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Characterization of Some Fruit Quality Traits on Apple 'Kaşel-41' × 'Williams Pride' F1 Population

Ümit Ürek[1] · Salih Kafkas[1] · Mozhgan Zarifikhosroshahi[1] · Şerif Özongun[2] · A. Nilgün Atay[2] · Servet Aras[3] · Nesibe Ebru Kafkas[1]

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Abstract
Apple (*Malus* × *domestica* Borkh) is one of the most important fruit produced and consumed in all over the world. The large number of apple cultivars reflects also a broad range of variability in the quality traits. "Fruit quality" is a dynamic concept changing on the basis of the consumer needs and perceptions that reflect sociocultural evolution. Almost all the characteristics determining apple quality can be measured or classified. The modern apple cultivation is probably the result of interspecific hybridization and cross-breeding programmes were mostly applied to improve new varieties with desirable quality. For this purpose, in this study, it was aimed to detect some pomological and fruit characteristics such as aroma compounds, sugars, organic acids and vitamin C contents in 83 F1 individuals created by crossing 'Kaşel-41' (female parent) and 'Williams Pride' (male parent) cultivars. Flavor components which have a high importance for fruit quality were detected by using HS-SPME/GC/MS (Headspace Solid Phase Micro Extraction Gas Chromatography/Mass Spectrometry) techniques. HPLC (High-Performance Liquid Chromatography) technique was applied for the sugars, organic acids, and vitamin C analyses. According to the obtained results a great differences were detected among apple individuals. Concerning their chemical composition, the main sugar constituent of fruits was fructose ranging from 1.89 to 6.67%. Malic acid was the major organic acid reaching the maximum value of 7.77% followed by succinic acid. Moreover, a total of 11 different aldehydes, 24 esters, 10 acids, 12 alcohols, 3 ketones, and 3 terpenes were identified and quantified in F1 individuals and their parents.

Keywords Apple · HPLC · HS-GC/MS · Fruit quality · Flavour

Frucht-Qualitätsmerkmale von F1-Hybriden aus einer Kreuzung der Apfelsorten 'Kaşel-41' × 'Williams Pride'

Schlüsselwörter Apfel · HPLC · HS-GC/MS · Fruchtqualität · Aroma

Introduction

Apple (*Malus* × *domestica* Borkh.) is one of the most popular temperate fruit crops worldwide grown for fresh consumption and juice processing. Apple is nutritionally important due to its source of vitamin C, minerals, dietary fibre (Wu et al. 2007). The health benefits of apples are attributed to their chemical composition that reflects fruit quality.

Fruit quality has importance for both human health and fruit market value. Sugars, organic acids, free amino acids, aroma compounds considerably affect the quality of apples (Ashoor and Kanox 1984; Dolenc and Stampar 1997). The compounds possess important roles in providing fruit traits such as flavour, bitterness, and color (Miller and Rice-Evans 1997). The concentration of these compounds depends on the apple varieties. Many studies were conducted

✉ Nesibe Ebru Kafkas
ebruyasakafkas@gmail.com

[1] Faculty of Agriculture, Department of Horticulture, University of Çukurova, Adana, Turkey

[2] Eğirdir Fruit Research Centre, Isparta, Turkey

[3] Faculty of Agriculture, Department of Horticulture, University of Yozgat Bozok University, Yozgat, Turkey

in molecular, biochemical and pomological characterizations in many fruits (Božović et al. 2017; Güney et al. 2018, 2019). Most of the work on chemical characterization subject has been carried out with many fruits such as walnut (Keles et al. 2014), pear (Yilmaz et al. 2015), apricot (Kafkas et al. 2007; Imrak et al. 2017), kumquat (Güney et al. 2015) and fig (Gozlekci et al. 2011). Moreover, there have been several studies focused on the chemical composition of apple fruit, such as organic acids, sugars, volatile compounds (Scalzo et al. 2001; Wu et al. 2007; Ma et al. 2015). Apples are a good source of organic acids and malic acid is the major organic acid in apple fruit (Zhang et al. 2010; Ma et al. 2015). Moreover, apples possess other components that may be beneficial for health including vitamin C, volatile compounds, phenolics, amino acids (Li et al. 2008; Reis et al. 2009; Zhang et al. 2010). Esters are the major chemical class of volatile compounds of apples. In addition, alcohols, aldehydes, ketones, acids and terpenoids are also play an important role of apple aroma (Paillard 1990; Scalzo et al. 2001).

Fructose and glucose are the major sugars in apple fruits contribute to flavour (Berüter 1985). Organic acids and their content affect sweetness and flavor, also (Bordonaba and Terry 2010). According to the previous reports, there is a considerable interaction among the volatile compounds, sugars and organic acids of apples (Eisele and Drake 2005; Rowan et al. 2009; Ma et al. 2015). Many papers previously reported on characterization of fruit quality characteristics on commercial apple cultivars. However, in the current stuy, we characterized chemical composition of 83 individuals of 'Kaşel-41' × 'Williams Pride' apple F1 population.

Material and Methods

Plant Material

Eighty-three apple individuals obtained from a controlled cross between local apple variety ('Kaşel-41') and 'Williams Pride' (commercial foreign variety) as plant materials were used in the current study in Eğirdir Fruit Research Institution in 2012–2013 growing season. Fruits were randomly harvested at commercially ripening stage and transferred to analysis lab immediately under cold-chain conditions for pomological and biochemical analysis. After pomological analysis, fruit juices were treated with liquid nitrogen and then stored at –80 °C until biochemical analysis. Three apples were used for each replicate and triplicate analysis were done.

Pomological Analysis

Fruits were weighted and core width, fruit length, fruit diameter were measured using a digital caliper (INSIZE, series 1108). Fruit firmness was measured after removing the skin using penetrometer (CONCRETE, I.S.P.). Total soluble solids (TSS) content was determined in the juice of each fruit with digitale hand refractometer (Krüss DR201-95). Fruit external color was measured by Hunterlab colorimeter (MiniScan EZ 4500).

Chemical Analysis

Fruit volatiles were extracted by Headspace Solid Phase Micro Extraction Technique (HS-SPME) using 1 ml of fruit juices in each replicate. The fruit juices were diluted with 1 ml saturated aqueous solution of $CaCl_2$ containing *n*-octane as an internal standard for quantitative analysis. Headspace sampling immediately was conducted on 85 µm fused silica fibres coated with polydimethylsiloxane/divinylbenzene (CAR/PDMS) (Supelco). Volatile components then were separated on a GC-MS apparatus (Perkin Elmer Clarus 600) using a 30 m × 0.250 mm Innowax column for 70 min. Helium (0.8 ml/min) was used as a carrier gas. The injector temperature was 250 °C, set for splitless injection. The oven conditions were set to 60 °C for 10 min and then the temperature was increased to 220 °C at a rate of 4 °C/min. Thermal desorption was allowed for 1.5 min. The detector temperature was 280 °C. Mass spectra were obtained with quadrupole mass spectrometer. Samples were analyzed by HS-GC/MS using identification was based on comparison of spectra by Wiley and NIST library match.

For sugar analysis, 1 ml of fruit juice samples were diluted with 3% metaphosphoric acid and filtered through a 0.22 um filter. The amount of sugar (glucose, fructose, sucrose, and total sugar) was determined by HPLC (Shimadzu, LC20A), equipped with a refraction index detector (RID). The individual suagr sepration was done by ICSep COREGEL-87H column (100 × 7.8 mm) with the injection of 20 µl. Sugars were identified and quantified using external standards. Components were identified by comparison of their retention times with those of authentic standards (Miron and Schaffer 1991).

Organic acids were analyzed by HPLC (Agilent, HP 1100 series) equipment using HPX 87 H (300 mm × 7.8 mm) column. Organic acids were identified and quantified by comparison of their retention time and peak area with standard solutions of known organic acids, using a UV detector with wavelength set 210 nm (Bozan et al. 1997).

Vitamin C content of apple juice was analyzed according to Bozan et al. (1997) using HPLC equipment (Agilent, HP 1100 series) and HPX 87 H (300 × 7.8 mm) column. An ultraviolet-visible detector (UV) was utilized with wavelength

Table 1 Some pomological and biochemical characteristics of F1 progenies and their parents

	F1 average	F1 max	F1 min	Kaşel 41	Williams Pride
Fruit weight (g)	144.75 ± 23.99	219.63 ± 49.74	81.75 ± 13.46	144.10 ± 21.9	155.14 ± 26.41
Fruit length (mm)	59.51 ± 4.54	71.75 ± 6.32	48.38 ± 5.21	59.40 ± 5.58	60.59 ± 4.55
Fruit width (mm)	69.45 ± 4.23	82.50 ± 4.78	56.38 ± 4.07	70.00 ± 4.06	74.54 ± 5.82
Core width (mm)	39.29 ± 1.64	63.00 ± 0.15	24.23 ± 2.11	36.01 ± 0.55	14.00 ± 0.57
Fruit firmness (kg/cm^2)	4.45 ± 0.59	5.87 ± 0.58	1.85 ± 0.21	4.39 ± 0.31	3.55 ± 0.17
L	48.03 ± 4.36	67.91 ± 2.09	27.91 ± 5.02	53.12 ± 1.99	35.38 ± 2.96
a	28.87 ± 4.25	70.92 ± 0.78	9.73 ± 2.51	28.14 ± 4.66	24.62 ± 1.47
b	23.79 ± 5.60	39.58 ± 9.29	4.24 ± 0.25	27.32 ± 8.69	17.02 ± 1.45
C	39.66 ± 5.06	51.55 ± 4.21	16.51 ± 9.34	42.43 ± 3.12	31.10 ± 2.01
h	39.79 ± 4.44	84.60 ± 6.16	12.38 ± 5.71	45.27 ± 3.56	56.30 ± 5.98
Sucrose (%)	0.82 ± 0.14	2.91 ± 0.12	0.22 ± 0.08	0.43 ± 0.07	1.93 ± 0.56
Glucose (%)	4.89 ± 0.39	7.44 ± 1.49	1.01 ± 0.26	5.25 ± 1.48	5.96 ± 1.56
Fructose (%)	4.37 ± 0.79	6.67 ± 0.54	1.89 ± 0.36	4.96 ± 1.15	3.63 ± 1.36
Total sugar (%)	10.08 ± 0.07	14.08 ± 1.16	6.41 ± 0.87	10.64 ± 0.89	11.52 ± 1.56
TSS (%)	13.74 ± 0.82	17.60 ± 0.83	9.33 ± 1.66	14.30 ± 0.34	12.00 ± 1.70
Malic Acid (%)	2.88 ± 0.55	7.77 ± 1.03	0.75 ± 0.02	1.59 ± 0.25	3.50 ± 0.21
Citric Acid (%)	0.07 ± 0.02	0.31 ± 0.01	0.02 ± 0.00	0.04 ± 0.02	0.06 ± 0.01
Succinic Acid (%)	0.51 ± 0.19	1.75 ± 0.08	0.03 ± 0.01	0.24 ± 0.04	0.36 ± 0.02
Total Acid (%)	3.41 ± 0.45	8.34 ± 1.05	1.57 ± 0.68	1.87 ± 0.11	3.93 ± 0.83
L-Ascorbic Acid (mg/100g)	2.83 ± 0.14	6.15 ± 0.07	0.60 ± 0.02	3.10 ± 0.17	1.90 ± 0.15

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set 242 nm. L-ascorbic acid was identified by comparing its retention time with authentic standards under analysis conditions and UV spectra.

Statistical Analysis

The experiment was arranged as a completely randomized block design with three replications. Each replication consisted of 30 fruits for some pomological and biochemical analyses. The obtained data were analyzed with the statistical program JMP. 5.0.1 (SAS institute, North Carolina-USA).

Results and Discussion

The experimental apple fruits were harvested between 13th July and 30th September, 2013. 'Williams Pride' was found to be earlier than 'Kaşel-41' and the most of the progenies were found to be similar with 'Kaşel-41' and line 306 was the earliest among apple progenies.

Pomological Analysis

Fruit length ranged from 48.38 to 71.75 mm and the maximum and minimum values were obtained from 339 and 348 lines, respectively. Moreover, the fruit lengths in 'Williams Pride' and 'Kaşel-41'were 60.59 mm and 59.40 mm, respectively. The fruit width ranged from 56.38 to 82.50 mm the maximum and minimum values were in 306 and 380 lines, respectively. Furthermore, the fruit widths in 'Williams Pride' and 'Kaşel-41' were 74.54 mm and 70.00 mm, respectively. The fruit firmness ranged from 1.85 to 5.87 kg/cm^2 and the mean values in 'Williams Pride', 'Kaşel-41' and hybrids were 3.55, 4.39 and 4.45 kg/cm^2, respectively (Table 1, Fig. 1).

Regarding with apple core width, the value was higher in 'Kaşel-41' compared with 'Williams Pride' and core width of progenies were found similar with 'Kaşel-41' (Fig. 1).

Regarding external color, L value of lines ranged from 27.91 to 67.91 and Hue value ranged from 12.38 to 84.60. L and Hue values were detected as 53.12 and 45.27 in 'Kaşel-41' and 35.38 and 56.53 in 'Williams Pride', respectively (Fig. 2).

Fruit weight can be changed genetic factors, maturity stage, irrigation and fertigation practices (Martínez-Esplá et al. 2014; Usenik et al. 2014; Imrak et al. 2017). Şahinoğlu (2011) previously reported that fruit weight varied among apple varieties between 75.07 to 140.33 g in 'Royal Beauty Gala', 'Red Gala', 'Mitch Gala', 'Shiniga Gala', 'Brookfield Gala', 'Summerred', 'Pink Lady', 'Vista Bella' and 'Jerseymac' apple varieties. Fruit length, fruit width of apple varieties were previously reported as between 32.8–54.3 mm, 35.4–60.3 mm, respectively (Özrenk et al. 2011).

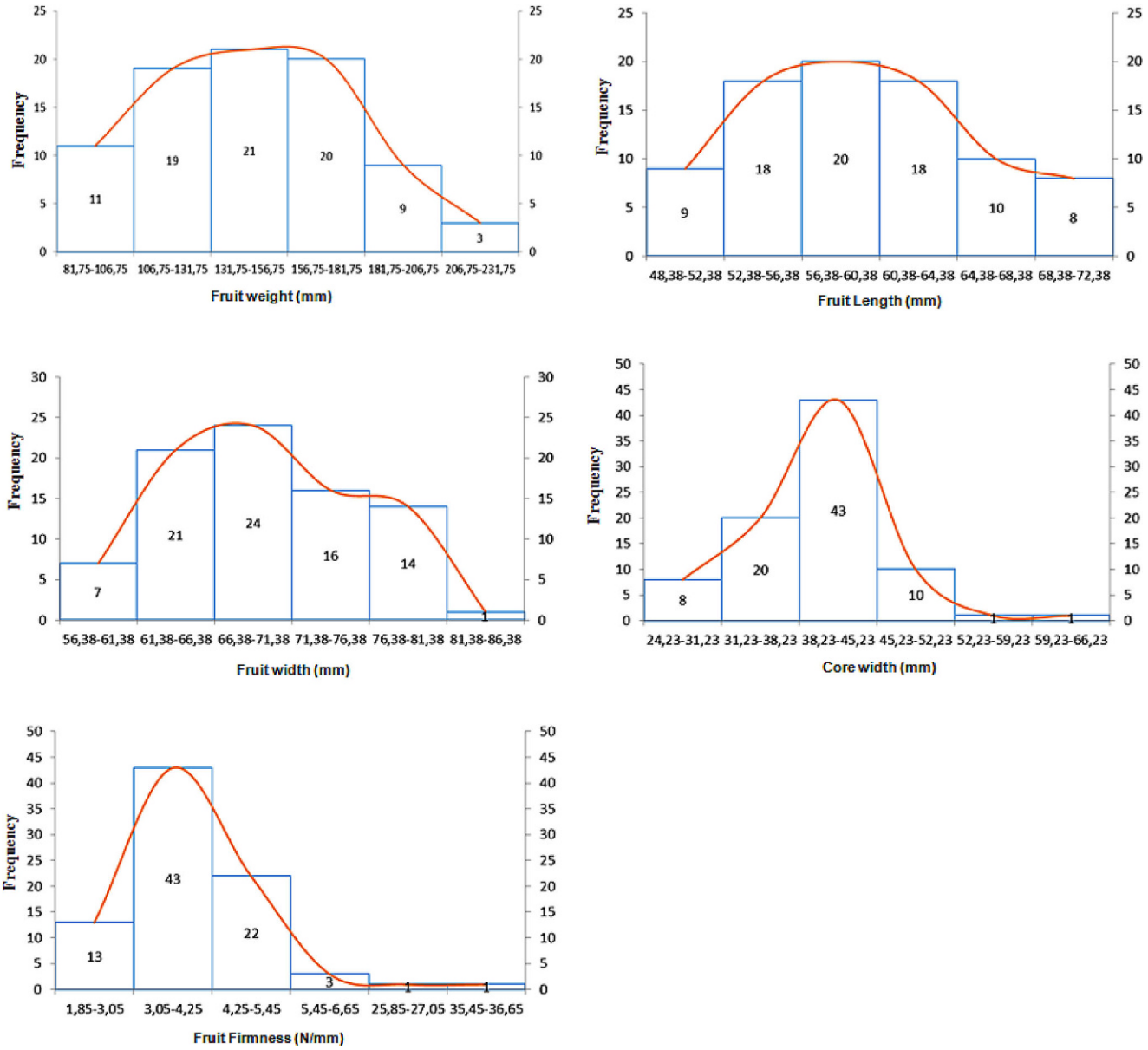


Fig. 1 Distribution of some pomological characteristics of 'Kaşel-41' × 'Williams Pride' population

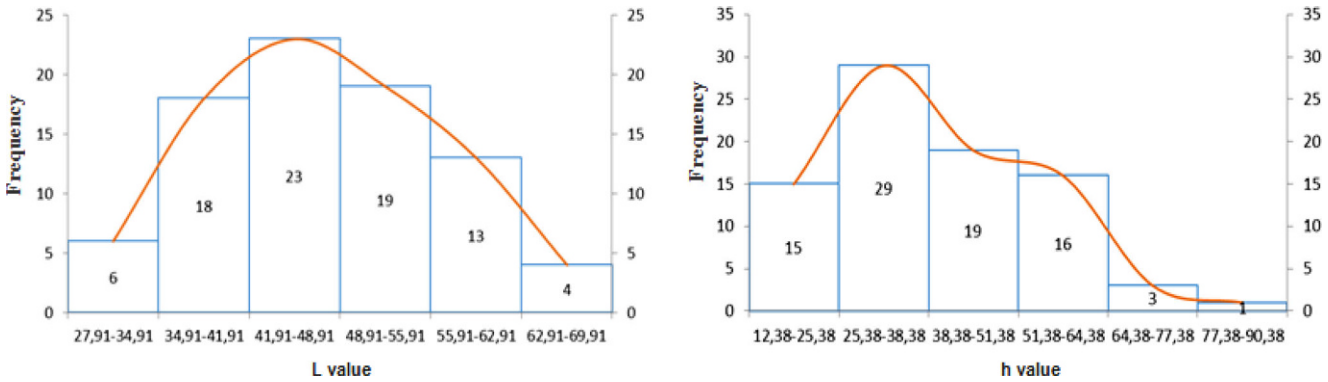


Fig. 2 Distribution of L and h values of 'Kaşel-41' × 'Williams Pride' population

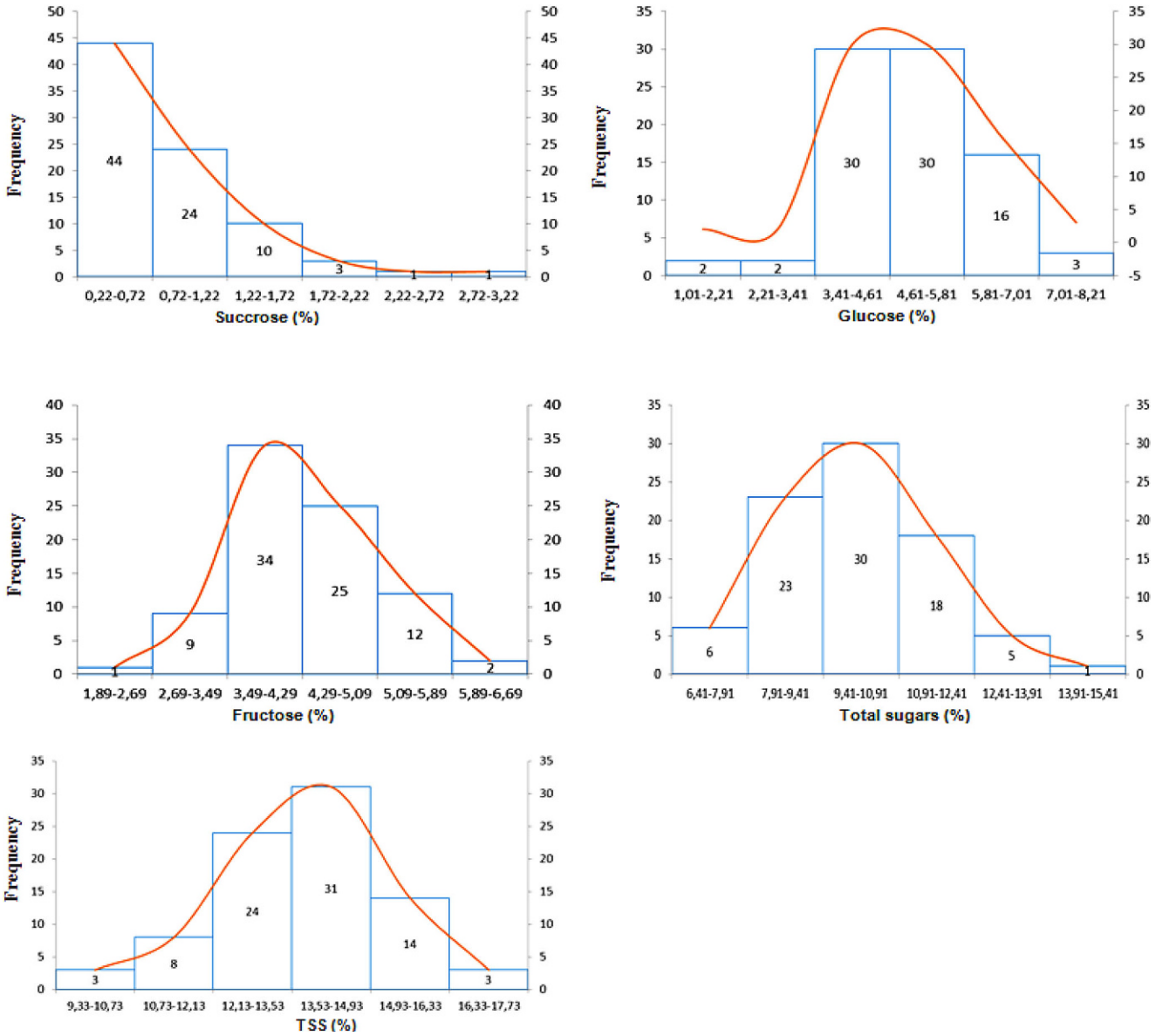


Fig. 3 Distribution of sugar contents of 'Kaşel-41' × 'Williams Pride' population

Fruit firmness has a big importance for consumers and must be higher than 4.5 kg/cm^2 for being accepted as high quality (Prange et al. 1993). The fruit firmness values of many lines such as 288, 307, 308, 320 and 322 were found higher than 4.5 kg / cm^2. For fruit external color, there was also variation among lines and varieties. Veberic et al. (2007) reported that there was a considerable variation in fruit color among 'Fuji' clones. According to our results, in general, exhibited the variation of pomological characteristics among genotypes.

Biochemical Analysis

The distribution of sugar content in F1 progenies and their parents is shown in Fig. 3. The average concentrations of fructose, glucose, sucrose and total sugar were 4.37, 4.89, 0.82 and 10.08%, respectively. The results clearly indicated that the major components of soluble sugars are different between parents and their progenies. Fructose, glucose, sucrose and total sugar ranged between 1.89–6.67, 1.01–7.44, 0.22–2.91 and 6.41–14.08%, respectively. Regarding the mean value of total sugar in all experimental fruits, fructose is the major component of apple soluble sugars, followed by glucose, which is consistent with the finding of a previous study (Wu et al. 2007). The role of sugars on fruit

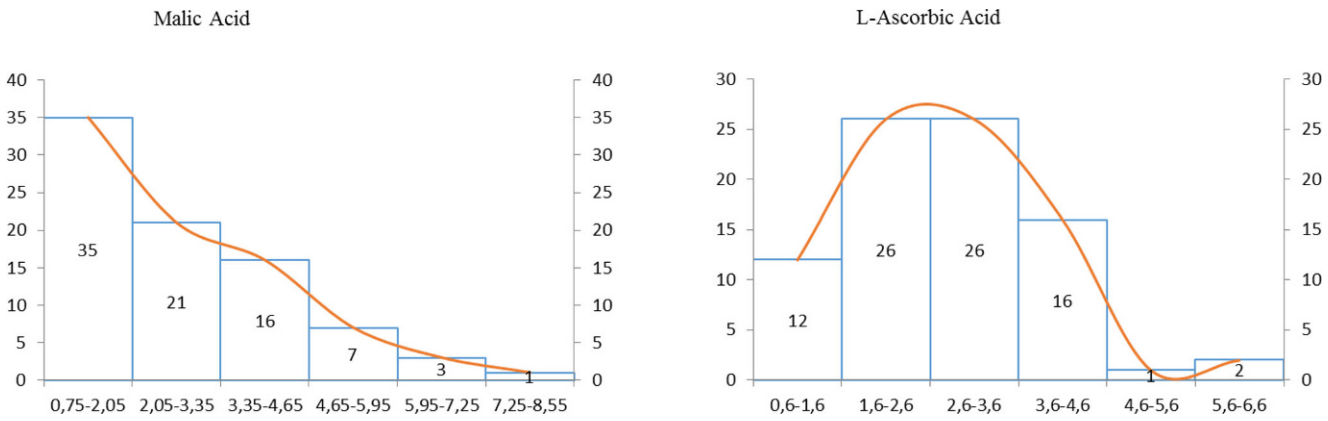


Fig. 4 Distribution of malic acid and L-ascorbic acid contents of 'Kaşel-41' × 'Williams Pride' population

aroma has been reported in previous research (Veberic et al. 2007).

The average concentrations of fructose in 'Williams Pride' and 'Kaşel-41' were 3.63% and 4.96%, respectively and the value was 4.37% in F1 progenies. The average glucose concentrations in 'Williams Pride' and 'Kaşel-41' were 5.96% and 5.25%, respectively and the value was 4.89% in hybrid samples. Furthermore, the mean concentrations of sucrose in 'Williams Pride' and 'Kaşel-41' were 1.93% and 0.43%, respectively and the average sucrose concentration was 0.82% in F1 progenies. The average concentrations of total sugar in 'Williams Pride' and 'Kaşel-41' were 11.52% and 10.64%, respectively and the average value was 10.08% in F1 progenies. Moreover, TSS content ranged from 9.33 to 17.60%. Ticha et al. (2015) reported that fructose, glucoese, succrose and total sugar content in different cultivars ranged between 4.8–8.1; 0.9–3.0; 2.1–7.2 and 10.1–16.1 g/100 g of apple, respectively (Ticha et al. 2015).

The composition of sugars affects the sweetness of fruits and it is reported that fructose is sweeter than sucrose (Setser 1993). Therefore, the hybrid samples, which showed high values of both sugars, may appear sweetness. Our results indicated that fructose and glucose are the major components of apple soluble sugars and similar proportions of individual sugars were reported in experiment by Vermeir et al. (2007). The author reported that fructose content in apple fruit was found 6.78% as predominant sugar followed by glucose (2.70%), sucrose (0.88%) and sorbitol (0.27%). In a study of 175 non-commercial apple cultivars, fructose level was found to be ranging from 3.84 to 8.01 g/100 ml (Eisele and Drake 2005). The results of our study exhibited that the major components of sugars are different among the F1 population and their parents. In the studied genotypes, the fructose level was greatest in hybrid E-327.

Malic acid content had a significant variability ranging from 0.75 to 7.77% and the predominant organic acid in the experimental apples among the detected organic acids. The average concentrations of malic acid in 'Williams Pride' and 'Kaşel-41' were 3.50% and 1.59%, respectively and the value was 2.88% in F1 progenies. This was followed by succinic acid. Succinic acid concentration ranged from 0.05 to 1.75%. The average concentrations of succinic acid in 'Williams Pride' and 'Kaşel-41' were 0.36% and 0.24%, respectively and the value was 0.55% in F1 progenies. Citric acid concentration ranged from 0.02 to 0.30%. The mean concentrations of citric acid in 'Williams Pride' and 'Kaşel-41' were 0.06% and 0.04%, respectively and the value was 0.05% in F1 progenies. Total acid concentration ranged from 1.57 to 8.34%. The average concentrations of total acid in 'Williams Pride' and 'Kaşel-41' were 3.93% and 1.87%, respectively and the value was 2.87% in F1 progenies. L-ascorbic acid content in 100 g fruit ranged from 0.60 to 6.15 mg. The average concentrations of L-ascorbic acid in 'Williams Pride' and 'Kaşel-41' were 1.90 mg/100 g and 3.10 mg/100 g, respectively, while the value in F1 progenies was 2.83 mg/100 g (Fig. 4).

Organic acids possess importance in fruit flavour together with sugars and aroma (Campeanu et al. 2009). Malic acid is the most abundant organic acid in apple fruit (Hecke et al. 2006). These results are similar to Sturm et al. (2003) who studied malic acid in fruits of 'Gala' clones. Regarding with total acid, F1 population was more acidic than 'Kaşel-41'. The differences in organic acid concentrations among apple lines can be a result of an indirect effect of total sugar concentration. These results are according to Zhang et al. (2010) who studied organic acids in apple fruits. When the F1 progenies and their parents were evaluated according to their total acid contents; the highest value was obtained from line E-326. Similar results were obtained by Eberhardt et al. (2000). The author characterized the contents of acids and the level ranged from 0.10 to 6.00 g/100 g fruit. The results of our study reflect that there is a variation among F1 progenies based on their individual organic acids. Besides that, significant quantitative differences have been observed in vitamin C content. The range values for

Table 2 Volatile profiles of F1 progenies and their parents

	Compounds	F1 average	F1 max	F1 min	Kaşel 41	Williams Pride
Esters	Propanoic acid ethyl ester	103.03	1898.68	0	41.33	8.62
	Acetic acid methyl ester	3.74	145.94	0	16.44	0
	Ketogluconic metyl ester	2.23	48.8	0	17	0
	Ethyl acetate	130.01	1555.25	0	51.79	0
	Acetic acid 2 methylpropyl ester	7.39	268.95	0	7.35	0
	N-propyl acetate	47.02	2790.13	0	14.59	0
	Butanoic acid methyl ester	15.07	303.38	0	0	0
	Acetic acid butyl ester	217.09	6699.34	0	180.45	0
	Butanoic acid ethyl ester	137.56	2155.34	0	107.67	0
	Butanoic acid 2-methyl ethyl ester	62.36	927.94	0	10.88	11.21
	Butanoic acid propyl ester	39.7	1932.5	0	0	14.23
	Butanoic acid pentylester	105.59	6090.79	0	4.63	2.5
	Acetic acid hexyl ester	138.85	4379.93	0	56.81	3.23
	Acetic acid pentyl ester	8.5	339.47	0	1.43	0
	Butanoic acid butyl ester	116.61	5961.84	0	2.81	12.06
	Butanoic acid, 3 methylbutyl ester	2.7	27.25	0	0.49	0
	Hexanoic acid, propyl ester	39.85	3093.09	0	0.38	0
	Acetic acid 2-ethylhexyl ester	8.79	202.5	0	1.84	0.41
	Butanoic acid hexyl ester	118.04	2455.59	0	41.47	3.83
	Hexanoic acid octy ester	0.69	37.26	0	0	54.49
	Hexanoic acid hexyl ester	0.97	21.89	0	1.12	0
	Carbonic acid butyl ester	0.41	7.95	0	0.35	0.29
	2-methyl-1-butanol-acetate	162.93	2173.68	0	275.34	0
	2 hexen-1 ol acetate	1.89	85.2	0	1.15	0
	Total esters	1471.01	34776.64	6.31	835.32	110.88
Acids	Sinapic acid	12.77	112.5	0	0.94	0
	Lactic acid (L)	23.26	1254.93	0	17.19	0
	Acetic acid	23.48	204	0	10.05	5.09
	Butanoic acid	7.17	313.75	0	0.59	0.24
	Hexanoic acid	10.04	390	0	4.47	0.73
	Octanoic acid	6.94	165	0	3.49	0.47
	Benzoic acid	7.95	292.5	0	3.1	1.08
	2-etyhlhexanoic acid	14.24	578.75	0	4.75	1.05
	Nonanoic acid	21.44	900	0	9.43	2.61
	2 methyl butanoic acid	3.11	42.89	0	5.97	0
	Total acids	130.41	2912.25	2.11	59.98	11.27
Alcohols	1-propanol	27.47	1534.5	0	0	0
	2- methyl, 1-propanol	7.61	154.66	0	4.61	0
	1-butanol	321.98	3971.53	0	149.17	59.72
	2-methyl-1-butanol	145.74	1306.89	0	182.39	31.04
	1-hexanol	264.69	2351.19	0	47.99	103.87
	3-hepten-1 ol	0.33	13.24	0	0	0
	2,4,e,hexandienal-1-ol	0.25	17.73	0	0	0
	3-ethyl-3-hexanol	0.09	5.24	0	0	0
	2-ethyl-1-hexanol	2.43	28.31	0	5.06	1.71
	1-octanol	1.37	42.84	0	6.44	0
	Phenol	17.17	897.5	0	6.33	0
	4 methyl-1-pentanol	27.35	562.73	0	38.94	0
	Total alcohols	816.48	6449.2	0.18	440.92	196.32

Table 2 (Continued)

	Compounds	F1 average	F1 max	F1 min	Kaşel 41	Williams Pride
Ketons	Heptan-2-one	41.83	1935	0	17.47	4.79
	2(3H)furanone	14.92	762.5	0	12.33	0.76
	1-octen-3 one	0.1	5.06	0	0	0.29
	Total ketons	1677.82	73993.81	1.45	470.72	202.17
Aldehydes	Butanal	7.93	300	0	0	0
	Acetaldehyde	9.12	268.09	0	7.14	4.75
	Hexanal	533.2	6102.96	11.05	341.4	94.51
	3-hexenal	15.59	355	0	35.44	21.74
	Heptanal	4.57	263.62	0	0.23	0
	2-hexenal	563.86	4442.17	0	672.46	52.54
	Octanal	4.53	169.11	0	0	0
	2,4 hexadienal	14.2	887.5	0	11.65	4.07
	Furfural	6.76	312.5	0	2.04	0
	Benzaldehyde	2.94	135	0	0.73	0
	2-5- furancarboxaldehyde	14.28	742.5	0	2.46	1.19
	Total aldehydes	1176.98	8358.51	47.39	1073.57	178.8
Terpens	Limonene	4.85	59.59	0	11.74	0
	Estragole	0.66	23.05	0	0	0
	Farnesene	0.37	8.38	0	0	0
	Terpenler	5.89	59.59	0	11.74	0
	Total terpens	6.92	91.02	0	11.74	0

vitamin C agree closely to that found in an apple juice concentrate characterization study by Eberhardt et al. (2000).

The aroma profiles of apple F1 progenies and their parents were evaluated. Sixty-three aroma compounds were determined including 11 aldehydes, 24 esters, 10 acids, 12 alcohols, 3 ketones, and 3 terpenes. Among the detected aldehyde compounds butanal, acetaldehyde, hexanal, 3-hexenal, 2-hexenal, heptanal, octanal, 2,4 hexadienal, furfural, benzaldehyde, 2-5-furancarboxaldehyde were determined. The main aldehyde was 2-hexanal (average 563.86 µg/L) and followed by hexanal. The predominant ester compound was acetic acid butyl ester and this compound detected in 'Kaşel-41' (180.45 µg/L) while not determined in 'Williams Pride' variety (Table 2).

Ten different acids (sinapic acid, lactic acid, acetic acid, butanoic acid, hexanoic acid, octanoic acid, benzoic acid, 2-ethyl hexanoic acid, nonanoic acid, 2 methyl ve butanoic acid) were determined in both parents and F1 progenies. The major acids in F1 progenies were acetic acid and lactic acid. Moreover, the major alcohol compound was detected as 1-butanol. Heptane-2-one was the most abundant compound in ketone group with average of 41.83 µg/L and the main terpene compound was limonene with average of 4.85 µg/L.

Over 350 volatile compounds have been determined in apple fruit (Maarse 1991). In the current study, the major volatile compounds were esters and alcohols, which is consistent with the finding of a previous study (Scalzo et al. 2001). Paillard (1990) also reported that the main volatile compounds in apple are esters (78–92%) and alcohols (6–16%). Many studies have been conducted on the sensory contributions of individual volatile compounds to the aroma of apples (Dunemann et al. 2009; Kafkas et al. 2009). Reis et al. (2009) identified seventy four esters, 9 terpenoids, 7 alcohols, 5 acids, 5 aromatic hydrocarbons, 4 phenols, 3 aldehydes, and 1 ketone, in a total of 108 compounds, in an apple variety.

2-methyl butyl acetate and/or hexyl acetate compounds contribute flavour in red apple varieties such as Royal Gala (Young et al. 1996; Dixon and Hewett 2000). Moreover, some ester compounds such as norisoprenoid; β-damascenone, hexanal, Z-3-hexanal, hexyl acetate, methyl-2-methyl butanoate, ethyl-2-methyl butanoate, 2-methyl butyl acetate and terpenes such as linalool were charactered as impact odorant in apples (Fuhrmann and Grosch 2002). Furthermore, Young et al. (1996) determined butyl acetate, hexyl acetate, 2-methyl butyl acetate, butanol, 2-methyl butanol and hexanol compounds in Royal Gala apple variety. In an other study it was reported that some ester compounds belonging to the sulphur compounds family, ethyl 3-(methylthio)-propionate, are known to have a low odour (Reis et al. 2009).

Conclusion

Our study represents the report of pomological analysis and a large-scale HPLC and HS/GC-MS assessment of chemical compounds in apples of the F1 population and their parents. In a conclusion, apple fruits are a good resource of fructose, malic acid, vitamin C and aroma compounds. Besides that, a total of 11 different aldehydes, 24 esters, 10 acids, 12 alcohols, 3 ketones and 3 terpenes were identified and quantified. The predominant terpene compound was limonene and Heptane-2-one was the most abundant compound in ketone group. The results indicate that some apple hybrids may be useful sources of genetic variation for further breeding programmes.

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Conflict of interest U. Urek, S. Kafkas, M. Zarifikhosroshahi, Ş. Ozongun, A. N. Atay, S. Aras and N. E. Kafkas declare that they have no competing interests.

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