Screening of aroma profiles in Albanian *cvs.* Kalinjot and Bardhi Tirana olive oils using purge and trap extraction technique

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Aroma compounds of extra virgin olive oils obtained from Kalinjot and Bardhi Tirana cultivars were investigated for the first-time employing GC-MS. The Kalinjot oils were obtained from two different regions, namely Vlora and Himara, while the Bardhi Tirana oils were obtained from the Tirana Region during the 2017-2018 harvesting season. In total, the number of detected volatile compounds in both cultivars was 32. A total of 29 aroma compounds were detected in the Kalinjot cv. oils from Vlora and Himara. The total comprised aldehydes (6), alcohols (12), esters (3), terpenes (6), and phenols (2) were detected. Meanwhile, the investigation of the Bardhi Tirana cv. olive oil resulted in the discovery of 17 aroma compounds including aldehydes (6), alcohols (8), esters (2), and phenols (1). Therefore, the profile and concentration of volatile compounds in oils were affected by both variety and geographical area. (E)-2-Hexenal was the main volatile compound in both the Kalinjot and Bardhi Tirana samples.

Keywords: Extra virgin olive oils, GC-MS, Aroma compounds, Kalinjot, Bardhi Tirana.

INTRODUCTION

Currently, the olive tree is cultivated in many regions of the world with climatic characteristics similar to the those of the Mediterranean region. Albania is situated in South-eastern Europe on the Balkan Peninsula of the Mediterranean region with olive plantations covering more than 38889 ha and with 99075 tons of olive fruit production. Albania is ranked 17th in the world for olive fruit production according to FAO statistics in 2016 [1]. The olive tree is native to Albania and cultivated in the Western Plain, alongside the Adriatic and Ionian Sea, by penetrating the mainland through the river valleys. Genetic studies have concluded that Albania owns 22 native olive cultivars, clustered in 7 different groups and the main factor differentiating them is the size of the olive fruit [2]. Olive oil production, according to unofficial FAO data in 2014, was 8000 tons [1].

Olive oil is one of the most popular oils in the world and a major edible oil of Mediterranean countries. Its increased demand in consumer markets is due to its nutritional and organoleptic properties. The characteristic flavour note of virgin olive oil is one of the main traits that distinguish this oil from the other edible vegetable oils [3, 4]. Aroma and taste are parameters of edible oils that consumers can appraise directly [5]. Volatile compounds are key factors in the aromas that virgin olive oils possess [6], and are generally related to aldehydes, esters, alcohols, hydrocarbons, furans and ketones groups. (*E*)-2-Hexenal (*Z*)-2-hexen-1-ol, and (*Z*)-3-hexenyl acetate are found in extra virgin olive oils of Spanish, Greek, and Italian cultivars [4, 7].

Volatile compound levels depend on the geographical region, cultivar, fruit maturity, extraction procedure, cultural practices and ripening stage [8, 9]. The

major volatile compounds reported in extra virgin olive oils are related to the C5 and the C6 aldehyde and alcohol volatile compounds [10]. During maturation, numerous metabolic processes occur in olives with successive variations on the chemical structure and content of some compounds. These changes are reflected in the quality level, sensorial properties, oxidative stability, and nutritional value of the final product [11]. Most of these aromatic volatile compounds are formed through the different endogenous chemical reactions. The enzymes action is released when the fruit is crushed and continues to form during malaxation [12]. Some volatile compounds are responsible for undesirable sensory attributes (defects) of olive oil. Such is the case with 1-octen-3-ol (musty–humid), ethyl butanoate (fusty), 3-methylbutanol and ethyl acetate (winey–vinegary), and various saturated and unsaturated aldehydes (rancid) [13, 14]. The volatiles produced by chemical oil oxidation are accountable for the off-flavour attributed to oxidative rancidity [6]. Nonetheless, the enzymatic activity of extra virgin olive oils, such as the lipoxygenase pathway, is considered responsible for most of the aroma fraction of olive oil [8].

To the best of our knowledge, no research has been published to establish the aroma profiles of Albanian extra virgin olive oils by GC–MS. Most studies on Albanian virgin olive oil have focused on the characterization of major constituents such as fatty acids and polyphenols [15]. Consequently, our study was primarily established for the determination of the aroma profiles of Albanian extra virgin olive oils from Kalinjot and Bardhi Tirana *cvs*. using the purge and trap isolation method.

MATERIALS AND METHODS

REAGENTS AND CHEMICALS

Dichloromethane and sodium sulphate were purchased from Fluka (Buchs, Switzerland). Hexanal, 3-hexenal, 1-penten-3-ol, 3-penten-2-ol, isoamyl alcohol, D-limonene, (E)-2-hexenal, styrene, β-ocimene, (E)-3-hexenyl acetate, hexanol, (Z)-3-hexenol, nonanal, (E)-2-hexenol, 1-heptanol, 2-butoxyethyl acetate, 2-ethyl-1-hexanol, benzaldehyde, 1-octanol, (E)-4-oxo-2-hexenal, α-bergamotene, benzeneacetaldehyde, 1-nonanol, methyl salicylate, 4-methoxy phenol, benzyl alcohol, phenethyl alcohol, 3-ethyl phenol and 4-ethyl phenol were obtained from Sigma-Aldrich (Steinheim, Germany). Deionised water (resistivity over 18 MX cm) from a Millipore Q (Millipore Corp., Saint-Quentin, France) water purification system was used in all analyses.

OLIVE OIL SAMPLING

Olive oil samples were collected directly from olive mills during the harvesting season in the Mid-November period of 2017-2018. The average weight of 50 kg olive fruits from each variety were handpicked from 10 representative trees of each plot and from all four sides of each tree (N, S, E and W) and at differing heights from each variety. The samples were kept in dark bottles at low temperatures. The Kalinjot cv is cultivated in the Vlora and Himara regions, while the Bardhi Tirana olive *cv.* is cultivated in the region of the same name. Despite the two being cultivated in different regions, they share a similar Mediterranean climate (Fig. 1). Even though both regions, according to Köppen's climate classification, belong to a subtropical climate, there are differences, concerning average precipitations, specifically for Himara and Tirana. The annual rainfall and temperature averages during the year of 2017 were 1410 mm and 18.1°C for Himara; 892 mm and 16.3°C for Vlora; and 1259.8 mm and 16.5°C for Tirana Region [16].

EXTRACTION OF THE VOLATILE COMPOUNDS

The volatile compounds of olive oil were extracted by the purge and trap system under a source of nitrogen (N_2), controlled by a flow-meter and connected to a splitter system to divide the flow into several channels to purge three samples at the same time. The detail of this extraction technique is well-explained in our previous studies [11, 17]. Briefly, the needle of the source of N_2 and the cartridge were installed through

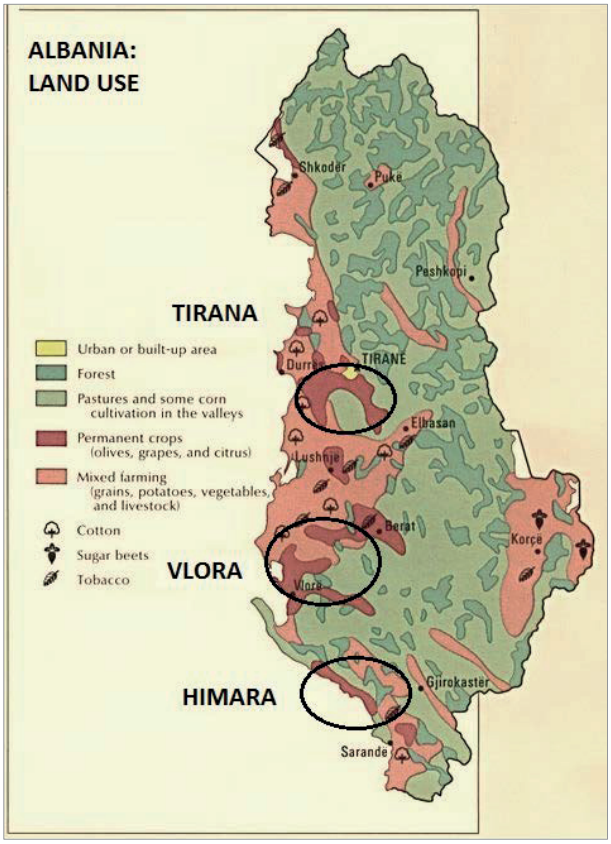

Figure 1 - Geographical regions in the study.

the septum to urge and trap the volatiles. 200 mg of Lichrolut EN resins (Merck) was chosen as an absorbent. For the extraction, a 5 g of olive oil sample was delivered to the vial (20 mL) then the sample was pre-incubated at a temperature of 60°C for 10 minutes. The purge and trap extraction was applied for 90 minutes under the nitrogen flow of 500 mL/min. After the extraction process, the volatile compounds kept in the cartridge were eluted with 6 mL of dichloromethane. After dehydration by anhydrous sodium sulphate, the pooled aromatic extract volume was reduced to 5 mL in a Kuderna Danish concentrator (Sigma Aldrich, St. Louis, MO, USA) fitted with a Snyder column at 40°C (Supelco, St Quentin, France) and then to 200 µl volume under a gentle stream of N_2. Then, the extract was placed in a glass vial and stored at -20°C until GC-MS analysis. Each procedure was repeated in triplicate and the concentration of volatiles was expressed as 4-nonanol (IS) (with the concentration of 41.5 mg/L) equivalent.

GC-FID AND GC-MS ANALYSIS OF VOLATILE COMPOUNDS

An aromatic extract (2 µL) was injected by pulsed splitless (40 psi; 0.5 min) mode into a 6890 Agilent GC-FID (Wilmington, DE, USA), and 5973-Network-MSD (mass selective detector). Aroma compounds were separated on the polar column (DB-WAX 30 m length × 0.25 mm i.d. × 0.5 µm thickness). The flow rate of carrier gas (helium) was 1.5 mL/min. The oven temperature was first increased from 50°C to 200°C at a rate of 5°C min^{-1}, and then to 260°C at a rate of 8°C/min with a final hold at 260°C for five minutes. The same oven temperature was programmed for the MSD. The MSD conditions were as follows: electronic impact ionisation energy of 70 eV; interface temperature, 250°C; ionisation source temperatures, 180°C, mass range, 30-300 amu; at 2.0 scan/s scan rate. The identification and quantification were performed in full scan mode. The compounds were identified by comparing their retention index and Wiley 6 and NIST 98 mass spectral data libraries installed in the GC-MS and the internal library created with previous laboratory studies. Some identifications were confirmed by injection of the chemical standards into the GC-MS system. Retention indices of the compounds were calculated by using the retention data of the linear n-alkane (C6 – C30) series [17-18].

STATISTICAL ANALYSIS

The findings of this study were subjected to analysis of variance using the SPSS 22 software package, and Duncan's multiple-comparison test was used to find significant differences among the different extra virgin olive oils. Furthermore, XLStat trial software (Addinsoft, New York City, New York, USA) was used for the principal component analysis (PCA) in this study.

RESULTS AND DISCUSSION

AROMA COMPOUNDS

The data of this study presents, for the first time, the volatile compounds identified in two extra virgin olive oils from native cultivars in Albania. Aroma compounds identified and quantified in the Kalinjot and Bardhi Tirana extra virgin olive oils are shown in Table I. The total amount of aroma groups is also shown in Figure 2. The oils obtained from the Kalinjot *cv*. were compared with representative samples from two regions, while the Bardhi Tirana, due to its pedoclimatic characteristics, was cultivated in the regions with the same name. A cardboard smelling strip (reference 7140 BPSI, Granger-Veyron, Lyas, France) was used to check the representativeness of the aromatic extract obtained from oil samples with the similarity and intensity test [19] by a group of 10 trained panellists (four females and six males between 22 and 51 years of age) from the Department of Food Engineering at Cukurova University. The purge and trap isolation technique gave highly representative aromatic extract in analysed oil samples. The results were expressed as the mean value (µg/kg) of GC analysis of triplicate extractions.

A total of thirty-two aroma compounds have been characterised by GC-MS analysis in two monocultivar extra virgin olive oils. A total of 29 aroma compounds were detected in the Kalinjot *cv*. extra virgin olive oils from Vlora and Himara. The total comprised aldehydes (6), alcohols (12), esters (3), terpenes (6), and phenols (2) were detected. Comparison of samples for Kalinjot *cv*. from the two different regions, Himara and Vlora, revealed that the styrene was only in the sample from Himara region. (*E*)-2-Hexenal has been reported to be the main volatile among constituents of olive oil aroma. Moreover, volatile compounds in high percentages were hexanal (6.6-9.8%), 3-hexenal (4.6-9.8%), 3-penten-2-ol (7.7-9.4%), (*E*)-3-hexenyl acetate (4.0-8.8%), (*Z*)-3-hexenol (2.9-4.1%), (*E*)-2-hexenol (1.4-3.1%), ***β***-ocimene (n.d-4.2%) and hexanol (n.d-4.2%).

Aldehydes

The major aldehyde compound in all olive oil samples was (*E*)-2-hexenal. Among aldehyde C6 compounds, (*E*)-2-hexenal was the principal compound characterised in Kalinjot samples with 37.2% (Himara), 39.1% (Vlora) and 55.5% (Bardhi Tirana). Other aldehydes found in Kalinjot olive oil from Himara were hexanal (3017 µg/kg), 3-hexenal (3639 µg/kg), nonanal (779 µg/kg), benzaldehyde (277 µg/kg) and (*E*)-4-oxo-2-hexenal (419 µg/kg). Kalinjot *cv*. extra virgin olive oils from the Himara region exhibited the highest value of total aldehyde concentration (23177 µg/kg), followed by oils from the Vlora region (22103 µg/kg and oils

Table I - Aroma compounds of the Kalinjoti and Bardhi Tirana olive oils, including different regions.

No.	Aroma compounds	LRI [a]	Concentrations [b]			Identification [c]
			Kalinjoti		Bardhi Tirana	
			Himara	Vlora		
1	Hexanal	1069	3017±122[b]	3607±13[a]	1830±65[c]	LRI, MS, and std
2	3-Hexenal	1120	3639±88[a]	3415±63[b]	1254±27[c]	LRI, MS, and std
3	1-Penten-3-ol	1146	723±26[a]	747±2[a]	537±42[b]	LRI, MS, and std
4	3-Penten-2-ol	1163	3100±94[b]	3442±83[a]	2504±74[c]	LRI, MS, and std
5	Isoamyl alcohol	1184	nd	nd	623±35[a]	LRI, MS, and std
6	*d*-Limonene	1197	513±17[b]	698±3.6[a]	nd	LRI, MS, and std
7	(*E*)-2-Hexenal	1217	15046±99[a]	14351±215.59[a]	15282±242[a]	LRI, MS, and std
8	Styrene	1236	3508±277[a]	nd	nd	LRI, MS, and std
9	*β*-Ocimene	1247	1717±29[a]	596±22[b]	nd	LRI, MS, and std
10	2-Hexanol	1254	nd	735±23[a]	nd	LRI, MS, and tnt
11	(*E*)-3-Hexenyl acetate	1276	3555±49[a]	2705±113[b]	1108±64[c]	LRI, MS, and std
12	Hexanol	1315	nd	961±60[b]	1149±64[a]	LRI, MS, and std
13	(*Z*)-3-Hexenol	1342	1172±1.0[b]	1378±62[a]	1124±76[a]	LRI, MS, and std
14	Nonanal	1391	779±41[a]	413±13[b]	299±23[c]	LRI, MS, and std
15	(*E*)-2-Hexenol	1403	550±41[c]	1155±26[a]	755±45[b]	LRI, MS, and std
16	1-Heptanol	1449	131±4.7[a]	98±4.8[b]	nd	LRI, MS, and std
17	2-Butoxyethyl acetate	1462	194±12[a]	208±21[a]	nd	LRI, MS, and std
18	2-Ethyl-1-hexanol	1489	437±9.7[a]	421±16[a]	nd	LRI, MS, and std
19	Benzaldehyde	1520	277±0.8[a]	nd	217±2.3[b]	LRI, MS, and std
20	1-Octanol	1554	273±21[b]	328±11[a]	nd	LRI, MS, and std
21	(*E*)-4-Oxo-2-hexenal	1599	419±15[a]	317±25[b]	nd	LRI, MS, and std
22	*α*-Bergamotene	1611	nd	315±14[a]	nd	LRI, MS, and std
23	Benzeneacetaldehyde	1625	nd	nd	99±6.2[a]	LRI, MS, and std
24	(*E*)-*β*-farnesene	1650	nd	286±15[a]	nd	LRI, MS, and tnt
25	1-Nonanol	1665	450±7.8[a]	nd	nd	LRI, MS, and std
26	Methyl salicylate	1715	nd	371±18[b]	476±19[a]	LRI, MS, and std
27	*α*-Farnesene	1734	711±9.0[a]	nd	nd	LRI, MS, and tnt
28	4-Methoxy phenol	1858	37±2.8[a]	nd	nd	LRI, MS, and std
29	Benzyl alcohol	1867	45±1.4[b]	43±1.3[b]	78±0.3[a]	LRI, MS, and std
30	Phenethyl alcohol	1909	67±1.2[c]	110±8.3[b]	183±8.4[c]	LRI, MS, and std
31	3-Ethyl phenol	2150	50±1.3[a]	nd	nd	LRI, MS, and std
32	4-Ethyl phenol	2152	nd	nd	24±2.1[a]	LRI, MS, and std
	Total volatiles		40411[a]	36700[b]	27543[c]	
	Total C6 compounds		27435±255[b]	28624±283[a]	22502±240[c]	
	Total C5 compounds		3823±67[b]	4189±80[a]	3663±151[c]	
	Total terpenes		6449±256[a]	1895±36[b]	nd	
	Total aldehydes		23177±178[a]	22103±153[b]	18982±117[c]	
	Total alcohols		6948±75[b]	9418±37[a]	6953±44[b]	
	Total phenols		87±4.0[a]	nd	24±2.1[b]	
	Total esters		3749±38[a]	3284±252[b]	1584±45[c]	

[a] LRI retention indices on DB-WAX column.
[b] Results are the means of three repetitions as µg/kg (n = 3) ± standard deviation.
[c] Methods of identification: LRI, linear retention index; MS tent., tentatively identified by MS; and std, chemical standard. When only MS or LRI is available for the identification of a compound, it must be considered as an attempt of identification.

from Bardhi Tirana cv. (18982 µg/kg).
The enzymatic breakdown of the 13-hydroperoxide of linoleic acid in leaf homogenates causes the production of (*E*)-2-hexenal, while the aldehyde-lyases generate hexanal [4]. These compounds were found in most virgin extra virgin olive oils obtained from the Italian *cv.* Coratina and Leccino; the Spanish *cv.* Cornicabra and Arbequina; the Greek *cvs.* Koroneiki and Adramytini [20]. The Tunisian *cvs.* Fakhari and Touffehi [11], the Turkish *cv.* Halhali [21], the Iranian *cv.* Mari [17] and the Croatian olive Masnjaca and Krvavica cultivars [22]. Data shows that Kalinjot and Bardhi Tirana extra virgin olive oils have a similarity with other European extra virgin olive oils [23] that which show high levels of (*E*)-2-hexenal. In comparison with published data from the Italian olive *cv.* Leccino (73%) the percentages of Kalinjot (37.2-39.1%) and Bardhi Tirana (55.5%) are lower, and higher compared to the Croatian *cv.* Masnjaca (27.6-28.9%) [22].

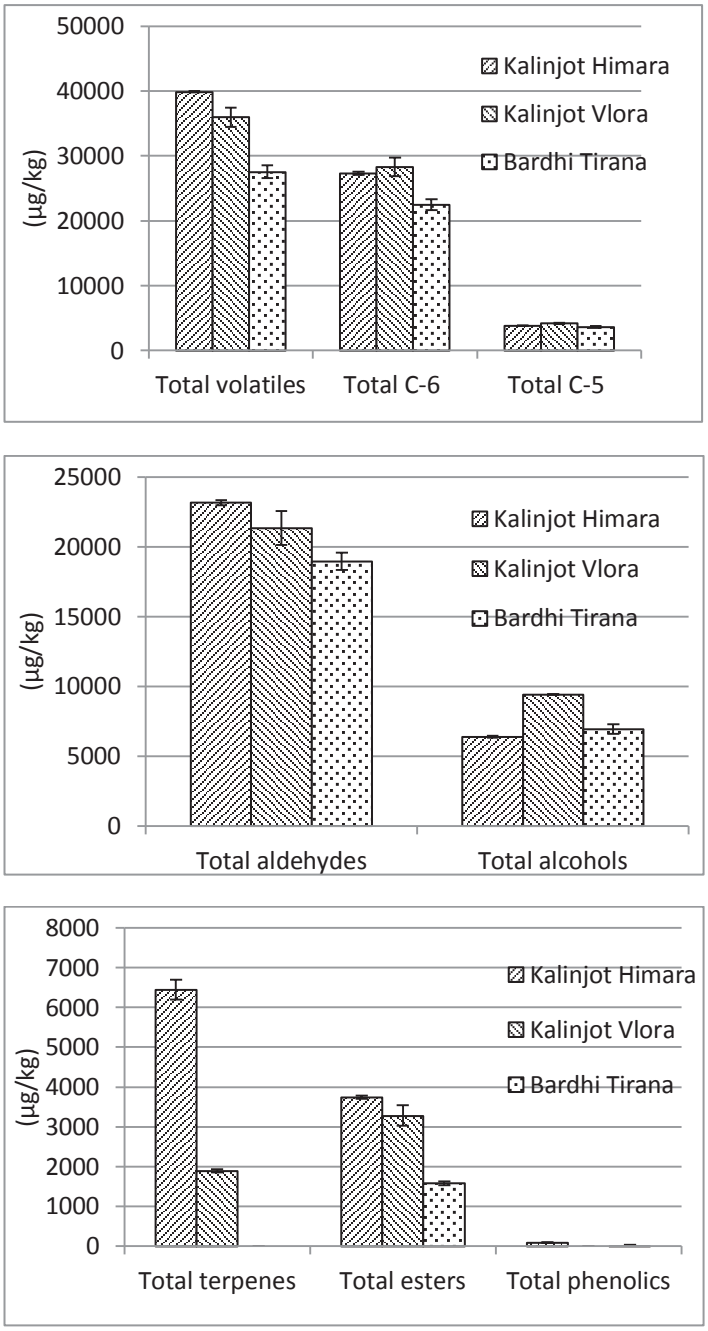

Figure 2 - Aroma chemical groups in two varieties of Albanian olive oils.

Alcohols

Alcohols were the most abundant family related to the specimens, while the second group in regard to the quantity present in the specimens. For the Kalinjot *cv.* total alcohols amount ranged from 6948 µg/kg (Himara) to 9418 µg/kg (Vlora), while in Bardhi Tirana *cv.* this compound's family was found in 6953 µg/kg. For both two olive *cvs*., despite the region, the main C-5 alcohol resulted 3-penten-2-ol in the range 2504-3442 µg/kg. Other abundant alcohols present in the olive oil of Kalinjot *cv.* from Himara region were 1-penten-3-ol (723 µg/kg), (*Z*)-3-hexenol (1172 µg/kg), (*E*)-2-hexenol (550 µg/kg), 1-heptanol (131µg/kg), 2-ethyl-1-hexanol (437 µg/kg), and 1-nonanol (450 µg/kg). Alcohol quantities for Kalinjot olive oil from the Vlora region resulted 1-penten-3-ol (747 µg/kg), 3-penten-2-ol (3442 µg/kg), (*Z*)-3-hexenol (1378 µg/kg), (*E*)-2-hexenol (1155 µg/kg), hexanol (961µg/kg), and 2-hexanol (735 µg/kg). Alcohol quantities for Bardhi Tirana *cv.* were lower (6953 µg/kg) compared with Kalinjot extra virgin olive oils from two regions: 1-penten-3-ol (536 µg/kg), 3-penten-2-ol (2504 µg/kg), (*Z*)-3-Hexenol (1124 µg/kg), (*E*)-2-hexenol (755 µg/kg), hexanol (1149 µg/kg), and isoamyl alcohol (623 µg/kg). (*Z*)-3-Hexenol is derived from corresponding (*Z*)-3-hexenal (aldehyde), through the reduction from alcohol dehydrogenase (ADH) enzyme

activity. Main alcohol was 3-penten-2-ol that was in higher levels compared to extra virgin olive oils from the Greek, Italian and Spanish olive cultivars like Italian *cv. Coratina* and *Leccino*, Spanish *cv. Cornicabra* and *Arbequina*, Greek *cv. Koroneiki* and *Adramytini* [20], as well as in many other extra virgin olive oils like the Tunisian *cv*. Fakhari and Touffehi, [11], Turkish *cv*. Halhali, [24], and Iranian *cv*. Mari [17].

Terpenes

Several terpenes were detected in Kalinjot cultivar olive oil samples of both regions (Himara and Vlora): -β-ocimene (1.6-4.2%), *D*-limonene (1.3-1.9%) α-bergamotene (n.d.-0.9%), (*E*)-β-farnesene (n.d.-0.8%), α-farnesene (1.8%), and styrene (n.d.-8.7%). These terpenes may be used as markers to differentiate extra virgin olive oils from different studied cultivars, where their presence was only in the Kalinjot cultivar. Also, their values were different from the Kalinjot extra virgin olive oils of two geographical regions, Himara and Vlora. *D*-limonene, styrene, α-farnesene and β-ocimene were found in extra virgin olive oils of Kalinjot *cv*. from Himara region, while in the case of Kalinjot *cv*. from Vlora region, the identified terpenes were *D*-limonene, β-ocimene, α-bergamotene and (*E*)-β-farnesene. Meanwhile, no terpene was detected in Bardhi Tirana. The total content of terpenes in oils of Kalinjot *cv*. from Himara and Vlora regions were 6449 and 1895 µg/kg. The difference in the total content and the profiles found for the same cultivar from two different regions might be proposed as a fingerprint to distinguish the geographical origin. And, it is evident that difference among two olive *cv*. was evident and Kalinjot *cv*. were found in high content. Additionally, the distinguishing element of extra virgin olive oils from Kalinjot *cv*. could be related to the presence of β-ocimene with high levels (1717 µg/kg) only in Himara. The terpene presence was found in the Turkish *cv*. Halhali [21], Iranian *cv*. Mari [17], and Tunisian *cv*. Fakhari and Jemri [11].

Volatile phenols

Volatile phenols are usually present in olive oil aroma. These compounds are responsible for both its fragrance and peculiar flavour providing both bitter and pungent sensory notes [25]. Three volatile phenols, 4-methoxy phenol; 3-ethyl phenol and 4-ethyl phenol, were found in olive oil samples. Their presence was found in low levels; 87 µg/kg was found in Kalinjot from Himara, as well as 24 µg/kg in Bardhi Tirana *cv.* extra virgin olive oils. Some of these volatile phenols were found in Turkish extra virgin olive oils [21], and Iranian extra virgin olive oils [17].

Esters

(*E*)-3-Hexenyl acetate (2705 µg/kg), 2-butoxyethyl acetate, and methyl salicylate were found in Kalinjot from Vlora region with a total of 3284 µg/kg. Regarding the Bardhi Tirana olive oil, (*E*)-3-hexenyl acetate (1108 µg/kg) and methyl salicylate (476 µg/kg) were detected. Meanwhile, in Kalinjot olive oil samples from Himara, (*E*)-3-hexenyl acetate (3555 µg/kg) and 2-butoxyethyl acetate (194 µg/kg) were found. This group of compounds is responsible for the fruity and flowery odour of the fruits [21]. The concentration of esters in comparison with other olive oil cultivars, was lower than the Greek *cv*., however, higher than the Italian and Spanish *cv*. [20], and the Tunisian olive *cv*. Fakhari and Jemri [11]. This high production of volatile esters is dependent upon the increase of alcohol acetyl transferase activity [23].

PCA analysis was performed to evaluate the possibility of distinguishing the extra virgin olive oil samples obtained from different regions and varieties concerning the aroma fraction. All the aroma compounds quantified were considered to construct PCA biplot. Thirty-two variables were selected for the PCA analysis and the elucidated variance was 100% (Factor 1: 63.83%; Factor 2: 36.17%). Figure 3 displays the projection of the variables with respect to the PCA biplot including the single factor on the factor plane of the Kalinjot Himara, Kalinjot Vlora and Bardhi Tirana extra virgin olive oils. As demonstrated in the PCA biplot, PC1 accounted for the highest proportion of variance (63.83%). The first class was composed of oils obtained from the Bardhi Tirana olives, which were characterised by benzeneacetaldehyde, 4-ethylphenol, isoamyl alcohol, (*E*)-2-hexenal, and benzaldehyde variables. The second class was identified by oils produced from the Kalinjot Vlora olives and discriminated by 2-hexanol, (*E*)-β-farnesene, α-bergamotene, (*Z*)-3-hexenol, 3-penten-2-ol, hexanal, 1-octanol, *D*-limonene, 1-penten-3-ol, 2-butoxyethyl acetate, 2-ethyl-1-hexanol, and 3-hexenal. Finally, the third class was made up with oils generated from the Kalinjot (Himara) olives and differentiated by (*E*)-4-oxo-2-hexenal, 1-heptanol, (*E*)-3-hexenyl acetate, β-ocimene, nonanal, styrene, 1-nonanol, α-farnesene, 4-methoxy phenol, and 3-ethyl phenol.

CONCLUSION

This study reports data on the aroma compounds in Albanian native olive *cvs., Kalinjot* and *Bardhi Tirana*. Aromatic extracts were obtained by the purge and trap extraction system. GC/MS revealed 32 different volatile compounds in two cultivars. Kalinjot *cv*. extra virgin olive oils from Himara region exhibited the highest value of total aroma concentration, followed by oils from the Vlora region and oils from Bardhi Tirana cv. Aldehydes were the dominating aroma compounds in both monocultivar extra virgin olive oils, and (*E*)-2-hexenal, responsible for the odour associ-

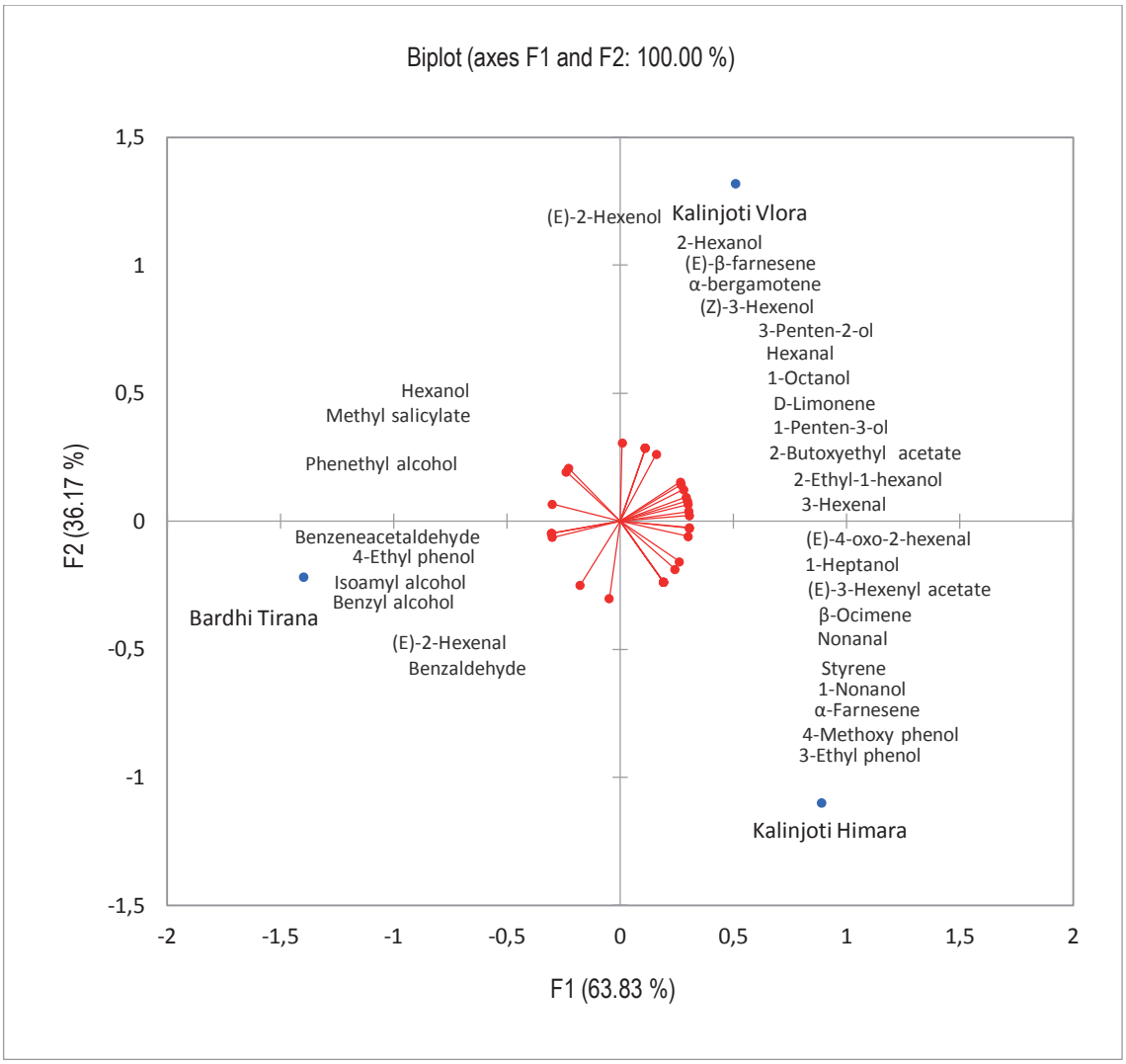

Figure 3 - PCA biplot of aroma compounds.

ated with freshly cut grass, was the major constituent, accounting for 37.2% (Kalinjot), 55.5% in (Bardhi Tirana).

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