Pistachio Kernel Composition of ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ in California

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Abstract. Moisture and fat content, fatty acid profile, and volatile terpenes were measured for the first time for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ pistachios grown at two California microclimates: Lost Hills and Parlier. ‘Kaleghouchi’ had the highest moisture content, followed by ‘Pete 1’ and ‘Lost Hills’, respectively. While the moisture content of ‘Kaleghouchi’ was not significantly affected by location, it was lower for ‘Pete 1’ grown at Parlier (40.8 vs. 40.8 g/100 g) and higher for ‘Lost Hills’ grown there (48.2 vs. 45.2 g/100 g). ‘Pete 1’ grown at the Parlier site had a higher fat content compared with ‘Lost Hills’ (47.7 vs. 43.0 g/100 g). ‘Kaleghouchi’ had a lower fat content at Parlier compared with Lost Hills (42.0 vs. 44.9 g/100 g), and ‘Lost Hills’ was unaffected by location. The main fatty acid measured in the pistachio samples was oleic acid (52% to 58%), followed by linoleic (26% to 33%) and palmitic acids (11% to 13%). While oleic acid content of ‘Lost Hills’ and ‘Kaleghouchi’ was higher for pistachios grown in Parlier, no impact of location was observed for ‘Pete 1’. The fatty acid profiles of all three cultivars appeared to be more dependent on genotype and less affected by microclimate. α -pinene (95–1682 ng/kg), limonene (37–741 ng/kg), and α -terpinolene (1–368 ng/kg) were the most abundant volatiles among all the cultivars and locations. Microclimate was the primary factor in determining volatile terpenes concentration in pistachio kernels.

Pistachios are highly appreciated for their nutritional properties. In particular, pistachios’ lipids composition has been linked to their positive effects on human health (Dreher, 2012; Kris-Etherton et al., 2008; Lin and Yen, 2010; McGuire, 2011; Sabaté and Ang, 2009). Pistachio nuts are rich in oleic acid, a monounsaturated fatty acid (MUFA) reported as a preventive against coronary heart disease (Renaud et al., 1995). Additionally, pistachios are cherished for a unique flavor and aroma. Volatile terpenes are the key components for their aroma, being the major compounds in raw kernels limonene, α -pinene and β -myrcene (Kendirci

and Onoğur, 2011; Rodríguez-Bencomo et al., 2015).

In California, pistachios are the third most economically important nut crop after almonds and walnuts. Though a relatively young industry, economic production started in 1974; acreage is expanding rapidly because of profitability, California’s suitable microclimates, and market demand (Blank, 2016). While the overall production is dominated by ‘Kerman’ and ‘Golden Hills’, other minor cultivars are also planted in the region, such as ‘Kaleghouchi’, ‘Pete 1’ and ‘Lost Hills’. ‘Kaleghouchi’ is a major Iranian pistachio cultivar. When grown in California microclimates, it is characterized by large nuts, good yields, large nut size, and a high split percentage, relative to California’s major cultivar, Kerman (Parfitt et al., 2005). ‘Pete 1’ is a new commercial cultivar. Its patent describes it as having a white shell, high split percentage, and large nut size (US PP17836 P3). ‘Lost Hills’ is a relatively new female cultivar released by the California Agricultural Experiment Station in 2005. It has good yields, a large nut size, and an earlier and more compact harvest period that decreases

the potential for little navel orange worm infestation (Parfitt et al., 2008).

Although much of the demand is driven by its health benefits and flavor, little is known about how fatty acid and volatiles terpenes of pistachio cultivars are affected by the geographical location of the orchards (Arena et al., 2007; Satil et al., 2003). Our group recently made the first report of how microclimate and harvest time influenced the fatty acid and volatile terpenes for ‘Kerman’ and ‘Golden Hills’ (Polari et al., 2019). In addition, a recent report shows the potential of using fatty acids to differentiate among the five main Iranian cultivars (Esteki et al., 2019). Given that pedoclimatic conditions affect fruit growth and metabolism, it follows that specific geographical locations could be expected to produce different fatty acid and volatile terpenes profiles, even within a cultivar.

In this study, we investigated for first time the oil composition and volatile terpenes for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ pistachios cultivated at two locations in California’s Central Valley with the following aims: first, to characterize the composition of these three California minor cultivars; and second, to understand the extent of the impact of microclimate over the concentration and profile of these compounds.

Materials and Methods

Solvents and reagents. Toluene, methanol, hydrochloric acid, hexane, and sodium sulfate were obtained from Fisher Scientific (Pittsburgh, PA); deionized water was obtained from a Milli-Q water purification system by Millipore Corp. (Saint-Quentin, France); fatty acid methyl ester standard mix was obtained from Supelco (Bellefonte, PA); and dodecane from Sigma-Aldrich (St. Louis, MO).

Sampling plan. Pistachio rachis of ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ were collected during early Sept. 2016 at two Central Valley sites, Lost Hills (Kern County, lat. 35°35’28” N, long. 119°33’25” W, elevation 54.8 m) and Parlier (Fresno County, lat. 36°36’3” N, long. 119°30’36” W, elevation 105.0 m). Climate data for both locations is shown in Table 1. For each cultivar, 24 rachises were collected from six marked trees at each location. Randomly, three portions of 30 kernels were assayed in triplicates for moisture and oil content, fatty acid profile, and volatile compounds. The soil type in both locations was sandy loam. In Lost Hills and Parlier, the irrigation, weed control, pruning, and nutrient schedules were standard commercial orchard management practices.

Moisture content. Pistachio kernels (10.0 ± 0.1 g) were weighed in a 250-mL beaker and placed in an oven at 105 °C until constant weight (≈ 12 h). The beaker was transferred to a desiccator and weighed after 2 h for moisture content, and all other determinations described below were done in triplicate.

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Table 1. Climate data at Parlier and Lost Hills locations in California during 2016.

	Lost Hills	Parlier
Rainfall (mm)	190	250
Average minimum temperature (°C)	10.2	10.2
Average maximum temperature (°C)	27.6	25.7
Average minimum relative humidity (%)	32.9	36.2
Average maximum relative humidity (%)	86.5	88.2

Fig. 1. Moisture content for 'Kaleghouchi', 'Pete 1', and 'Lost Hills' pistachio kernels grown at Lost Hills and Parlier, CA.

Fig. 2. Fat content on dry basis for 'Kaleghouchi', 'Pete 1', and 'Lost Hills' pistachio kernels grown at Lost Hills and Parlier, CA.

Fat content. Dried pistachio kernels (5.0 ± 0.1 g) were ground in a coffee grinder (JavaPress Coffee Company, WY), weighed into a cellulose extraction thimble, placed in the Soxhlet extractor, and extracted using *n*-hexane for 6 h. The solvent was distilled in a rotary evaporator, and the residual solvent eliminated in an oven at 105 °C for 3 h. Fat content was expressed as grams of fat per 100 grams of dry sample.

Fatty acid profile. Sample (0.010 ± 0.001 g) was weighed in a 12-mL amber vial and dissolved in toluene (0.4 mL). Methanol (3 mL) and methanol/HCl (0.6 mL, 80:20, v/v) were added. The vial was closed and put in a heating block at 80 °C for 1 h. Hexane (1.5 mL) and deionized water (1 mL) were added, and the resulting solution was mixed in a vortex. The upper hexane layer containing the methyl esters was decanted into a 1.5-mL

Eppendorf tube with the aid of a glass transfer pipet. Anhydrous sodium sulfate (0.5 g) was added to dry out the water residue. The clear solution was then transferred into gas chromatography (GC) autosampler vials for GC injection.

GC analysis was conducted on a Varian 450-GC (Agilent Technologies, Santa Clara, CA) equipped with a flame ionization detector (FID). Helium was the carrier gas at a flow rate of 1.5 mL/min. Fatty acid methyl esters (1 µL) were injected onto a DB-23 capillary column (60 m × 0.25 mm × 0.25 µm (Agilent Technologies), with an injector temperature of 270 °C at a split ratio of 1:100, and FID temperature at 280 °C. The GC oven temperature was initially held at 100 °C for 8 min, ramped at 6.5 °C/min to 160 °C, ramped at 2.7 °C/min to 215 °C, and held for 12 min, ramped at 15 °C/min to 230 °C, and held for 10 min. A mix of FAME standard was used as references for peak identification by retention times; relative fatty acid proportions were determined by peak area normalization.

Volatile terpenes. Fresh pistachio kernels were ground to a paste in a mortar, and a sample (1.5 ± 0.1 g) was weighed in a 20-mL glass vial (Agilent Technologies) and spiked with dodecane (2.5 mg/kg nutmeat). Deionized water (3 mL) was added, and the vial was sealed with a PTFE/silicon septum (Supelco, Bellefonte, PA). After 15 min at 50 °C, a solid-phase microextraction (SPME) fiber (DVB/CAR/PDMS, Sigma-Aldrich, St. Louis, MO) was exposed to the sample headspace for 45 min for volatile extraction.

The volatile compounds analysis was performed with a Varian 450-GC equipped with a Varian 220-MS ion trap (Agilent Technologies). A DB-5MS capillary column (30 m × 0.25 mm × 0.25 µm, Agilent Technologies) was used for compound separations. After sampling, the fiber was thermally desorbed in the GC injector for 5 min at 260 °C. Helium was the carrier gas at a flow rate of 1 mL/min. Oven temperature started at 40 °C during the 5-min desorption process and was ramped at 3.5 °C/min to 120 °C, then ramped at 10 °C/min to 220 °C and held for 10 min. Ionization energy of 70 eV was adopted, and the ions were analyzed in the *m/z* range from 40 to 400. The data were recorded and analyzed using MS Workstation v. 6.9.3 (Agilent Technologies) software. Volatile compounds were identified by their mass spectra and Kovats retention index (KI). Results were expressed as nanograms of dodecane per kilogram of sample.

Statistical analysis. The influence of location and cultivar and their interactions on moisture and fat content, fatty acid profile,

and volatile compounds of pistachio kernels was analyzed by analysis of variance (ANOVA). Fisher's least significant difference test was applied to establish differences between means. Significance level was set as 0.05. Data normality and homoscedasticity assumptions were tested using the Shapiro–Wilk and Breusch–Pagan tests, respectively. Minitab v. 19.2 was used for data processing and statistical analysis.

Results and Discussion

Moisture content. To reduce rancidity and to ensure high quality nuts, pistachio must be harvested fast and then dried within 24 h. During the drying process, kernel moisture is reduced up to 4% to 6% on dry weight basis (Kashani Nejad et al., 2003); hence, initial moisture content of the pistachio kernel is a relevant parameter that determines the appropriate drying conditions required to produce a high-quality product. Results for moisture content are detailed in Fig. 1. ANOVA indicates that cultivar and the interaction between cultivar and location are significant ($P = 0.000$). At both locations, 'Lost Hills' had the lowest level of moisture (40.8 g/100 g at Lost Hills, 42.8 g/100 g at Parlier) while 'Kaleghouchi' had the highest (50.8 g/100 g at Lost Hills, 49.8 g/100 g at Parlier). 'Pete 1' presented values for moisture content in-between the other cultivars, with 48.2 g/100 g at Lost Hills and 45.3 g/100 g at Parlier. While moisture content of 'Kaleghouchi' remained unaffected by location, 'Pete 1' had lower moisture content at Parlier compared with Lost Hills; whereas the trend was opposite for 'Lost Hills', presenting lower moisture content at Lost Hills. Given that rainfall was higher at Parlier, precipitation does not explain variations in moisture content between locations, underlying the relevance of genotype for the water content of pistachio nuts.

Fat content. The high monounsaturated fat content is a major nutritional parameter of pistachio kernels (Dreher, 2012). Values for fat content on dry basis are shown in Fig. 2. Values ranged from 42.0 g/100 g for 'Kaleghouchi' located at Parlier, to 47.7 g/100 g for 'Pete 1' in the same location. Similar to moisture content, both cultivar and the interaction between cultivar and location were statistically significant ($P = 0.000$). However, in this case, the impact of the interaction is stronger than the one exerted by the cultivar. The Lost Hills microclimate produced higher fat content in 'Kaleghouchi' (44.9 g/100 g), followed by 'Pete 1' (43.3 g/100 g) and 'Lost Hills' (42.0 g/100 g), respectively. In the Parlier microclimate, 'Pete 1' produced the highest fat content (47.7 g/100 g), followed by 'Lost Hills' (43.3 g/100 g) and 'Kaleghouchi' (42.0 g/100 g). 'Pete 1' had higher fat content when grown in the Parlier microclimate, while this trend was reversed for 'Kaleghouchi', which had the highest oil concentration in the Lost Hills microclimate. The fat content of 'Lost Hills' remained unaffected by location.

Table 2. Normalized area percentage of fatty acids for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ pistachios at Parlier and Lost Hills locations in California.

	Lost Hills			Parlier		
	Kaleghouchi	Pete 1	Lost Hills	Kaleghouchi	Pete 1	Lost Hills
Palmitic acid (C16:0)	12.2 ± 0.2 ab	12.6 ± 0.2 a	11.7 ± 0.2 cd	12 ± 0.2 bc	12.4 ± 0.2 a	11.4 ± 0.2 d
Palmitoleic acid (C16:1)	1.2 ± 0 c	1.3 ± 0 a	1.1 ± 0 d	1.1 ± 0 d	1.3 ± 0 b	1 ± 0 e
Heptadecenoic acid (C17:1)	0.1 ± 0 b	0.1 ± 0 a	0.1 ± 0 b	0.1 ± 0 b	0.1 ± 0 b	0.1 ± 0 c
Stearic acid (C18:0)	1.2 ± 0 b	1.1 ± 0 c	1.2 ± 0 b	1.4 ± 0 a	1 ± 0 d	1.4 ± 0 a
Oleic acid (C18:1)	54.4 ± 0.8 bc	54 ± 0.8 bc	55.1 ± 0.8 b	59.1 ± 0.8 a	52.7 ± 0.7 c	58.6 ± 0.8 a
Linoleic acid (C18:2)	31 ± 0.4 b	30.9 ± 0.4 b	30.9 ± 0.4 b	26.3 ± 0.4 d	32.6 ± 0.5 a	27.6 ± 0.4 c
Linolenic acid (C18:3)	0.4 ± 0 c	0.4 ± 0 b	0.4 ± 0 a	0.4 ± 0 b	0.4 ± 0 ab	0.4 ± 0 b
Arachidic acid (C20:0)	0.1 ± 0 b	0.1 ± 0 d	0.1 ± 0 c	0.2 ± 0 a	0.1 ± 0 d	0.1 ± 0 b
Gondoic acid (C20:1)	0.4 ± 0 b	0.4 ± 0 b	0.4 ± 0 b	0.4 ± 0 b	0.3 ± 0 c	0.4 ± 0 a
Behenic acid (C22:0)	0.1 ± 0 b	0.1 ± 0 a	0.1 ± 0 a	0.1 ± 0 b	0.1 ± 0 a	0.1 ± 0 c
SFA	13.7 ± 0.2 a	13.9 ± 0.2 a	13.1 ± 0.2 b	13.6 ± 0.2 a	13.6 ± 0.2 a	13 ± 0.2 b
UFA	87.3 ± 1.2	87.1 ± 1.2	87.9 ± 1.2	87.4 ± 1.2	87.4 ± 1.2	88 ± 1.2
MUFA	56 ± 0.8 bc	55.8 ± 0.8 bc	56.6 ± 0.8 b	60.7 ± 0.8 a	54.4 ± 0.8 c	60 ± 0.8 a
PUFA	31.3 ± 0.4 b	31.4 ± 0.4 b	31.3 ± 0.4 b	26.7 ± 0.4 d	33 ± 0.5 a	28 ± 0.4 c
SFA/UFA	0.2 ± 0	0.2 ± 0	0.2 ± 0	0.2 ± 0	0.2 ± 0	0.2 ± 0
MUFA/PUFA	1.9 ± 0.1 b	1.9 ± 0.1 b	1.9 ± 0.1 b	2.4 ± 0.2 a	1.7 ± 0.1 b	2.3 ± 0.2 a

Values are expressed as mean ± SD; within a row, different letters indicate significant differences according to the Fisher's least significant difference test ($\alpha = 0.05$).

Fig. 3. Total volatile terpenes for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ pistachio kernels grown at Lost Hills and Parlier, CA.

Fatty acid profile. Normalized area percentage results for main fatty acids are detailed in Table 2. ANOVA results indicate that cultivars, location, and their interaction have an effect on the concentration of all fatty acids ($P = 0.000$). The main fatty acid measured in the pistachio samples was oleic acid (52% to 58%), followed by linoleic (26% to 33%) and palmitic acids (11% to 13%); this is consistent with previous reports on other varieties (Tsantili et al., 2010). All other fatty acids were detected at levels of 1% or below. Comparing with values reported by Esteki et al. (2019), ‘Kaleghouchi’ grown in Iran’s microclimates had lower C16:0 (9.7 vs. 12.1), C16:1 (0.7 vs. 1.1), C18:2 (22.2 vs. 28.6), and C18:3 (0.3 vs. 0.4) than those of ‘Kaleghouchi’ grown in California, while C18:1 content is lower in the United States (65.3 vs. 56.8). Cultivar was the main factor impacting the fatty acids content in these pistachio cultivars, except for C22:0, which was affected by the interaction of microclimate and cultivar. ‘Pete 1’ and ‘Kaleghouchi’ had the highest values for C16:0 (12.6% and 12.2%, respectively), with Lost Hills showing slightly lower values (11.4% at Parlier and 11.7% at Lost Hills). No significant differences in oleic acid content were

detected among the three cultivars at Lost Hills. However, ‘Kaleghouchi’ and ‘Lost Hills’ had higher values in the Parlier vs. Lost Hills microclimate. For ‘Pete 1’, no differences were detected between microclimates. As previously reported for multiple pistachio cultivars and other nut crops (Agar et al., 1998; Cristofori et al., 2008; Rudolph et al., 1992), linoleic acid followed an inverse trend compared with oleic acid. Cultivar, and the interaction between location and cultivar had the strongest effect on C18:2 content ($P = 0.000$). In addition, the Lost Hills microclimate produced no statistically significant differences in C18:2 among the three cultivars. While the Parlier microclimate produced significantly lower C18:2 values in the ‘Kaleghouchi’ and ‘Lost Hills’, for ‘Pete 1’ the Parlier microclimate produced a slightly higher C18:2 compared with the Lost Hills microclimate. This was translated in an increment in the MUFA/PUFA ratio for both ‘Kaleghouchi’ and ‘Lost Hills’ located at Parlier compared with Lost Hills, while ‘Pete 1’ remained unaffected (Table 2).

Volatile compounds. Terpenes are the main volatile fraction components of fresh pistachio kernels (Kendirici and Onoğur, 2011) and pistachio hulls (Chahed et al., 2008). ANOVA indicates that both factors and their interaction are significant regarding their impact on total and individual volatile terpenes ($P = 0.000$). Total volatile terpenes concentrations for ‘Kaleghouchi’, ‘Lost Hills’, and ‘Pete 1’ are detailed in Fig. 3. ‘Kaleghouchi’ values increased (1014–1718 ng/kg), while ‘Pete 1’ values decreased (1967–1448 ng/kg) between Lost Hills and Parlier microclimates. ‘Lost Hills’ was unaffected by location (763–756 ng/kg).

Concentrations of individual volatile terpenes are detailed in Table 3. It shows that α -pinene (95–1682 ng/kg), limonene (37–741 ng/kg), and α -terpinolene (1–368 ng/kg) were the most abundant volatiles among all the cultivars and locations; this is consistent with earlier reports on other cultivars (Chahed et al., 2008; Polari et al., 2019).

Location was the main factor that impacted volatile terpenes concentration, except for camphene and β -pinene, for which cultivar was a larger influence. We found that α -pinene, the most abundant volatile terpene, was higher in Lost Hills compared with Parlier microclimates for all three cultivars. An inverse trend was found for β -pinene, α -terpinene, 4-carene, p-cymene, limonene, ocimene, α -terpinolene, and (*E,E*)-cosmene; the Parlier microclimate produced higher values than the Lost Hills cultivar for all three cultivars. In general, ‘Pete 1’ had higher concentrations of volatile terpenes, except for α -pinene, camphene, and 3-carene at the Parlier microclimate, where ‘Kaleghouchi’ had higher values. The Lost Hills microclimate produced the highest concentration of α -pinene in ‘Pete 1’. ‘Kaleghouchi’ had the highest α -pinene levels when grown in the Parlier microclimate. Interestingly, ‘Pete 1’ had the largest difference in the α -pinene concentration between microclimates.

Conclusions

Moisture, fat content, fatty acids, and the volatile profile were measured for first time for three minor pistachio cultivars from two California microclimates. ‘Kaleghouchi’ cultivar had the highest values for moisture content, followed by ‘Pete 1’ and ‘Lost Hills’ cultivars, respectively. While moisture content of ‘Kaleghouchi’ was unaffected by microclimate, it was higher at Parlier for ‘Lost Hills’ and lower for ‘Pete 1’. Strong interactions between microclimate and cultivar were detected in pistachio kernel fat content. ‘Pete 1’ had higher fat content when grown in the Parlier, compared with the Lost Hills microclimate; ‘Kaleghouchi’ a lower fat content, and ‘Lost Hills’ was unaffected by location. Based on these results, genotype had a larger impact on the fatty acid profile than the microclimate. However, oleic acid content of both ‘Lost Hills’ and ‘Kaleghouchi’ were higher when grown in the Parlier microclimate. Microclimate

Table 3. Major volatile terpenes (ng/kg) for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ pistachios at Parlier and Lost Hills locations in California.

	Lost Hills			Parlier		
	Kaleghouchi	Pete 1	Lost Hills	Kaleghouchi	Pete 1	Lost Hills
α -pinene	904 $\pm$ 1 b	1682 $\pm$ 48 a	714 $\pm$ 43 c	792 $\pm$ 87 c	95 $\pm$ 6 d	202 $\pm$ 7 d
camphene	3.8 $\pm$ 0.3 c	9.7 $\pm$ 1.4 b	1.3 $\pm$ 0.5 d	19.8 $\pm$ 1.2 a	8.9 $\pm$ 0.6 b	4.5 $\pm$ 0.7 c
β -pinene	12.5 $\pm$ 0.8 c	44.6 $\pm$ 4.2 a	5 $\pm$ 1.1 c	36.5 $\pm$ 5.4 b	47.7 $\pm$ 3.2 a	7.1 $\pm$ 1 c
3-carene	0.7 $\pm$ 0.1 c	3.3 $\pm$ 0.4 b	0.6 $\pm$ 0 c	9.8 $\pm$ 1.6 a	0.7 $\pm$ 0 c	9.6 $\pm$ 2 a
α -terpinene	0.7 $\pm$ 0.1 cd	2.3 $\pm$ 0.3 c	0 $\pm$ 0 d	7.7 $\pm$ 0.4 b	23.1 $\pm$ 1.6 a	6.6 $\pm$ 0.6 b
4-carene	0.7 $\pm$ 0.1 cd	2.2 $\pm$ 0.2 c	0 $\pm$ 0 d	7.1 $\pm$ 1 b	17.8 $\pm$ 1.2 a	5.5 $\pm$ 0.7 b
p-cymene	6.6 $\pm$ 0.2 e	27 $\pm$ 4.2 d	2.9 $\pm$ 0.4 e	64.8 $\pm$ 3.3 b	136.5 $\pm$ 9.2 a	42.9 $\pm$ 1.1 c
limonene	80.2 $\pm$ 9.1 d	173.4 $\pm$ 14.7 c	37.1 $\pm$ 0.7 d	731.1 $\pm$ 48.8 a	740.6 $\pm$ 49.9 a	337.3 $\pm$ 16.2 b
ocimene	0.6 $\pm$ 0.1 cd	1 $\pm$ 0.2 c	0 $\pm$ 0 d	6.4 $\pm$ 0.4 a	6.3 $\pm$ 0.4 a	2.7 $\pm$ 0.2 b
α -terpinolene	4.2 $\pm$ 0.9 d	20.7 $\pm$ 0.2 cd	1.4 $\pm$ 0.2 d	41.1 $\pm$ 0.5 c	367.6 $\pm$ 24.8 a	135.6 $\pm$ 5.1 b
(E,E)-cosmene	0 $\pm$ 0 e	0.5 $\pm$ 0 d	0 $\pm$ 0 e	1.3 $\pm$ 0.1 c	4.1 $\pm$ 0.3 a	1.7 $\pm$ 0.1 b

Values are expressed as mean $\pm$ SD; within a row, different letters indicate significant differences according to the Fisher's least significant difference test ($\alpha = 0.05$).

had no impact on the oleic acid content of ‘Pete 1’. The terpenes α -pinene, limonene, and α -terpinolene were the volatile compounds with higher concentration among all the cultivars and locations. The Lost Hills microclimate, characterized by less relative humidity and rainfall, would contribute to increase total volatiles for ‘Pete 1’, potentially improving flavor. On the contrary, the Parlier microclimate, characterized by lower annual maximum temperatures and more rainfall compared with Lost Hills, would positively increase flavor in ‘Kaleghouchi’ nuts. Because location was the main factor determining the concentration of volatile terpenes in the pistachio kernels, there is a potential of these analytes to be used as origin markers.

This article constitutes the first report of the fatty acids and terpenes composition for ‘Kaleghouchi’, ‘Pete 1’, and ‘Lost Hills’ grown in California. Understanding the interactions between microclimate and cultivars would help pistachio growers to maximize nutritional and sensory properties of these cherished nuts.

Literature Cited

- Agar, I.T., S. Kafkas, and N. Kaska. 1998. Lipid characteristics of Turkish and Iranian pistachio kernels. *Acta Hort.* 470:378–386.
- Arena, E., S. Campisi, B. Fallico, and E. Maccarone. 2007. Distribution of fatty acids and phytosterols as a criterion to discriminate geographic origin of pistachio seeds. *Food Chem.* 104:403–408.
- Blank, S.C. 2016. The economic outlook for California pistachios, p. 3–10. In: L. Ferguson and D. Haviland (eds.). *Pistachio production manual* (Vol. 3545), UCANR Publications, Oakland, CA.
- Chahed, T., A. Bellila, W. Dhifi, I. Hamrouni, B. M'hamdi, M. E. Khouk, and B. Marzouk. 2008. Pistachio (*Pistacia vera*) seed oil composition: Geographic situation and variety effects. *Grasas Aceites* 59:51–56.
- Cristofori, V., S. Ferramondo, G. Bertazza, and C. Bignami. 2008. Nut and kernel traits and chemical composition of hazelnut (*Corylus avellana* L.) cultivars. *J. Sci. Food Agr.* 88:1091–1098.
- Dreher, M.L. 2012. Pistachio nuts: Composition and potential health benefits. *Nutr. Rev.* 70:234–240.
- Esteki, M., P. Ahmadi, Y. Vander Heyden, and J. Simal-Gandara. 2019. Fatty acids-based quality index to differentiate worldwide commercial pistachio cultivars. *Molecules* 24:58.
- Kashani Nejad, M., L.G. Tabil, A. Mortazavi, and A. Safe Kordi. 2003. Effect of drying methods on quality of pistachio nuts. *Dry. Technol.* 21:821–838.
- Kendirci, P. and T.A. Onogur. 2011. Investigation of volatile compounds and characterization of flavor profiles of fresh pistachio nuts (*Pistacia vera* L.). *Intl. J. Food Prop.* 14:319–330.
- Kris-Etherton, P.M., F.B. Hu, E. Ros, and J. Sabaté. 2008. The role of tree nuts and peanuts in the prevention of coronary heart disease: Multiple potential mechanisms. *J. Nutr.* 138:1746S–1751S.
- Lin, C.T.J. and S.T. Yen. 2010. Knowledge of dietary fats among US consumers. *J. Amer. Diet. Assoc.* 110:613–618.
- McGuire, S. 2011. Dietary guidelines for Americans, 2010. 7th ed. U.S. Department of Agriculture and U.S. Department of Health and Human Services, U.S. Government Printing Office, Washington, DC, January 2011. *Adv. Nutr.* 2:293–294.
- Parfitt, D.E., C.E. Kallsen, B. Holtz, and J. Maranto. 2008. ‘Lost Hills’: A new pistachio cultivar. *HortScience* 43:247–249.
- Parfitt, D., C. Kallsen, and J. Maranto. 2005. Pistachio cultivars, p. 62–66. In: *Pistachio production manual*.
- Polari, J.J., L. Zhang, L. Ferguson, N.O. Maness, and S.C. Wang. 2019. Impact of microclimate on fatty acids and volatile terpenes in ‘Kerman’ and ‘Golden Hills’ pistachio (*Pistacia vera*). *Kernels. J. Food Sci.* 84:1937–1942.
- Renaud, S., M. De Lorgeril, J. Delaye, J. Guidollet, F. Jacquard, N. Mamelle, J.L. Martin, I. Monjaud, P. Salen, and P. Toubol. 1995. Cretan Mediterranean diet for prevention of coronary heart disease. *Amer. J. Clin. Nutr.* 61:1360S–1367S.
- Rodríguez-Bencomo, J.J., H. Kelebek, A.S. Sonmezdag, L.M. Rodríguez-Alcalá, J. Fontecha, and S. Sellí. 2015. Characterization of the aroma-active, phenolic, and lipid profiles of the pistachio (*Pistacia vera* L.) nut as affected by the single and double roasting process. *J. Agr. Food Chem.* 63:7830–7839.
- Rudolph, C.J., G.V. Odell, H.A. Hinrichs, D.A. Hopfer, and S.J. Kays. 1992. Genetic, environmental, and maturity effects on pecan kernel lipid, fatty acid, tocopherol, and protein composition. *J. Food Qual.* 15:263–278.
- Sabaté, J. and Y. Ang. 2009. Nuts and health outcomes: New epidemiologic evidence. *Amer. J. of Clinical Nutr.* 89:1643S–1648S.
- Satıl, F., N. Azcan, and K.H.C. Baser. 2003. Fatty acid composition of pistachio nuts in Turkey. *Khimiya Prir. Soedin.* 2003:257–259.
- Tsantili, E., C. Takidelli, M.V. Christopoulos, E. Lambrinea, D. Rouskas, and P.A. Roussos. 2010. Physical, compositional and sensory differences in nuts among pistachio (*Pistacia vera* L.) varieties. *Scientia Hort.* 125:562–568.