulut & Karabulut 2012). Esters were detected in high concentrations in Alida hybrid. Only two acids, hexanoic and octanoic acids were found in the samples. The level of acid was higher in Alida hybrid.

4. Conclusions

In conclusion, we identified a significant variation between hybrid tomatoes in terms of biochemical parameters and volatiles. Ege F1 was outstanding in terms of phenolic compounds, ascorbic acid and volatiles. However, the highest lycopene content and mineral values were recorded in Alida F1. Comparison of biochemical properties of these varieties will serve as a significant database for local breeders, farmers and consumers to select the best variety with high level of health related compounds and good flavour. The results of this research may provide better understanding of the importance of evaluating of morphological properties together with the biochemical properties of tomatoes when assessing fruit and vegetable quality. Further research and breeding programs should investigate the selection of tomato genotypes superior in all biochemical parameters as well as flavour.

Acknowledgements

The authors would like to thanks Selcuk University Advanced Technology Research and Application Center for their research infrastructure and Cumra tomato producer cooperative for their seedling supply.

References

Barros L, Dueñas M, Pinela J & Carvalho A M (2012). Characterization and quantification of phenolic compounds in four tomato (*Lycopersicon esculentum L.*) farmers' varieties in northeastern Portugal homegardens. *Plant Food for Human Nutrition* **67**: 229-234

Buttery R G (1993). Quantitative and sensory aspects of flavor of tomato and other vegetables and fruits. In:

Acree TE, Teranishi R (Eds), *Flavor Science Sensible Principles and Techniques,* Washington DC, pp. 259-286

Cakmakci S & Hayaloglu A A (2011). Evaluation of the chemical, microbiological and volatile aroma characteristics of Ispir kaymak, a traditional Turkish dairy product. *International Journal of Dairy Technology* **64**: 444-450

Carbonell-Barrachina A A, Agusti A & Ruiz J J (2006). Analysis of flavor volatile compounds by dynamic headspace in traditional and hybrid cultivars of Spanish tomatoes. *European Food Research and Technology* **222**: 536-542

Demir N, Yildiz O, Alpaslan M & Hayaloglu A A (2014). Evaluation of volatiles, phenolic compounds and antioxidant activities of rose hip (*Rosa* L.) fruits in Turkey. *LWT-Food Science and Technology* **27**: 126-133

De Souza V R, Pereira P A P, Queiroz F, Borges S V & De Deus Souza Carneiro J (2012). Determination of bioactive compounds, antioxidant activity and chemical composition of cerrado brazilian fruits. *Food Chemistry* **134**: 381-386

Erba D, Casiraghi M C, Ribas-Agusti A, Cáceres R, Marfà O & Castellari M (2013). Nutritional value of tomatoes (*Solanum lycopersicum L*) grown in greenhouse by different agronomic techniques. *Journal of Food Composition and Analysis* **31**: 245-251

Fanasca S, Colla G, Maiani G, Venneria E, Rouphael Y, Azzini E & Saccardo F (2006). Changes in antioxidant content of tomato fruits in response to cultivar and nutrient solution composition. *Journal of Agricultural and Food Chemistry* **54**: 4319-4325

Frusciante L, Carli P, Ercolano M R, Pernice R, Matteo A, Fogliano V & Pellegrini N (2007). Antioxidant nutritional quality of tomato. *Molecular Nutrition and Food Research* **51**: 609-617

Gokbulut I & Karabulut I (2012). SPME-GC-MS detection of volatile compounds in apricot varieties. *Food Chemistry* **132**: 1098-1102

Gómez E & Ledbetter C A (1997). Development of volatile compounds during fruit maturation: characterization of apricot and plum × apricot hybrids. *Journal of the Sciences of Food and Agriculture* **74**: 541-546

Guler Z & Sekerli Y E (2013). Distribution of volatile compounds in organic tomato (*Lycopersicon esculentum*) at different ripening stages. *Academic Food Journal* **11**: 6-13

Harmanescu M (2007). Metals contents of tomatoes cultivated ın different conditions. *Journal of Agroalimentary Processes and Technologies* **13**: 169-174

Heredia A, Peinado I, Rosa E, Andrés A & Escriche I (2012). Volatile profile of dehydrated cherry tomato: ınfluences of osmotic pre-treatment and microwave power. *Food Chemistry* **130**: 889-895

Leonardi C, Ambrosino P, Esposito F & Fogliano V (2000). Antioxidative activity and carotenoid and tomatine contents in different typologies of fresh consumption tomatoes. *Journal of Agricultural and Food Chemistry* **48**: 4723-4727

Martinez-Valverde I, Periago M J, Provan G & Chesson A (2002). Phenolic compounds, lycopene and Antioxidant activity in commercial varieties of tomato (*Lycopersicum esculentum*). *Journal of the Sciences of Food and Agriculture* **82**: 323-330

Mu-Lin L, Bo-Di H & Ke-Nuo P (2007). Quantitative analysis of lycopene from tomato and ıts processed products by C18-HPLC-PDA. *Food Science* **28**: 453-456

Nour V, Trandafir I & Ionica M E (2013). Antioxidant compounds, mineral content and antioxidant activity of several tomato cultivars grown in southwestern Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* **41**: 136-142

Olives Barba A I, Ca´mara Hurtado M, Sa´nchez Mata M C, Ferna´ndez Ruiz V & Sa´enz de Tejada M L (2006). Application of a UV-vis detection-HPLC method for a rapid determination of lycopene and β carotene in vegetables. *Food Chemistry* **95**: 328-336

Palafox-Carlos H, Ayala-Zavala J F & González-Aguilar G A (2011). The role of dietary fiber in the bioaccessibility and bioavailability of fruit and vegetable antioxidants. *Journal of Food Science* **76**(1): 6-15

Radzevičius A, Karklelienė R, Viškelis P, Bobinas Č, Bobinaitė R & Sakalauskienė S (2009). Tomato (*Lycopersicon esculentum* Mill.) Fruit quality and physiological parameters at different ripening stages of Lithuanian cultivars. *Agronomy Research* **7**: 712-718

Ragab A S, Van Fleet J, Jankowski B, Park J H & Bobzin S C (2006). Detection and quantitation of resveratrol in tomato fruit (*Lycopersicon esculentum* Mill.). *Journal of Agricultural and Food Chemistry* **54**: 7175-7179

Ristovska N & Mirčeska V B (2011). Quality characterization and processing of some tomato varieties. *Journal of Habitat Engineering and Design* **61**: 261-265

Sánchez-Rodríguez E, Leyva R, Constán-Aguilar C, Romero L & Ruiz J M (2012). Grafting under water stress in tomato cherry: improving the fruit yield and quality. *Annals of Appled Biology* **161**: 302-312

Sawant L, Prabhakar B & Pandita N (2010). Quantitative HPLC analysis of ascorbic acid and gallic acid in *Phyllanthus emblica*. *Journal of Analytical & Bioanalytical Techniques* Doi: 10.4172/2155-9872.1000111

Singh S, Singh J & Rai M (2008). Nutritional attributes of processed tomatoes. In Symposium on Food Technology for Better Nutrition. *Comprehensive Review in Food Science and Food Safety* **7**(4): 320-396

Viljanen K, Lille M, Heinio R L & Buchert J (2011). Effect of high-pressure processing on volatile composition and odour of cherry tomato purée. *Food Chemistry* **129**: 1759-1765

Vogel J T, Tieman D M, Sims C A, Odabasi A Z, Clark D G & Kleea H J (2010). Carotenoid content impacts flavor acceptability in tomato (*Solanum lycopersicum*). *Journal of the Sciences of Food and Agriculture* **90**: 2233-2240

Wen D, Li C, Di H, Liao Y & Liu H (2005). A universal HPLC method for the determination of phenolic acids in compound herbal medicines. *Journal of Agricultural and Food Chemistry* **53**: 6624-6629

Yilmaz E (2001). The chemistry of fresh tomato flavor. *Turkish Journal of Agriculture & Forestry* **25**: 149-155