Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.33017

The general and volatile properties and the quality of two newly selected Satsuma clones (11/1 İzmir and 30/ İzmir) grown under Mediterranean ecological conditions

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Abstract

The general and volatile properties, and the quality of two new Satsuma clones – 11/1 İzmir and 30/İzmir – selected under a Citrus Bud Wood Selection Program, were compared with Owari Satsuma samples grown under Adana ecological conditions. Gas chromatography, mass spectrometry, flame ionization detection (GC/MS/FID) analysis was used in the identification and quantification of the aromatic compounds, and a sensory profile analysis was performed to complete the general understanding using chemical analysis. The general analysis showed that the clone samples have higher yields, are more intense in skin color and more acidic; however, the total soluble solids and total sugar amount are lower than the Owari Satsuma samples. The terpenes are the major aromatic compound class. Along with other terpenes, there were significant amounts of dl-limonene followed by γ-terpinene, β-elemene, linalool and α-terpineol. The sensory analysis showed that the Owari Satsuma samples are sweeter and riper, with a better floral, spicy-citrus flavor than both clones. Both clones had a lower "Overall liking" rating than the Owari Satsuma samples.

Keywords: Satsuma; postharvest quality; aroma; sensory analyses; GC/MS/FID.

Practical Application: For the first time this study focuses on the quality of two Satsuma clones, which were declared to have better fruit quality and a higher yield than the Owari Satsuma in the National Citrus Bud Wood Selection Program. This study investigates the fruit quality characteristics of these recommended clones to understand whether cultivation of these clones is appropriate or not. According to our analytical results, the Owari Satsuma was declared to have a better fruit quality than the clones, whereas the clones are more efficient in terms of yield.

1 Introduction

The mandarin has a popular place among citrus fruits and is normally freshly consumed. It has a characteristically elegant flavor, smaller in size by comparison to an orange or grapefruit and can be easily peeled (Plotto et al., 2011). There has been a global increase in demand for easy-to-peel fresh citrus fruits. Satsuma mandarins (*Citrus unshiu Marc.*) have been grown primarily for fresh consumption due to early ripening, their ease of peeling, because they are seedless and low acidic tasting with a refreshing aroma.

Even though the citrus fruits' natural genetic center isn't Turkey, these fruits have been produced in this country for decades. To find new Satsuma varieties that have the properties to meet market demands for a high yield, the First National Citrus Bud Wood Selection Program was implemented in the Aegean and Mediterranean regions of Turkey beginning in 1979 by Özsan et al. (1986). That project searched the regions for trees with a high yield, that were free from disease and that produced a high quality crop every 4 years (Özsan et al., 1986). The main purpose of that study was to determine the variations in some selected agronomical traits of 21 Satsuma mandarins derived from selection breeding programs and to characterize them by Simple sequence repeats (SSR) and Random Amplification of Polymorphic DNA (RAPD) genetic markers. The project succeeded in determining the variations in the selected agronomical traits and genetic markers from the 21 new Satsumas identified from previous research (İncesu et al., 2011). From this research project, two new clones: namely 30/İzmir and 11/1 İzmir selected from the Aegean region – out of the selected 21 Satsuma clones – were declared to have better fruit quality and a higher yield than the Owari Satsuma samples under Adana ecological conditions (İncesu et al., 2011).

The aim of this study was to better understand the quality and the general properties of the newly selected 30/İzmir and 11/1 İzmir Satsuma clones in the light of general and volatile compound analysis. This work will help to optimize the cultivation of these new cultivars in order to achieve the best flavor and the best quality and provide valuable data for new breeding programs related to these two clones.

2 Materials and methods

2.1 Materials

The 30/İzmir clone, 11/1 İzmir clones and the Owari Satsuma (control sample) were obtained from the Çukurova University Citrus Genetic Resources orchard in Adana, Turkey. Fruits were

Received 06 Oct., 2017
Accepted 26 Feb., 2018
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harvested at the commercially ripe stage from 25-year-old trees. Analytical grade chemicals and commercial reference aromatic compounds were used in the analyses.

2.2 Methods

The samples were weighed and digital calipers were used for diameter measurements. A standard juicer was used for fruit juice extraction prior to weighing, and the result expressed as a fruit juice content percentage (FJC). A portable refractometer (Atago-Japan) was used to determine the total soluble solids content (TSS). The titratable acidity (TA) of the mandarin samples was measured by titration of 5 mL of the juice sample with 0.1 N of sodium hydroxide (NaOH) until a pH of 8.2 was reached and then expressed as a percentage equivalent of citric acid.

The skin color measurement of samples was performed on ten mandarins for each treatment. The average value of two measurements at equidistant points around the equatorial circumference of the fruits was used for each evaluation. A colorimeter (Minolta CR 300, Konica Minolta, Tokyo, Japan), after calibrating against a white tile, was used for the colorimetric evaluation and the results were expressed as the Hue angle (ho) [arctangent (b*/a*)] (McGuire, 1992). For citric acid and sugar analysis, 1 mL of mandarin juice was diluted to 10 mL with ultrapure water followed by centrifuging at 10,000 × g at 4 °C for 20 minutes. The samples were filtered through a 0.45 µm cellulose–acetate membrane and then directly injected into high-performance liquid chromatography (HPLC) equipment with an Aminex HPX-87H column and a refractive index detector (Shimadzu-Japan). The mobile phase was 0.005 N H2SO4 at a flow rate of 0.5 mL min^{-1}. The presence and amount of citric acid and sugars (fructose, glucose and sucrose) were calculated by comparing sample peak areas against standards.

For the determination of the aromatic compounds, the liquid–liquid extraction method – commonly used for plant products – was used, and the solvent dichloromethane (CH_2Cl_2) was used for extraction of hand-peeled mandarin samples. GC-MS-FID analysis was carried out using an Agilent 6890 N-5973 N GC-MS-FID. A J&W fused silica DB-wax capillary column (60 m, 0.25 ID, 0.25 film) was used during the analyses, and the NIST© and Wiley© flavor libraries were used for the identification of the aromatic compounds (Schneider et al., 1998).

Mandarins were evaluated using a sensory profile analysis (Meilgaard et al., 2007). Eleven assessors trained in sensory evaluation techniques performed the sensory analyses. Three taste descriptors: "Sweet", "Sour", "Bitter", and six palate descriptors: "Mandarin", "Fruity-non-citrus", "Floral", "Spicy", "Green-underripe" and "Overripe" with an "Overall liking" qualification were established (Table 1).

On the day of the sensory panel test, 10 mandarin fruits from each clone were peeled and segmented. The fruit segments were separated, cut in half, and then put in a bowl to guarantee that each assessor evaluated parts of various fruits. Ten mixed segmented half fruits were served in identical clear glass cups. Evaluation sessions took place in a sensory room at ambient temperature under daylight at the Department of Horticulture (University of Çukurova). Unsalted crackers and filtered water were provided to panelists to cleanse their palate between samples. For each sample, panelists evaluated each descriptor on a horizontal unstructured scale of 10 cm. The marks given for each descriptor by all panelists were summed up and an average value was used for a spider web diagram (Figure 1).

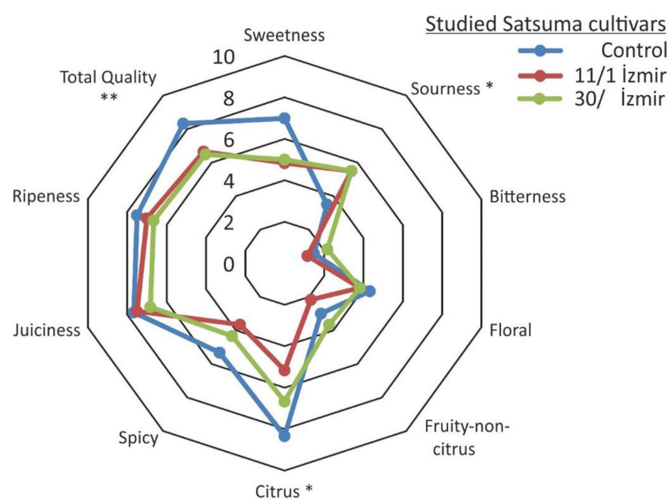

Figure 1. Sensory profile of Owari Satsuma and 11/1 İzmir-30/İzmir mandarin clones (taste and palate *Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$).

Table 1. Descriptors and reference solutions used in sensory analysis of mandarin samples. Reference solutions were provided to trained panelists at each evaluation.

Descriptor	Reference
Sweet	6.0% sucrose in water
Sour	0.2% citric acid in water
Bitter	0.1% caffeine in water
Mandarin	Mandarin oil (5.6 mL/100 mL) in a sugar/acid solution
Fruity-non-citrus	A mixture of mango, pineapple and apple juice with peach and apricot nectar
Floral flavor	Linalool (10 ppb) in a sugar/acid solution
Spicy-vegetable- pumpkin	Pumpkin homogenate
Green-underripe	Underripe green Satsuma mandarin sample
Overripe	Overripe Satsuma mandarin fruit stored at room temperature

Sugar-acid solution: 6% sucrose + 0.2% citric acid in water Reference Table is adapted from Plotto et al. (2011).

Statistical analysis

The statistical analysis used for the data was one-way analysis of variance (ANOVA). Duncan's multiple-range tests were used to compare the significant differences of the mean values with the family error rate held at 0.05. The statistical analyses were performed using SPSS© statistics software version 18.0 (SPSS Inc., Chicago, IL, USA).

3 Results

3.1 General composition of mandarins

The chemical composition of the Owari Satsuma and the clones are given in Table 2. The Owari Satsuma juice showed a higher concentration of total soluble solids than both clones, whereas the total soluble solids in the 30/İzmir clone was slightly higher than the 11/1 İzmir clone. Sugars are the main constituents of fruit juices, especially citrus juices. According to the total sugar levels, the Owari Satsuma sample had higher values than the 11/1 İzmir clone, and the 30/İzmir clone had the lowest total sugar level. Sucrose is known as the major sugar translocated in a plant, and it can be degraded by cell-wall sucrose synthase to glucose and fructose (Yu et al., 2015). The sucrose and the glucose levels were higher in the Owari Satsuma sample than the 11/1 İzmir clone, and the 30/İzmir clone had the lowest level. The fructose level of the 11/1 İzmir clone and the Owari Satsuma were very close to each other at about 20.2 g/kg, whereas the 30/İzmir clone had a fructose level of 14.86 g/kg. Both organic acids and sugars are regarded as significant quality factors by customers and the food industry. The 30/İzmir clone had the highest total acidity amount, followed by the 11/1 İzmir clone and then the Owari Satsuma sample, respectively. In particular, citric acid is the main organic acid in citrus fruit juice. Yun et al. (2010) found that citric acid made up to 90% of the total organic acid content throughout the entire postharvest period (Yu et al., 2015). According to citric acid levels, the Owari Satsuma sample is the least acidic sample followed by the 11/1 İzmir clone, whereas the 30/İzmir clone had the highest citric acid level.

The color of a fruit or fruit juice is the first quality factor that the consumer notices, and it has an important influence on consumers' preferences (Cortés et al., 2008). The skin color values of the clones were similar and/or higher than the Owari Satsuma. In Clemenules mandarin samples, Pérez-López et al. (2007) found the hue angle to be between 72.89 and 73.75, which is in agreement with the color properties of the mandarin clone samples examined in this study. The yield amount is also one of the most important properties for citrus fruits. The 30/İzmir had a slightly higher fruit juice content (FJC) than 11/1 İzmir, where both clones showed a higher FJC than the Owari Satsuma sample (Table 2). The fruit weight (g) and diameter of (mm) the Owari Satsuma sample and the clone samples are shown in Table 3. It can be said that clone samples are bigger than Owari Satsuma as fruit weight and diameter. According to the general analysis, the clone samples had higher yields, greater color intensity and more acidity, but the total soluble solids and total sugar amount was lower than the Owari Satsuma sample.

3.2 Aromatic compounds of mandarins

The volatile compounds of the mandarin juices studied, and the linear retention index values on the DB-Wax column for these compounds, are presented in Table 4. A total of 48 aromatic compounds, including terpenes, aldehydes, esters, ketone alcohols and volatile acids were identified and quantified (Table 4). In correlation with published literature, terpenes quantitatively represented the main group of volatile compounds, predominantly limonene (as much as 90%) (Arena et al., 2006; Maccarone et al., 1998; Pérez-López et al., 2007; Selli & Kelebek, 2011) followed by γ-terpinene, then at different levels, β-myrcene, α-pinene, methyl butanoate, ethyl hexanoate, α-terpinolene, linaool, β-pinene and α-terpineol (Elmaci & Altug, 2005; Pérez-López et al., 2007; Ren et al., 2015; Qiao et al., 2007) are common for all samples. The Owari Satsuma has a greater amount of total aromatic compounds (101578 μg/L) than the studied clones (11/1 İzmir: 4851 μg/L; 30/İzmir: 2901 μg/L). Ren et al. (2015) reported a total volatile compound concentration of 90700 μg/L in Owari Satsuma, which is close to the results in this study, whereas selected clones have less aromatic properties. The 11/1 İzmir clone has a higher amount of limonene (2826 μg/L dl-limonene), total terpenes and total aromatic compounds than some of the other mandarin samples in published literature (40 to 46 μg/L in Guoqing, Miyagawa wase and Owari Satsuma varieties (Qiao et al., 2007). These values are moderately lower than the Owari Satsuma sample (91433 μg/L) and the other mandarin varieties, such as organic and conventional Clemenules mandarins (31200 to 77200 μg/L) (Pérez-López et al., 2007). In the 11/1 İzmir clone, the other important compounds are γ-terpinene (264. μg/L), β-myrcene (61 μg/L), 2-methyl-4pentanal (51 μg/L), α-terpineol (44 μg/L) and linalool (28 μg/L), respectively. The 30/İzmir clone had the lowest amount of total aromatic compounds (2901 μg/L) and amount of terpenes (2310 μg/L) in all the studied mandarins. The most important aromatic compounds after dl-limonene and γ-terpinene are linalool (60 μg/L), (Z)-3-hexenal (58 μg/L) and β-myrcene (49 μg/L). Elmaci & Altug (2005) reported that they make up ~88% in the Satsuma, Bodrum, Clemantine cultivars. In this study, the dl-limonene content of the Satsuma had similar

Table 2. General composition and properties of the Owari Satsuma and Clone Samples.

	TSS (%)	TA (%)	Color (h°)	FJC (%)	Sucrose (g/kg)	Glucose (g/kg)	Fructose (g/kg)	Citric Acid (g/kg)
Owari Satsuma (TGK 1219)	11.5 a	1.0 b	71.9	0.5	41.7	27.0	20.2	8.4
11/1 İzmir	10.4 c	1.2 a	73.4	0.6	33.3	25.7	20.3	9.4
30/ İzmir	10.8 b	1.3 a	73.2	0.6	32.6	23.6	19.9	10
	*	*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

TSS = Total soluble solid; TA = Total acidity; FJC = Fruit juice content; *Significant at p≤0.05, NS: Non-significant at p>0.05 respectively showed in the table.

Table 3. Fruit weight (g) and diameter of (mm) Owari Satsuma and clone samples.

	Fruit weight (g)	Fruit diameter (mm)
Owari Satsuma (TGK 1219)	126.4	65.8
11/1 İzmir	131.1	66.5
30/ İzmir	135.3	69.0
	NS	**NS**

NS = Non-significant at p ≤ 0.05.

amounts (90%), whereas the 11/1 İzmir (2826 µg/L to 58%), and the 30/İzmir (1876 µg/L to 65%) clones had significantly smaller amounts of limonene and γ-terpinene amounts in the total amount of volatile compounds. The dl-limonene is represented by a lemon-mint odor in the Moro, Tarocco, Washington Navel and Valencia Late orange juices (representing 90 to 97% of the total odor distribution) (Arena et al., 2006). The dl-limonene has a relatively high odor-threshold value (13700 /L), together

Table 4. Volatile aroma compounds of Owari Satsuma and clones.

LRI[x]	Compounds	Satsuma	%[z]	Clon 11/1 Izmir	%[z]	Clon 30/ Izmir	%[z]	Identification [i]
		Concentration[y] (µg/L mean ± SD)						
	Terpens							
1032	α-pinene	672.0 ± 23.3a	0.66	12.1 ± 0.4b	0.25	5.5 ± 2.1b	0.19	S, MS, LRI
1116	β-pinene	207.0 ± 0.8a	0.20	17.8 ± 1.1b	0.37	14.8 ± 5.2b	0.51	S, MS, LRI
1231	sabinene	165.0 ± 8.1a	0.16	8.0 ± 0.1b	0.17	11.6 ± 3.7b	0.40	MS, LRI
1161	β-myrcene	5.1 ± 0.4a	0.00	61.2 ± 0.9b	1.26	48.6 ± 6.4c	1.68	MS, LRI
1224	dl-limonene	91432 ± 3818a	90.01	2825 ± 11b	58.25	1876 ± 218b	64.67	S, MS, LRI
1255	γ-terpinene	4192 ± 46a	4.13	263.9 ± 2.1b	5.44	115.9 ± 4.8c	3.99	S,MS, LRI
1288	α-terpinolene	239.0 ± 0.1a	0.24	17.7 ± 0.1b	0.36	13.7 ± 5.1b	0.47	MS, LRI
1466	δ-elemene	281.0 ± 2.5a	0.28	15.6 ± 0.1b	0.32	1.0 ± 0.2c	0.04	S, MS, LRI
1546	β-cububene	87.0 ± 2.0a	0.09	3.2 ± 0.1b	0.07	5.2 ± 0.2b	0.18	MS, LRI
1565	linalool	702.0 ± 8.5a	0.69	28.3 ± 0.1b	0.58	59.9 ± 8.6c	2.06	S, MS, LRI
1590	β-elemene	920.0 ± 0.0a	0.91	26.6 ± 0.5b	0.54	20.5 ± 11.6b	0.71	MS, LRI
1570	(E) caryophyllene	65.0 ± 2.4a	0.06	10.2 ± 0.4b	0.21	7.6 ± 1.1b	0.26	MS, LRI
1603	4-terpineol	115.0 ± 0.4a	0.11	18.6 ± 0.9b	0.38	26.1 ± 13.6b	0.90	MS, LRI
1890	γ-elemene	82.0 ± 1.8a	0.08	6.0 ± 0.1b	0.12	4.9 ± 1.6b	0.17	MS, LRI
1528	β-selinene	114.0 ± 2.8a	0.11	15.1 ± 2.1b	0.31	17.3 ± 3.2b	0.60	MS, LRI
1668	α-terpineol	388.0 ± 1.1a	0.38	44.3 ± 0.3b	0.91	6.2 ± 3.2c	0.21	MS, LRI
1710	germacrene d	279.0 ± 3.2a	0.27	15.1 ± 0.4b	0.31	18.8 ± 13.9b	0.65	MS, LRI
1749	α-farnesene	883.0 ± 12.6a	0.87	13.0 ± 0.2b	0.27	21.8 ± 11.9b	0.75	MS, LRI
1746	δ-cadinene	21.0 ± 0.3a	0.02	4.3 ± 1.0b	0.09	7.4 ± 2.2b	0.25	MS, LRI
1781	(E)-geraniol	25.0 ± 4.4a	0.02	3.9 ± 0.0b	0.08	14.0 ± 11.4c	0.48	S, MS, LRI
1840	p-mentha-1,8(10)-dien-9-ol	53.0 ± 4.9a	0.05	4.7 ± 1.6b	0.10	6.6 ± 1.6b	0.23	MS, LRI
1892	perilla alcohol	15.0 ± 0.3a	0.01	12.7 ± 1.9b	0.26	6.3 ± 1.8c	0.22	MS, LRI
	Total Terpens	**100948**	**99.38**	**3427**	**70.65**	**2310**	**79.61**	
	6-Carbon Volatile Compounds							
1091	hexanal	5.4 ± 0.2 b	0.01	23.9 ± 0.1a	0.49	4.8 ± 0.5b	0.17	MS, LRI
1220	(E)-2-hexenal	3.0 ± 0.1b	0.00	22.1 ± 1.1a	0.46	36.9 ± 13.7a	1.27	MS, LRI
1255	(Z)-3-hexanal	6.0 ± 0.1 c	0.01	12.2 ± 0.5b	0.25	58.5 ± 8a	2.02	MS, LRI
1313	2-hexanol	29.2 ± 0.3a	0.03	7.1 ± 0.1b	0.15	9.0 ± 0.3b	0.31	MS, LRI
1370	1-hexanol	5.2 ± 0.2b	0.01	5.3 ± 0.2b	0.11	13.3 ± 10.3a	0.46	MS, LRI
1377	(Z)-3-hexen-1-ol	8.1 ± 1.4b	0.01	13.0 ± 0.2b	0.27	22.7 ± 13.5a	0.78	MS, LRI
1481	2-ethyl-1-hexanol	9.0 ± 0.1b	0.01	11.3 ± 3.3b	0.23	24.9 ± 18.2a	0.86	MS
	Total 6-Carbon Volatile Compounds	**66.0**	**0.1**	**94.8**	**1.95**	**170.1**	**5.86**	
	Aldehydes							
1101	2-methyl-4-pentenal	6.8 ± 0.1b	0.01	51.0 ± 0.7a	1.05	8.9 ± 0.3b	0.31	MS, LRI
1294	Octanal	9.5 ± 0.1b	0.01	7.9 ± 0.6b	0.16	26.9 ± 10.8a	0.93	MS, LRI
1318	(E)-2-heptanal	7.8 ± 0.5b	0.01	5.8 ± 0.6b	0.12	28.3 ± 1.1a	0.98	MS, LRI
1334	(Z)-2-penten-1-al	5.7 ± 1.1b	0.01	-b	0.00	15.9 ± 9.1a	0.55	MS, LRI
1389	nonanal	5.3 ± 0.0b	0.01	2.8 ± 0.1b	0.06	13.3 ± 8.8a	0.46	MS, LRI

[x] = Linear retention index calculated on DB-Wax capillary column; [y] = Results are the means of three repetitions as µg/L; [z] = % values in total aroma compounds; [i] = Methods of identification; S (chemical standard); MS (identified by MS); LRI (linear retention index); S (chemical standard). a,b,c = Values within columns followed by the same letter are not significantly different at the 0.05 probability level.

Table 4. Continued...

LRI[x]	Compounds	Satsuma	%[z]	Clon 11/1 Izmir	%[z]	Clon 30/ Izmir	%[z]	Identification [i]
		Concentration[y] (μg/L mean ± SD)						
1499	decenal	6.2 ± 1.0b	0.01	4.3 ± 0.1b	0.09	17.3 ± 11.7a	0.60	MS, LRI
1616	(E)-2-decenal	7.3 ± 1.5b	0.01	4.9 ± 1.1b	0.10	33.9 ± 18.0a	1.17	MS, LRI
1768	perilla aldehyde	29.1 ± 1.5a	0.03	3.2 ± 1.3c	0.06	13.3 ± 8.2b	0.46	MS, LRI
1789	2,4-decadienal	3.1 ± 1.1b	0.00	2.1 ± 0.3b	0.04	33.6 ± 14.7a	1.16	MS, LRI
1792	(E,E)-2,4-decadienal	4.2 ± 1.1b	0.00	3.8 ± 1.1b	0.08	14.2 ± 3.1a	0.49	MS, LRI
	Total Aldehydes	**84.9**	**0.08**	**85.8**	**1.77**	**205.5**	**7.08**	
	Esters							
1850	linalyl propionate	5.1 ± 2.1b	0.01	3.3 ± 1.1b	0.07	42.5 ± 9.1a	1.46	MS
1890	geranyl butanoate	53.5 ± 1.6a	0.05	12.0 ± 2.6b	0.25	11.5 ± 0.1b	0.40	MS, LRI
1920	isopropyl myristate	36.0 ± 0.0a	0.04	1.5 ± 0.1b	0.03	- b	0.00	MS
	Total Esters	**94.6**	**0.09**	**16.8**	**0.35**	**54.0**	**1.86**	
	Ketons							
1287	acetoin	161.8 ±9.5a	0.16	7.0 ± 0.0c	0.15	31.6 ± 5.2b	1.09	MS, LRI
	Higher Alcohols							
1320	4-methyl-2-pentanol	2.1 ± 0.4c	0.00	12.3 ± 0.1b	0.25	21.9 ± 7.2a	0.75	MS
1329	(Z)-2-penten-1-ol	4.5 ± 1.1b	0.00	5.8 ± 0.1b	0.12	15.9 ± 9.1a	0.55	MS
1869	benzyl alcohol	45.9 ± 3.0a	0.05	6.2 ± 0.1b	0.13	9.3 ± 2.3b	0.32	MS, LRI
1905	phenylethyl alcohol	14.8 ± 0.0a	0.01	1.1 ± 1.2b	0.02	3.0 ± 1.3b	0.10	MS, LRI
	Total Higher Alcohols	**67.3**	**0.07**	**25.3**	**0.52**	**50**	**1.72**	
	Volatile Acids							
2692	hexadecanoic acid	155.3 ± 16.6b	0.15	1193 ± 241a	24.60	80.2 ± 24.2b	2.76	S, MS, LRI
	TOTAL	**101578**	**100**	**4851**	**100**	**2901**	**100**	

[x] = Linear retention index calculated on DB-Wax capillary column; [y] = Results are the means of three repetitions as μg/L; [z] = % values in total aroma compounds; [i] = Methods of identification; S (chemical standard); MS (identified by MS); LRI (linear retention index); S (chemical standard). a,b,c = Values within columns followed by the same letter are not significantly different at the 0.05 probability level.

with γ-terpinene (3260 μg/L) in the deodorized orange juice matrix (Plotto et al., 2004).

All samples exceeded the threshold value of dl-limonene, whereas the clones are below the γ-terpinene threshold value. The γ-terpinene has a sweet, citrusy aroma with slightly bitter herbaceous notes (Fan et al., 2009; Qiao et al., 2008). Pérez-López et al. (2007) found a level of 77200 μg/L of D-limonene and 860 μg/L of γ-terpinene in organic Clemenules mandarin samples. Ren et al. (2015) reported a level of 5740 μg/L of γ-terpinene in the Owari Satsuma close to the control sample's γ-terpinene level (4192 μg/L). Other terpene compounds were present in very low amounts when compared to dl-limonene and γ-terpinene. Among them, linalool (floral) and β-elemene (citrusy, floral, ponkan-like) were found in all samples, but their concentrations were high only in the Owari Satsuma sample (linalool 702 μg/L, β-elemene 920 μg/L).

The β-elemene concentration was reported to be 230 μg/L in the Owari Satsuma by Ren et al. (2015). C6 volatile compounds, which were products of the enzymatic breakdown of unsaturated fatty acids like Hexanal, (E)-2-hexenal, (Z)-3-hexanal and 2-hexanol, were the greatest in the 30/İzmir clone sample, followed by the 11/1 İzmir clone and were smallest in the Owari Satsuma sample. These compounds were primarily responsible for the green odor. Esters, which contribute to the strong fruity and floral odor of fruits were the highest in the Owari Satsuma sample. Aldehydes are most likely the enzymatic degradation products of unsaturated fatty acids such as oleic, linoleic and linolenic acids (Qiao et al., 2008). For orange fruit, according to Perez-Cacho & Rouseff (2008), aldehydes are formed during the ripening and maturation period, and their concentration increases with fruit maturity. The 30/İzmir clone had the highest aldehyde content (206 μg/L), whereas the Owari Satsuma and the 11/1 İzmir clone has 85 μg/L and 86 μg/L of aldehyde content, respectively. These compounds give a more mature flavor, and this will affect the fresh mandarin taste of the 30/İzmir clone. Both clones were found to be more efficient in maximizing the juice amount and sugar potential, but their flavor qualities seemed to be diluted. Aromatic compounds have a strong relationship with yield. There are references about this relationship in some other fruits which shows aroma decreasing with increasing yield (in grape, Jackson & Lombard, 1993, and in mango fruit, Léchaudel & Joas, 2007.)

3.3 Sensory evaluation

The sensory profile analysis is presented in Table 5 and the spider web diagram for the data is shown in Figure 1. The evaluation of both clones shows similar profiles. The Owari Satsuma sample had the highest sweetness and floral, citrusy, attractive spicy flavor and the highest total quality values, followed by the 30/İzmir and 11/1 İzmir clones, respectively. The sourness of both the 11/1 İzmir and 30/İzmir clones is high compared to the Owari Satsuma sample, which affected the total quality scores (Figure 1).

Table 5. Sensory profile results of Owari Satsuma and clones.

Descriptor	Satsuma	Clon 11/1 İzmir	Clon 30/ İzmir	
Sweetness	7.0 ± 1.0	4.8 ± 1.2	5.0 ± 1.6	NS
Sourness	3.5 ± 1.4 b	5.5 ± 0.8 a	5.5 ± 2 a	*
Bitterness	1.5 ± 1.3	1.2 ± 1.5	2.2 ± 1.2	NS
Floral	4.3 ± 1.2	3.8 ± 2.0	3.8 ± 2.1	NS
Fruity-non-citrus	3.0 ± 1.2	2.2 ± 1.2	3.7 ± 2.5	NS
Citrus	8.3 ± 1.4 a	5.2 ± 0.4 b	6.7 ± 1.2 c	**
Spicy	5.3 ± 1.4	3.7 ± 2.0	4.3 ± 2.0	NS
Juiciness	7.7 ± 1.4	7.5 ± 1.0	6.8 ± 1.0	NS
Ripeness	7.5 ± 0.5	7.0 ± 1.6	6.7 ± 1.0	NS
Total Quality	8.3 ± 1.0 a	6.7 ± 1.2 b	6.5 ± 0.6 b	**

*Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$; a,b,c; values within columns followed by the same letter are not significantly different at the mentioned probability level; NS = Non-significant at $p>0.05$.

4 Conclusions

This study investigated the aromatic compounds of two newly selected Satsuma clones, namely 11/1 İzmir and 30/İzmir cultivars, against the Owari Satsuma. The organic terpene compounds were the main volatile components in all samples. Both the terpene and the total aromatic compound concentrations of the Owari Satsuma sample was higher than the newly selected clones. The dl-limonene was the most abundant component in all samples followed by γ-terpinene. Thus, the Owari Satsuma sample is richer in terpenes, with its fresh piney and citrus aroma, than the clones. With regard to the chemical and instrumental analyses, the sensory analysis of the Owari Satsuma sample is sweeter and riper, with a better floral, spicy-citrus flavor than both the clones. The sourness is balanced in the Owari Satsuma sample. The 11/1 İzmir and 30/İzmir clones were both similar but with less sweetness and higher sourness values than the Owari Satsuma sample. The 30/İzmir clone has the highest bitterness values and greater citrus and spicy flavor values then the 11/1 İzmir clone. There is a clear correlation between the aromas and perceived flavor of the studied samples. The 30/İzmir clone has the lowest terpene concentration, the highest aldehyde concentration and the highest 6-Carbon volatile compound concentration that produces a lower total quality value on the palate and is less fruity and citrusy than the Owari Satsuma sample. The 11/1 İzmir clone also has a lower terpene concentration than the Owari Satsuma sample and the highest volatile acid value. The 11/1 İzmir clone has a lower total quality value and is less citrusy and aromatic than the Owari Satsuma sample. Both the 30/İzmir and 11/1 İzmir clones had lower “Overall liking” values than the Owari Satsuma sample. Based on these analytical results, it can be concluded that the clones are more efficient in the amount of juice produced, but their flavor qualities seem to be diluted.

Acknowledgements

We are grateful to three anonymous reviewers and Associated Editor for their invaluable suggestions that improved the quality of the paper. The editorial handling is greatly acknowledged.

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