Chapter

Olive Oil Production in Albania, Chemical Characterization, and Authenticity

Dritan Topi, Gamze Guclu, Hasim Kelebek and Serkan Selli

Abstract

Olive tree is present to the Western and Southern regions of Albania, alongside Adriatic and Ionian Sea, two body waters of the Mediterranean basin. Genetic studies have revealed the existence of 22 native olive cultivars, while several introduced foreign olive cultivars are present. Two most important olive cultivars respectively, exploited in the olive oil production, and table olive, are *Kalinjot* and *Kokërrmadh Berati*. Olive fruit production ranks the country 20th in the world. Olive tree comprises an important permanent crop with considerable potential for the Albanian economy. Principal component analyses (PCA) of fatty acids in OO displays their differentiation according to the cultivar and their region. Chemometric analysis gives support to the differentiation of OO according to the olive *cv.* in terms of phenolic compounds. Secoiridoids are found in abundance, *3,4-DHPEA-EDA* and *p-HPEA-EDA* as dominant compounds, especially in *Kalinjot* olive oils. Albanian OO shows high levels of aroma compounds with (*E*)-2-hexenal as the principal aroma compound. Its concentrations reach up to 40411 μg/kg in *Kalinjot cv.,* much higher compared to *Bardhi Tirana* cv (27542.7 μg/kg). The authenticity of OOs constitutes an opportunity for domestic production and certification according to the geography or origin and present an important resource to the development of a sustainable economy.

Keywords: Olive oil, *Kalinjot*, *Bardhi Tirana*, Phenolic compounds, Albania

1. Introduction

In the last decades, the interest in olive tree (*Olea europaea* L.), an important crop for Mediterranean countries, has been extended to other regions of the world, such as Australia, North and South America, due to its valuable products; olive oil and table olive [1]. *Olea europea* L. is an evergreen plant-derived from tropical and subtropical species. It is native to the Mediterranean region, tropical and central Asia, and other parts of North Africa. Fossil remains of olive species have been found in Italy, France, and many other countries. Olive tree includes many clusters and more than 2600 cultivars, many of which may be ecotypes. Native olive *O. oleaster* and cultivated olive *O. sativa* are the main species in the Mediterranean [2].

The geography of Albania has shaped the climate characteristics, with South and Western regions typical of the Mediterranean climate while the Eastern and Northern regions with typical continental climate (**Figure 1**). Olive tree is cultivated mainly in the regions with Mediterranean climate, by penetrating the

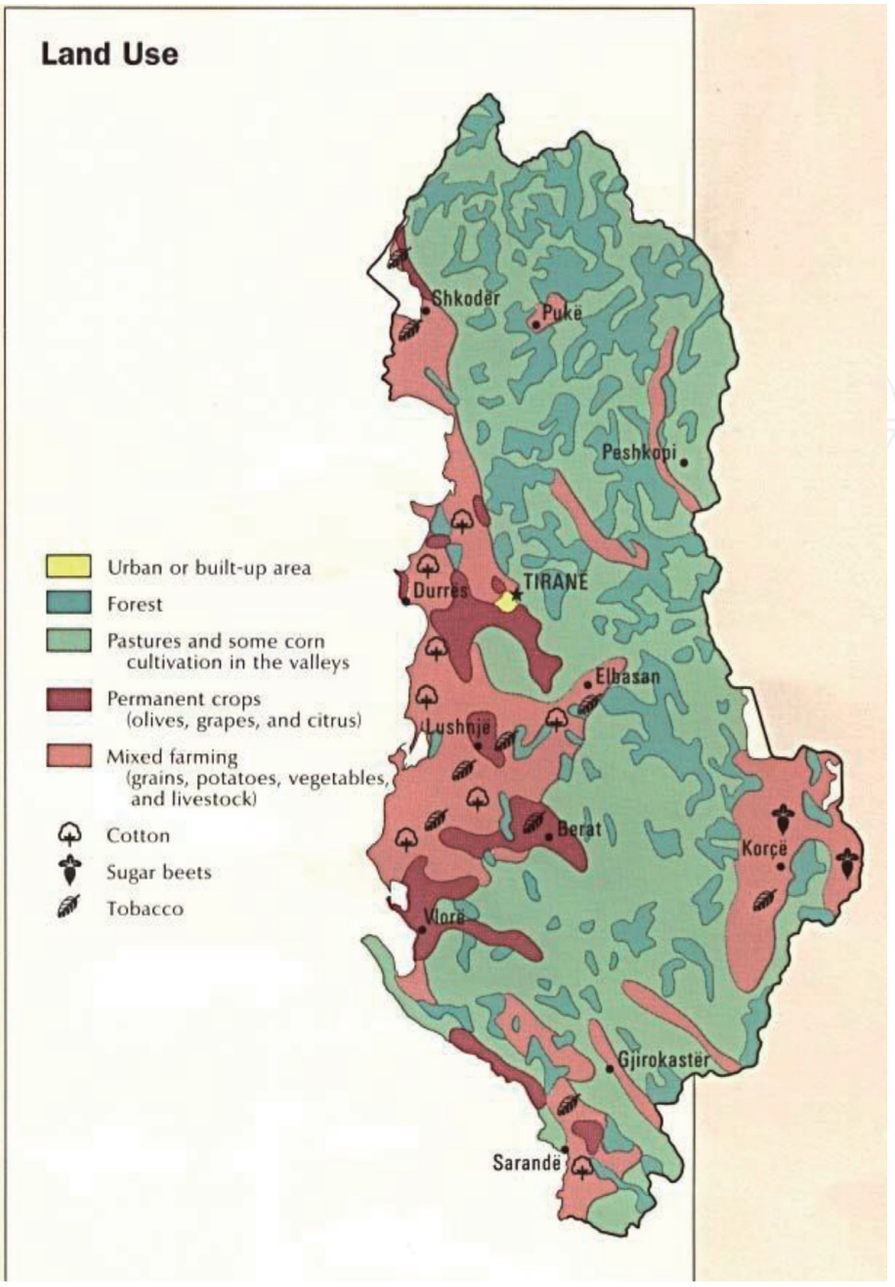

Figure 1.
Land use in Albania [3].

mainland through the river valleys, up to 560 m altitudes. Genetic studies have found 22 native olive cultivars strictly distributed into six regions - Berat, Elbasan, Kruja, Lezha, Tirana and Vlora. Native cultivars, namely: *Boç*, *Frëng, Kalinjot*, *Karre, Kushan, Kotruvs, Kokërrmadh Berati, Mixan, Kokërrmadh Elbasani, Micka, Krips, Managjel, Nisjot, Peperri*, *Ulli deti, Ulli i zi, Ulli bardhë Lezha, Sterbjak, Ulli i kuq, Bardhi Kruja, Bardhi Tirana (Bianco di Tirana)*, and *Ulli i bardhë Berati* [4, 5].

According to their area of plantation, they are classified as 'Principal' and 'Secondary' cultivars. *Kalinjot* is the most distinguished native olive cultivar and is distributed in over 50% of the country's plantation area. Other native cultivars important for the local economies are *Bardhi Tirana* and *Mixan*. *Kokërrmadh Berati* cultivar is the primary representative and consequently the most abundant table olive in Albania. The remaining cultivars presented in the study were classified as Secondary cultivars [5]. Olive cultivation is closely linked with local comunities for a long period. Olive cultivar names are conected with regions, as well as the olive fruit name, in albanian (ulli).

1.1 Olive tree cultivation and production

The olive tree dominates the country's permanent crops with 10.28 million in a total of 13.82 million fruit trees, or 74.4%. The main regions where the olive tree is cultivated are Vlora, Fieri, Berat, and Elbasan (**Table 1**) [6, 7].

The entire agriculture sector and especially permanent crops suffered in the last in the alternation of the 20th century with the 21st the consequences of economic transition (**Figure 2**). The arable land reform distributed the entire area to the small farms. This was a big reverse step toward the permanent crop's cultivation, which suffered the most, with negative consequences such decrease in tree

No	District	Fruit trees	Olives	Citrus	Vineyards (Ha)	Olive share/district
1	**Berat**	1,132	1,949	132	1,155	18.9
2	Dibër	1,521	—	—	2g00	0.0
3	**Durrës**	810	442	102	767	4.3
4	**Elbasan**	1,401	1,644	72	1,368	16.0
5	**Fier**	1,579	2,617	381	2,114	25.4
6	**Gjirokastër**	326	303	2	798	2.9
7	Korçë	3,228	—	—	1,117	0.0
8	Kukës	869	—	—	88	0.0
9	**Lezhë**	460	239	46	406	2.3
10	**Shkodër**	888	425	46	729	4.1
11	**Tiranë**	927	895	99	845	8.7
12	**Vlorë**	680	1,773	642	1,256	17.2
	Country	**13,822**	**10,288**	**1,521**	**10,842**	

Source: [6].

Table 1.
Permanent crops data in 2019 (× 1000).

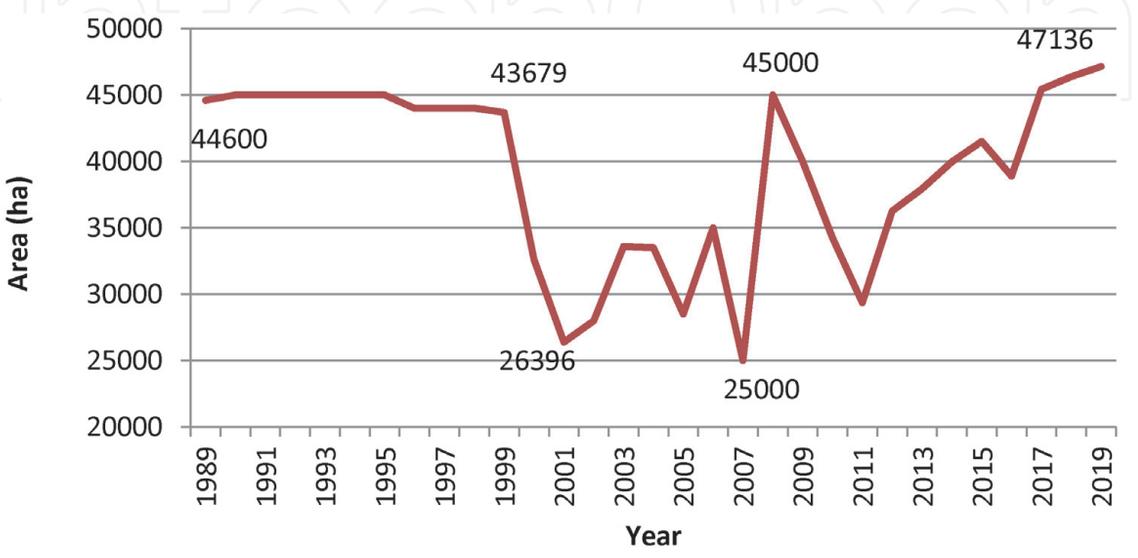

Figure 2.
Area of olive trees during 1989–2019 (in ha) [6].

numbers, and productivity. Only around 2010 because of the central government policy, focusing the priority on agriculture, and especially to crops that countries already have high productivity, the interest in olive culture highly increased. A steady increase was observed in the number of trees and the area planted. Currently, over 47000 ha are planted with olive tree, or 7.6% of the arable land [6, 8].

FAO statistics on olive fruit production ranks Albania the 20th in the world, with 98313 tons. The world production during 2019 harvesting year reached 19.46 million tons, with Albania's contribution of 0.51% [8]. A total of 8.23 out of 10.28 million olive trees are under production [6]. The olive oil production was calculated to as 20,038 tons, contribution up to 95% of domestic demands. Data on olive oil consumption increased to five liters per capita, being the highest level among the non-European Union member countries [9]. With an average production varying to 40,000 tons olive fruit, a sharp increase was evident in 2008 as well as in the following years (**Figure 3**) [10]. A key role to this positive trend was the application of support schemes subsidizing local farmers. Currently the annual production fluctuates in 100000 tons of olives. Intensive production belongs to three regions: Berat (38,000 tons), Fier (33,000 tons) and Vlora (17,000 tons), with figures belonging to 2019 [6].

1.2 Table olive production

The olive fruits are exploited in 79 percent for olive oil production, while the remaining goes to table olives production. Country holds the global record for table olive consumption per capita. According to International Olive Council, table olive consumption was 10.8 kilograms per capita [9]. *Kokërrmadh Berati* cv is the most distinguished native cultivar used as table olive. It is mainly present in the Berati region. Other olive cultivars used as table olive are not industrially processed but used only locally by families. Another important olive cultivar, *Kalinjot* is used both to extract olive oil, as well as table olive. Their nutritional profiles show small differences regarding to the main fatty acids (**Table 2**). Their n/6/n-3 ratio is around 10, showing very good profiles of unsaturated FA, compared to other distinguished olive cultivars worldwide [11]. Both are classified as High-Content Oleic Acid cultivars.

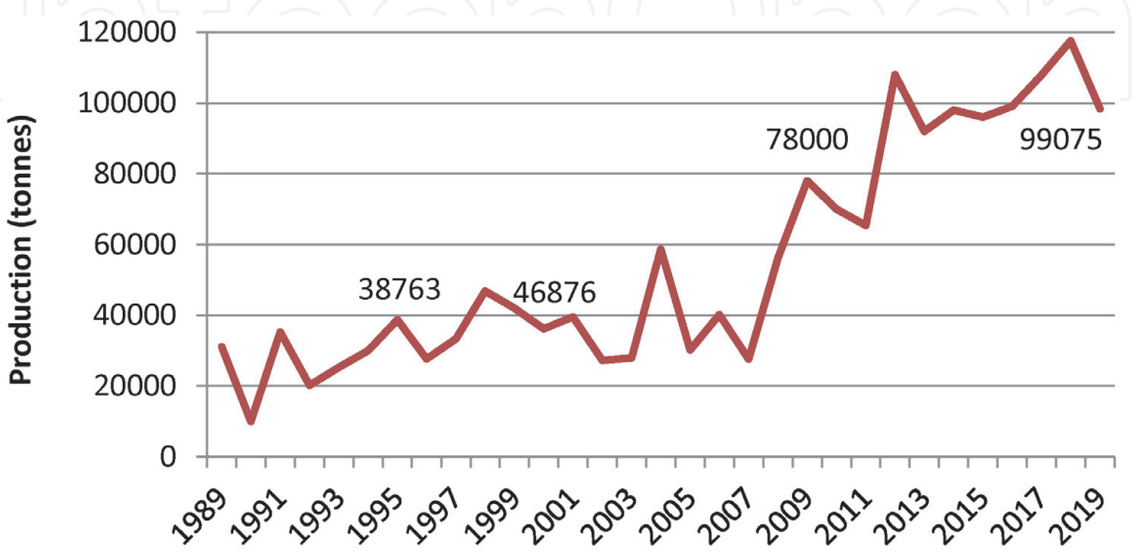

Figure 3.
Annual production for olive fruits during 1989–2019, in Albania [6].

Formula	Kalinjot	*Kokërrmadh Berati*
16:0	10.92	10.41
16:1(n-9)	0.09	0.13
16:1(n-7)	0.48	0.61
17:0	0.04	ND
17:1 (n-7)	0.14	ND
18:0	2.31	2.10
18:1(n-9)cis	75.11	76.26
18:1(n-7)	1.88	2.20
18:2 (n-6)cis	7.56	6.92
20:0	0.36	0.40
18:3 (n-3)	0.72	0.67
20:1 (n-9)	0.31	0.33
22:0	0.08	ND
n-6/n-3	10.47	10.31
Σ-SFA	13.36	12.92
Σ-MUFA	78.01	79.53
Σ-PUFA	8.29	7.59

Table 2.
Fatty acid profiles and nutritional interest of two main table olive cultivars (%).

1.3 Olive oil extraction industry in Albania

OO extraction is organized in small extraction mills, with only 1/3 of their extraction capacity exploited. OO production is reached mainly in Southern and Central parts of the country, comprising Vlora, Fieri, Berati, Elbasani and Tirana regions. These regions, in total they comprise more than 80% of the olive trees in production [12, 13]. The extraction process produces high amounts of Olive Husk (OH) and Olive Mill Wastewaters (OMWW). Their disposal in the environment is a critical issue to the Mediterranean countries. It has been shown that the OMWW disposal into surface waters influence negatively in their biodiversity due to high organic load and toxic substances. The OMWW composition varies qualitatively and quantitatively according to the olive variety, climate condition, cultivation practices, the olive storage time and olive extraction process. Composed of 83–92% water, 4–16% organic matter, and 1–2% minerals, constitute a potential for exploitation as irrigation source and fertilizer in arable lands [13, 14]. Solid residues show high interest if they are used in soil enrichment with potassium (K) and other minerals. Up to 254.85 mg/kg of K, 20 mg/kg magnesium on dry weight basis is found [14, 15].

Regions where the extraction lines are stationed face the deteriorating situation in the environmental conditions. OMWW discharge to surface waters, solid waste disposal produces bad odors on a large perimeter, disturbing the community. The OMWW amounts produced is 125–137 $\times$ 10^6 kg, while the OH approximately to 60 $\times$ 10^6 kg with a fluctuation in a yearly basis [15]. Traditionally, olive husk is used as feedstuff to animals or burned to farmers' houses. Recently, showing the high interest for exploitation of OH by-products, an investment in processing plant is operating at capacity 2.5 ton/hour for production of pellets.

2. Olive oils characterization and authenticity

2.1 *Kalinjot cv.* Olive oils

Unique in its nutritional and sensory characteristics [16], VOO plays a vital role as the primary source of fats in the traditional Mediterranean diet [1, 17].

Kalinjot, the most important olive cultivar, gives the main contribution to the national level on the OO production. It covers 70% of the plantations' structure, to Vlora and Mallakastra regions, and relatively resilient to drought and cold weather (**Figure 4**). Fruit and stone weight, respectively to approximate values of 3.6 g and 0.5 g, with the extractability rate that varies up to 28% w/w. Fatty acid composition for olive oils obtained from different locations from Vlora and Mallakastra regions, in different harvesting years the last decade (**Table 3**) [18–22].

The main fatty acid, Oleic acid, interval is 68.03–76.83%; with linoleic acid interval 7.85–14.22% and palmitic acid interval 8.54–13.62%. The Linolenic acid content range is 0.63–0.89% lying under the value established by EU legislation to olive oil (**Table 3**).

As expected, no statistically significant differences were observed between fatty acids of Kalinjot olive oils, and therefore the data presented refer to all samples analyzed. The distribution of fatty acid composition of the oil samples studied is shown in **Table 1** and covers the normal range expected for olive oil. The Kalinjot OO has a high percentage of oleic acid, with an average value of 74.25 and an interquartile range of 1.899 (the difference between samples percentiles), and a low percentage of linoleic acid, with an average value of 9.788 and an interquartile range of 1.471.

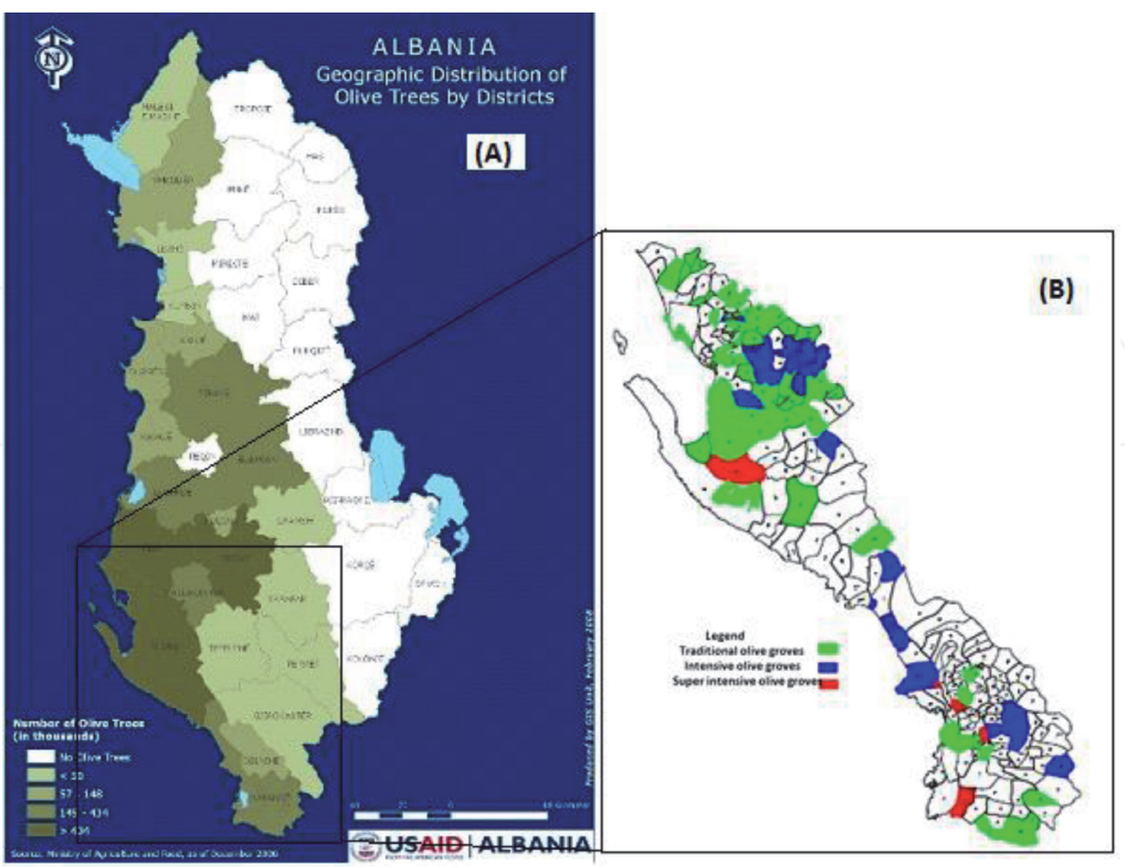

Figure 4.
(A) Olive tree cultivation regions in Albania; (B) Vlora region, classifyed as: traditional, intensive and superintensive groves. Olive tree cultivation regions in Albania, Vlora region [12].

	Mean	SDev	Max	Min
C14:0	**0.00**	0.00	0.00	0.00
C16:0	**10.43**	1.45	13.62	8.54
C16:1	**0.74**	0.53	2.91	0.42
C17:0	**0.11**	0.04	0.16	0.00
C17:1	**0.18**	0.04	0.23	0.07
C18:0	**2.69**	0.29	3.39	2.04
C18:1n9tr	**0.00**	0.00	0.00	0.00
C18:1n9c	**72.44**	2.34	76.83	68.03
C18:1n6c	**1.81**	0.71	3.16	0.00
C18:2n6c	**9.79**	1.47	14.22	7.85
C20:0	**0.47**	0.03	0.53	0.40
C18:3n3	**0.77**	0.06	0.89	0.63
C20:1	**0.38**	0.03	0.43	0.30
C21:0	**0.00**	0.00	0.00	0.00
C22:0	**0.13**	0.01	0.18	0.12
C24:0	**0.06**	0.03	0.09	0.00

Table 3.
Fatty acid mean, maximum and minimum values to Kalinjot OO.

Olive cultivar	Mean
Mixan	139.24 ± 6.56
Frëng	42.78 ± 7.04
Bardhi Kruja	322.05 ± 5.61
Kalinjot	285.16 ± 3.29
Bardhi Tirana	445.03 ± 16.83
Karren	89.74 ± 0.47
Nisjot	203.07 ± 7.51
Kotruvs	226.97 ± 1.40
Kokërrmadh	125.60 ± 6.09

Table 4.
Total phenolic content in OO from native cv (mg gallic acid/kg).

Principal component analysis given in **Figure 5** displayed the distribution of Kalinjot OO samples from different location within regions of Vlora and Mallakastra. As it can be seen in the chart, according to the PCA biplot, the samples were well categorized. The samples coded with numbers 1, 2, 6, 7, 12, 13, 16, 19, 21, 22, 23 and 24 were positioned on the positive F1 axis while the remaining were on the negative F1 axis. In addition to those, samples coded as 29 and 30 were positioned on the negative F1 axis and clearly separated from other OO samples. OO sample (29) belong to Nisjot olive cv., another olive cv of the Vlora and Mallakastra region, while the OO sample (30) belonged to the same olive cultivar, Kalinjot, but from a different geographical region, Central Albania.

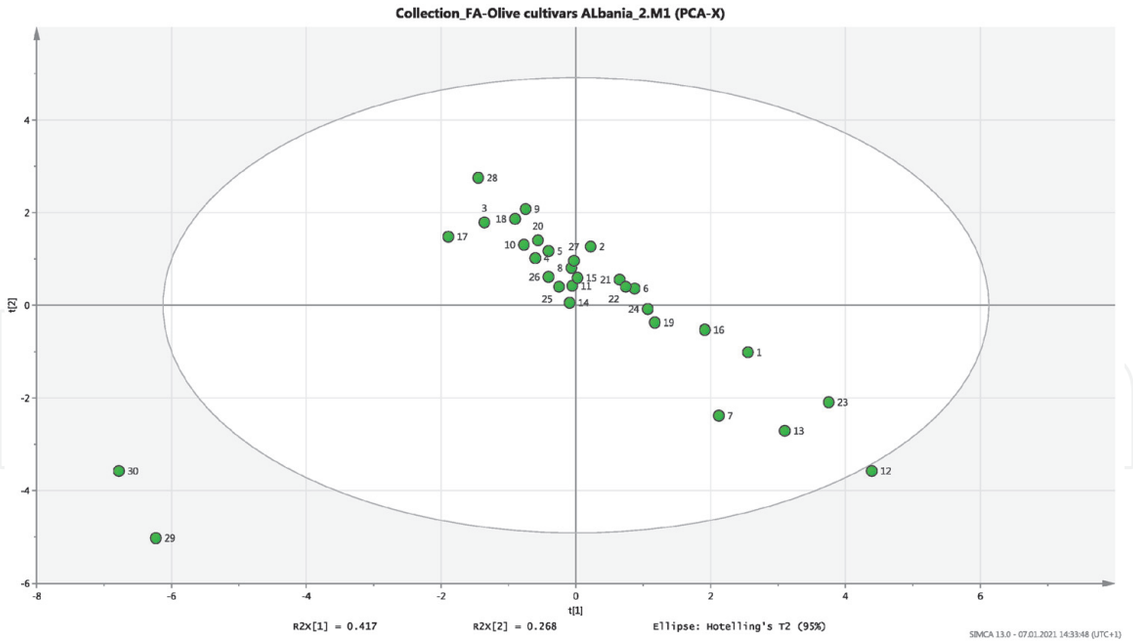

Figure 5.
Sample distribution for Kalinjot OO samples from different locations within regions of Vlora and Mallakastra.

2.2 Fatty acid composition

Fatty acid profiles from twenty-six different olive cv are presented in **Table 6**. Oleic (C18:1), palmitic (16:0), linoleic (C18:2), and stearic (C18:0) acids, are primary FA in decreasing order. Results revealed that the fatty acid content falls in the average percentage intervals described by FAO and IOOC [23]. These olive varieties presented a significant variation in oleic acid (OA). They are clustered into two groups containing Oleic acid, low-OA cultivars: *Krips Kruja* (66.24%) and *Peperri* (66.27%); and high-OA cultivars: *Kalinjot*, *Bardhi Tirana*, *Mixan*, *Frëng*, *Bardhi Kruja*, *Managjel*, *Ulli deti* (from *70.*87 to 76.58%) [24]. Aparacio and Luna [25] have suggested a correlation between the cultivars' chemical composition and the pedo-climatic conditions. These variations are probably more related to genetic factors than to environmental conditions.

Palmitic acid is found at concentrations five to eight-fold lower than OA, i.e., between 9.41% (*Kalinjot*) to 12.87% (*Ulli deti*), with no considerable differences among them. The content of linoleic acid (LA) varied from 5.73% (*Frëng)* to 15.19% (*Krips Kruja*), whereas the content of alfa-linolenic acid showed a small variation from 0.38% (*Ulli deti)* to 0.94% (*Sterbjak*) [11, 24].

Phenolic compounds	*Kalinjot* (Himara)	*Kalinjot* (Vlora)	Bardhi Tirana	Ulli-i-zi	Krips Kruja	Bardhi Kruja
Phenolic alcohols	61.44	84.91	72.31	72.12	34.10	15.68
Phenolic acids	0.95	0.53	1.04	1.21	6.23	12.48
Secoiridoids	135.72	162.50	146.61	170.16	61.70	22.36
Flavonoids	0.19	0.32	0.23	15.85	2.33	0.60
Phenolic aldehydes	0.24	0.08	0.27	0.31	1.64	3.07
Total phenolics	198.54	248.34	220.46	259.65	106.00	54.20

Table 5.
Total phenolic compounds of OO from Albanian olive cultivars (mg/kg).

No.	Sample name	16:0	16:1(n-9)	16:1(n-7)	17:0	17:1 (n-7)	18:0	18:1(n-9)c	18:1(n-7)	18:2(n-6)t	18:2 (n-6)c	20:0	18:3 (n-3)	20:1 (n-9)	22:0
1	Boç	13.05	0.15	0.63	0.12	0.22	2.11	67.65	2.24	0.00	12.46	0.354	0.64	0.2375	0.12
2	Kalinjot (Mkaster)	10.92	0.09	0.48	0.04	0.14	2.31	75.11	1.88	0.00	7.56	0.36	0.72	0.3059	0.08
3	Bardhi Tirana	10.88	0.07	0.35	0.13	0.19	2.83	74.61	1.53	0.00	8.00	0.43	0.58	0.2801	0.07
4	Bardhi Lezha	12.85	0.12	0.97	0.00	0.00	2.53	70.84	2.49	0.00	8.69	0.42	0.86	0.1758	0.04
5	Sterbjak	10.89	0.15	0.64	0.00	0.00	2.21	75.12	2.10	0.00	7.23	0.36	0.94	0.24	0.04
6	Ulli I kuq	12.95	0.10	0.83	0.15	0.24	2.64	66.26	2.28	0.00	13.29	0.41	0.45	0.25	0.12
7	Peperr	12.32	0.09	0.61	0.11	0.17	2.26	66.27	2.09	0.046	14.76	0.39	0.49	0.25	0.13
8	Ulli deti	12.87	0.09	1.17	0.03	0.08	2.29	70.87	2.84	0.02	8.60	0.31	0.38	0.24	0.18
9	Mixan	12.38	0.08	0.51	0.12	0.17	2.88	71.91	1.76	0.01	8.77	0.46	0.51	0.25	0.18
10	Managjel	10.15	0.09	0.34	0.14	0.22	2.72	75.22	1.48	0.05	8.29	0.38	0.50	0.23	0.19
11	Ulli i zi Tirana	11.01	0.09	0.51	0.09	0.16	2.76	70.99	2.03	0.05	10.80	0.38	0.72	0.22	0.14
12	Micka	10.80	0.02	0.61	0.08	0.17	2.30	73.47	2.27	0.03	9.10	0.35	0.54	0.21	0.05
13	Karre	11.17	0.00	0.36	0.14	0.18	3.22	73.94	1.44	0.00	8.35	0.50	0.45	0.24	0.00
14	Kamza	9.27	0.00	0.56	0.12	0.19	2.79	80.32	1.41	0.00	4.08	0.38	0.80	0.07	0.00
15	Kushan	9.12	0.10	0.41	0.05	0.15	3.17	77.15	1.73	0.00	6.95	0.42	0.52	0.22	0.00
16	Nisjot Pobrati	9.93	0.12	0.41	0.00	0.00	2.56	80.07	1.55	0.00	4.10	0.45	0.50	0.31	0.00
17	Kotruvs	12.21	0.09	0.82	0.00	0.00	1.96	71.53	2.87	0.00	9.31	0.37	0.51	0.34	0.00
18	Kokërrmadh Berati	10.41	0.13	0.61	0.00	0.00	2.10	76.16	2.20	0.00	6.92	0.40	0.67	0.33	0.12
19	Leccino	13.09	0.10	1.17	0.00	0.00	1.83	75.12	2.98	0.00	4.68	0.27	0.52	0.22	0.08
20	Krips Kruje	12.09	0.15	0.61	0.12	0.24	2.16	66.23	2.19	0.00	15.19	0.29	0.50	0.19	0.07
21	Ulli i Bardhë Kruje	11.16	0.09	0.55	0.13	0.22	2.35	72.59	1.97	0.00	9.90	0.35	0.43	0.25	0.04
22	Frëng Kruje	9.62	0.12	0.60	0.00	0.00	3.87	76.57	2.14	0.00	5.73	0.54	0.51	0.28	0.04

No.	Sample name	16:0	16:1(n-9)	16:1(n-7)	17:0	17:1 (n-7)	18:0	18:1(n-9)c	18:1(n-7)	18:2(n-6)t	18:2 (n-6)c	20:0	18:3 (n-3)	20:1 (n-9)	22:0
23	Ulli bardhë Pobrati	11.99	0.07	0.38	0.11	0.16	3.18	70.72	1.57	0.00	10.49	0.49	0.47	0.25	0.12
24	Kalinjot (Marikaj)	9.41	0.10	0.26	0.13	0.18	2.98	74.58	1.30	0.00	9.80	0.39	0.56	0.29	0.03
25	Bardhi Tirana (Priskë)	10.71	0.08	0.36	0.12	0.18	3.23	75.62	1.48	0.00	6.99	0.49	0.48	0.24	0.00
26	Ulli I kuq	15.21	0.00	0.94	0.13	0.20	2.37	64.70	2.20	0.00	12.92	0.34	0.64	0.11	0.18
27	Kalinjot (Vlorë)	9.57	0.14	0.26	0.10	0.15	3.02	73.61	1.48	0.00	10.11	0.46	0.75	0.34	0.09
28	Frantoio	14.16	0.05	1.42	0.00	0.00	2.23	71.65	2.90	0.00	6.64	0.29	0.52	0.06	0.14
30	Kalinjot (Panaja)	8.94	0.14	0.22	0.14	0.20	3.27	75.41	1.28	0.00	8.85	0.48	0.72	0.34	0.07
31	Nisjot	15.22	0.00	0.94	0.13	0.20	2.38	64.71	2.20	0.00	13.24	0.34	0.54	0.11	0.01
33	Kalinjot (Mallakastra)	10.38	0.11	0.50	0.09	0.15	2.80	74.41	1.78	0.00	8.36	0.42	0.69	0.30	0.00
	Mean	11.44	0.09	0.61	0.08	0.13	2.62	72.69	1.99	0.01	9.04	0.40	0.58	0.24	0.08
	Max	15.22	0.15	1.42	0.15	0.24	3.87	80.32	2.98	0.05	15.19	0.54	0.94	0.34	0.19
	Min	8.94	0.0	0.22	0.0	0.0	1.83	64.7	1.28	0.0	4.08	0.27	0.38	0.06	0.0

Table 6.
Fatty acid profiles for OO rom different cultivars (%).

Results showed a similarity among Albanian studied cultivars and other cultivars from Italy and Greece [25]. Comparison of olive cultivars from this region with data of cultivars from the Southern Mediterranean showed a profile with a high content of polyunsaturated fatty acids [26, 27]. Statistical analyses revealed differences among the cultivars for individual fatty acids ($p < 0.05$) (**Table 6**): only the primary fatty acids, C16:0, C18:1 (n-9), and C18:2 (n-6), presented differences among each other statistically.

Foreign olive cultivars were introduced last century during sixties, with two Italian cv. *Frantoio* and Leccino. Nowadays this olive cultivars are well adopted. Palmitic acid concentrations are higher 13,09% (*Leccino*) and 14.16% (*Frantoio*) compared to OO from native olive cv. There is a similarity in respect to OA among two foreign cv and others, while their LA concentrations were very low 4.68% (*Leccino*) and 6.64% (*Frantoio*), compared to OO from Albanian olive cultivars. The content of alfa-LA acid was 0.52% from both foreign cultivars [19].

A similarity was found in FA profiles among Albanian OO from native cultivars and OO from Italy and Greece [24]. In our study, the comparison of olive cultivars with cultivars' data from the Southern coast of the Mediterranean Sea showed a profile with a high content of polyunsaturated fatty acids [26, 27]. Statistical analyses reveal differences among the cultivars for individual fatty acids ($p < 0.05$) (**Table 6**): only the primary fatty acids, C16:0, C18:1 (n-9), and C18:2 (n-6), presented differences among them statistically.

Different authors suggest the ratio C18:1/C18:2 on evaluating VOO's oxidative stability, with a proposed minimum accepted value of 7.0. Among Albanian OO, two olive cultivars, *Frëng,* and *Nisjot* exhibited higher values, 13.37 and 19.54, respectively, while the remaining cultivars produced monovarietal olive oil with good oxidative stability. Only two olive cultivars, *Krips,* and *Peperr,* exhibited lower values, 4.4 and 4.5, respectively [11, 19].

Principal component analysis (PCA) was applied in order to determine the relations between fatty acid compositions in the OO samples. Based on the results of the PCA, two different principal components were determined, and these two components described 95% of the total variability of the experimental data. The PCA biplot of the fatty acids detected in the OO samples is shown in **Figure 6**. According to the PCA biplot, OO samples were well categorized. As seen in

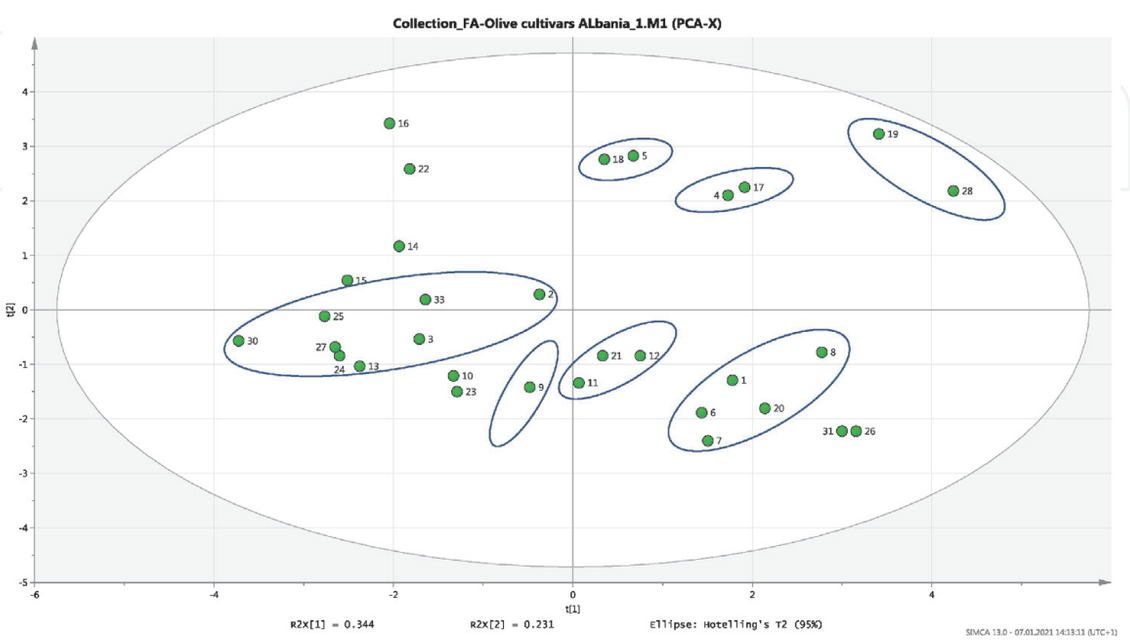

Figure 6.
PCA of FA profiles obtained from OO of different olive cultivars present in Albania.

Figure 6 and **Table 6**, the OO samples coded as 1, 4, 5, 6, 7, 8, 11, 17, 18, 19, 20, 21, 26, 28 and 31 were positioned on the positive F1 axis while the other OO samples were on the negative F1 axis.

Regarding the cultivar *Kalinjot*, OO samples have been taken from some regions of the country, because this cultivar is more widespread and more productive for olive oil. OO *Kalinjot* cv from Vlora region, no 2, and *Kalinjot* cv from Mallakastra region, no 33, fall very close, indicating the opportunity to produce OO with designated origin. OO samples no 24, 27 and 30, belonging to Kalinjot cv, fall together, telling the possibility yo produce OO from this cultivar and to authenticate them (**Table** 7). The same interesting picture belong two samples belonging to *Bardhi*

Sample nr.	Location	Harvesting season	Geographical coordinate
1	Hoshtim	2014	40° 32′ 28” North, 19° 29′ 9″ East
2	Drashovice	2014	40° 26′ 49” North, 19° 34′ 52″ East
3	Tragjas	2014	40° 19′ 32” North, 19° 30′ 36″ East
4	Trevellazer-2	2014	40° 34′ 46” North, 19° 30′ 40″ East
5	Vezhdanisht	2014	40° 29′ 11” North, 19° 36′ 37″ East
6	Kanina	2014	40° 26′ 23” North, 19° 31′ 8″ East
7	Kanina	2015	40° 26′ 23” North, 19° 31′ 8″ East
8	Panaja	2014	40° 32′ 13” North, 19° 28′ 20″ East
9	Kerkove	2014	40° 31′ 49” North, 19° 30′ 6″ East
10	Rromes	2015	40° 31′ 11” North, 19° 40′ 1″ East
11	Bestrove	2015	40° 31′ 4” North, 19° 29′ 3″ East
12	Babice	2015	40° 29′ 5” North, 19° 30′ 51″ East
13	Lubonje	2015	40° 30′ 28” North, 19° 34′ 20″ East
14	Bestrove-1	2014	40° 31′ 4” North, 19° 29′ 3″ East
15	Bestrove-2	2014	40° 31′ 4” North, 19° 29′ 3″ East
16	Himare	2014	40° 6′ 6” North, 19° 44′ 41″ East
17	Panaja	2015	40° 32′ 13” North, 19° 28′ 20″ East
18	Peshkepi	2014	40° 28′ 22” North, 19° 35′ 8″ East
19	Kanina-3	2014	40° 26′ 23” North, 19° 31′ 8″ East
20	Qeparo	2014	40° 3′ 25” North, 19° 49′ 19″ East
21	Kerkove	2014	40° 31′ 49” North, 19° 30′ 6″ East
22	Trevellazer	2014	40° 34′ 46” North, 19° 30′ 40″ East
23	Armen	2014	40° 32′ 11” North, 19° 35′ 46″ East
24	Vllahine	2014	40° 27′ 25” North, 19° 38′ 37″ East
25	Kanina-2	2014	40° 26′ 23” North, 19° 31′ 8″ East
26	Rromes	2014	40° 31′ 11” North, 19° 40′ 1″ East
27	Kanina	2015	40° 26′ 23” North, 19° 31′ 8″ East
28	Panaja	2015	40° 32′ 13” North, 19° 28′ 20″ East
29	Nisjot cv	2014	40° 33′ 32” North, 19° 40′ 53″ East
30	Marikaj-Vorë	2014	41° 22′ 20” North, 19° 37′ 56″ East

Table 7.
Sampling sites for OO Kalinjot cv. to the Vlora and Mallakastra regions..

Tirana cv, no 3 and 25, harvested from the region with the same name. OO samples respectively olive cultivars *Boç* (1), *Ulli i kuq* (6), *Peperr* (7), *Ulli deti* (8) belonging to coastal regions of Durres fall together with the olive cv from Kruja region, no 20 (*Krips Kruja*). Another interesting conclusion is similarity among OO samples belonging to olive cv from Tirana region *Ulli i zi Tirana* (11), *Micka* (12) with the olive cv *Bardhi Kruja* (21), from region with the same name. Three regions Tirana, Kruja and Durres, fall very close, Central Albania, while the olive cv show their expansion route. Through PCA box plot is found another connection among olive cv from Berat and Lezha regions. There are similarities among OO samples coded 5 (Sterbjak, Lezha region and 18, Kokerrmadh Berati, as well as OO no 4, Ulli bardhe Lezha, and 17, Kotruvs, Berati. OO no 9 belonging to Mixan cv., that belongs to Elbasan geographical region si different compared to other monocultivar OO. Very interesting is the isolation of two introduced Italian olive cv *Leccino* (19) and *Frantoio* (28).

2.3 Phenolic compounds in Albanian OO

Phenolic compounds in Olive oils usually range between 50 and 1000 ppm (mg/kg) depending on the cultivars, pedoclimatic conditions, maturity stage of the fruit, and extraction conditions [28]. OO is celebrated not only for its nutritional value but also for the content of minor compounds of pharmacologically active principles, belonging to the nutraceutical family, otherwise known as functional foods, such as polyhydroxylated phenolic and catecholic species [17] (**Figure 7**). A variety of over 230 chemical compounds, approx. 2% of the weight found in the VOO's unsaponifiable fraction, such as polyphenols, tocopherols, sterols, flavors [29–31]. Polyphenols present in VOO, are classified into two groups: lipophilic phenols (tocopherols) and hydrophilic or polar phenols [32, 33]. The hydrophilic phenols (HP) present in the VOO belong to different classes: phenolic acids, phenyl ethyl alcohols, secoiridoids, hydroxy-isochromans, flavonoids, and lignans [31]. Phenolic compounds show many health benefits, including reducing the risk factors of coronary heart disease, the prevention of several chronic diseases (for example,

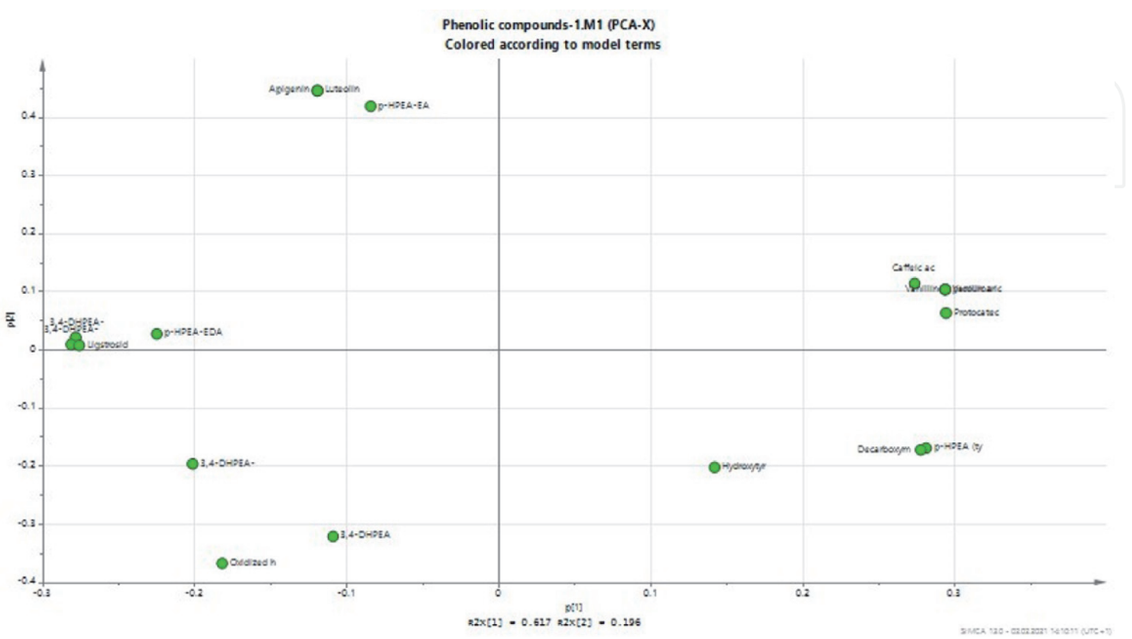

Figure 7.
PCA of phenolic compounds in six OO from Albanian native olive cv.

atherosclerosis), cancer, chronic inflammation, strokes, and other degenerative disorders [29, 34]. EFSA has concluded that polyphenols in olive are the health claims' subject. The claimed effects are "reduces oxidative stress," "antioxidant properties," "lipid metabolism," "antioxidant activity, they protect body cells and LDL from oxidative damages." An amount of 5 mg hydroxytyrosol and its derivatives (e.g., oleuropein complex and tyrosol) in olive oil should consume daily to bear the claim [35].

Results on Total Polyphenol Content (TPC) indicate that *Bardhi Tirana* variety presented the highest values, 445.03 ± 16.83 mg/kg Gallic Acid in olive oil. In contrast, *Frëng* cultivar shows the lowest levels, 42.78 ± 7.04 mg GAE/kg olive oil (**Table 4**). Results also show significant differences among cultivars, which may correlate to the cultivar, rather than agriculture practices or other factors. The comparison of TPC content in the ten studied cultivars with different cultivars, already published from Albania [18], and neighboring countries reveal that these cultivars are like cultivars from the Toscana Region (Italy) and Dalmatian Coast (Croatia) [26]. *Montedoro et al.* [36] have grouped the monovarietal olive oils according to the three groups' total phenol content. A classification for studied VOO is: "low" (50–200 mg/kg) *Ulli i Zi, Frëng, Krips, Mixan,* and *Peperri* cultivars; "medium" (200–500 mg/kg) *Bardhi Tirana, Bardhi Kruja*, *Managjel, Kalinjot,* and *Ulli deti* cultivars. The results obtained for the studied cultivars relate mainly to the cultivar differences. The results show that the studied olive oils' polyphenol content had significant differences ($p < 0.05$) among the cultivars. The actual stage of agriculture in Albania does not have a premise for irrigation of the olive plantations. Furthermore, concerning the maximum and minimum temperature values in the different regions, respectively, gives evidence that differences are not significant; hence, differences reported on the TPC content do not come due to climatic conditions. The TPC values of *Bardhi Tirana* are comparable with *Koreiniki* (Greece), *Picual* (Spain), and *Frantoio* (Italy) cultivars [25, 26].

Data on Total Polyphenol Content (TPC) indicate that OO from *Bardhi Tirana* cv present high values, 445.03 ± 16.83 mg GA/kg OO. In contrast, *Frëng* cv OO has the lowest levels, 42.78 ± 7.04 mg GA/kg (**Table 4**) [18, 19]. Total phenolic content in OO compared with OO from neighboring countries reveals that these cultivars are similar to cultivars from the Toscana Region (Italy) and Dalmatian Coast (Croatia) [26]. TPC values among studied cultivars resulted in statistically different. *Montedoro et al.* (*1992*) have grouped the monovarietal olive oils according to the three groups' total phenol content. The studied cultivars are classified as: "low" (50–200 mg/kg) *Frëng and Mixan* cultivars; "medium" (200–500 mg/kg) *Bardhi Tirana, Bardhi Kruja*, and *Kalinjot* olive cultivars. The results obtained can be related mainly to the cultivar differences. The results show that the studied olive oils' polyphenol content had significant differences ($p < 0.05$) among the cultivars. *Bardhi Tirana* samples are comparable with *Koreiniki* (Greece), *Picual* (Spain), *Frantoio* (Italy) and *Memecik*, *Ayvalik* and *Gemlik* (Turkey) cultivars [25, 26, 36].

Studying of Albanian OO from different cultivars by LC-DAD-ESI-MS/MS of has found the presence of 18 phenolic compounds. Based on their chemical structure, they were grouped as secoiridoids (6), phenolic alcohols (5), phenolic acids (4), flavonoids (2), and phenolic aldehyde (1) [37]. The highest amount of phenolic compounds was determined in *Ulli-i-Zi* cv. from Tirana region (259.65 mg/kg) followed by *Kalinjot* cv. from Vlora region (248.34 mg/kg), *Bardhi Tirana* cv. from Tirana region (220.46 mg/kg), *Kalinjot* cv. from Himara region (198.54 mg/kg), *Krips Kruja* cv. from Kruja region (106.00 mg/kg) and *Bardhi Kruja* cv. from Kruja region (54.20 mg/kg) (**Table 5**) [38].

In the study conducted by Topi et al., (2020), the results on phenolic compounds agreed with the same concentration pattern of all VOO in the literature with

the highest being *3,4-DHPEA-AC* (76.03 mg/kg), followed by *3,4-DHPEA* (11.36 mg/kg), *p-HPEA* (7.01 mg/kg), oxidized hydroxytyrosol (1.53 mg/kg) and the last as hydroxytyrosol quinone (1.21 mg/kg). The highest values for 3,4-*DHPEA-AC* (76.03 mg/kg) belonged to *Kalinjot* cv. from the Vlora region, followed by *Ulli-i-Zi* cv. (65.17 mg/kg). Phenolic alcohol pattern in Albanian VOOs is consistent with published data from Spanish cv. *Picual* [39], Turkish cv. *Halhali* [40] and Croatian olive oils [41]. Hydroxytyrosol levels (3.97–11.36 mg/kg) in the *Kalinjot* cv. VOO samples, in both regions, were observed higher when compared with different Greek olive *cvs*. [40], yet exhibited a lower value compared to Croatian olive oils *Krvavica* cv. (14.9–21.9 mg/kg) [41].

Additionally, PCA was applied to generate models for the classification of OO samples in terms of total phenolic contents. It can be observed that three groups were mainly formed on the plot, of these, *Krips Kruja* and *Bardhi Kruja* cv. as a group were positioned on the positive F1 axis, while the remaining samples were located on the negative axis. The formation of this group is expected as these two *cvs*. Had the lowest values of total phenolic content. On the other hand, *Ulli-i-Zi* cv. is seen to be clearly separated from the others, expectedly as it had the highest content of phenolics.

2.4 Olive oil aroma compounds

Aroma compounds are the main criteria affecting consumer acceptance and preference and also their purchasing power remarkably. Investigation on aroma compounds in *Kalinjot* and *Bardhi Tirana* OO indicate the aroma differences between oils obtained from two main Albanian olive varieties from different regions. (*E*)-2-hexenal is found as the principal compound in both these olive *cvs.* [13]. A total of 24 aroma compounds in *Kalinjot cv*. comprising: aldehydes, alcohols, ketones, esters, terpenes, phenols, and alkenes were detected; meanwhile, in *Bardhi Tirana cv*. 17 aroma compounds including aldehydes, alcohols, esters, and phenols. The aroma compounds in Kalinjot OO varied from 36700 to 40411 μg/kg, much higher compared to Bardhi Tirana *cv*. OO (27542.7 μg/kg). Different regions and varieties play a key role in the concentration and profile of volatile compounds in the samples under study. (*E*)-2-Hexanal in *Kalinjot* (37.2–39.1%) and *Bardhi Tirana* OO (55.5%) is found lower comparing with Italian Leccino *cv*. (73%) [41], but higher compared to Croatian OO from Masnjaca cv (27.6–28.9%) [42]. Volatile compounds present in high concentrations to Kalinjot *cv.* OO 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%) [13].

Total alcohols in *Kalinjot* OO vary between 6903 and 9375 μg/kg, and in *Bardhi Tirana* OO 6874 μg/kg. The main C-5 alcohol resulted is 3-penten-2-ol in the range 2504–3442 μg/kg. This alcohol was found in higher levels compared to olive oils from Greek, Italian and Spanish olive cultivarssuch as Croatian cv. *Coratina* [43], Italian cv. *Leccino*, Spanish *cv. Cornicabra* and *Arbequina*, Greek *cv. Koroneiki* and *Adramytini* [39], and Turkish *cv*. *Halhali*, [44]. Total content of terpenes in Kalinjot OO varies 1895–2941 μg/kg, while the presence of *β*-ocimene may serve to distinguish OO both in olive cv and region. Terpene compounds give olive oils characteristic floral odors. (*E*)-3-Hexenyl acetate and methyl salicylate are two esters found in OO from both *Kalinjot* and *Bardh Tiranai* cultivars. Another ester found only in OO from Kalinjot is 2-butoxyethyl acetate. (*E*)-3-hexenyl acetate concentrations vary between 2705 and 3555 μg/kg in Kalinjot OO, while are found in lower levels to *Bardhi Tirana* OO (1107.7 μg/kg). The esters concentration compared with Greek cultivars is lower, however, higher when compared with Italian and Spanish

cv. [42]. This ester compound gives olive oils pleasant and fruity odor notes. In conclusion, 2-butoxyethyl acetate may use as molecular marker to distinguish OO from these two cultivars.

3. Conclusions

Despite the modest contribution in global OO production, world ranking 20th, olive tree comprises an important permanent crop with considerable potential for the Albanian economy. OO with certified origin will increase the value of the final product. With a contribution of 0.51% to total world production, OO production reached 20,038 tons contributing almost to 95% of domestic demands. Interestingly, table olive consumption ranks the country the 1st in world. Principal component analyses (PCA) for OO samples from Kalinjot cv. displayed the differentiation with OO samples. The authenticity of OOs originating from Vlora region constitutes an opportunity for domestic production. In parallel, PCA of OO from different native and foreign olive cv. displayed differentiation regarding fatty acids.

Phenolic compounds found to be significantly different among the olive oil samples of different cultivars. *3,4-DHPEA-AC* was determined as the main phenolic compound. Secoiridoids are found in abundance, *3,4-DHPEA-EDA* and *p-HPEA-EDA* as dominant compounds, especially in *Kalinjot* OO. It was found that Albanian VOOs had lower levels of flavonoids consisting of luteolin and apigenin. Studies in OO aroma compounds from main cv indicate that Albanian OO is considered with high content OO with aroma compounds. (*E*)-2-hexenal is found as the principal aroma compound. *Kalinjot* OO concentrations vary between 36700 and 40411 μg/kg, much higher compared to *Bardhi Tirana* OO (27542.7 μg/kg).

Author details

Dritan Topi[1*], Gamze Guclu[2], Hasim Kelebek[3] and Serkan Selli[2]

1 Department of Chemistry, Faculty of Natural Sciences, University of Tirana, Tirana, Albania

2 Department of Food Engineering, Faculty of Agriculture, Cukurova University, Adana, Turkey

3 Department of Food Engineering, Faculty of Engineering, Adana Alparslan Turkes Science and Technology University, Adana, Turkey

*Address all correspondence to: dritan.topi@unitir.edu.al

References

[1] Tous J: The influence of growing region and cultivar on olives and olive oil characteristics and their functional constituents. In: Olives and olive oil as functional foods: bioactivity, chemistry, and processing. Edited by: A. Kiritsakis, F. Shahidi. Chichester, UK, Hoboken, NJ. John Wiley & Sons, 2017.

[2] Therios I: Olives. CABI, UK; 2009. pp. 425.

[3] Map of Land Use in Albania. http://www.lib.utexas.edu/maps/atlas_east_europe/albania-landuse.jpg) University of Texas. 1990.

[4] Kafazi N: *Vecorite morfologjike dhe agrobiologjike te varieteteve te Ullirit*. Tirana: ILB, 1980.

[5] Thomaj F. Panajoti Dh. *Olive cultivars* (1 ed). Tirana: ILB; 2003. ISBN 99927 941 86.

[6] Agriculture Statistical Yearbook; 2020. Source of information: Ministry of Agriculture and Rural Development. http://www.instat.gov.al/media/3658/statistical-yearbook-2020.pdf.

[7] FAO (2018): Accessed on the web address: http://www.fao.org/faostat/en/#data/QC

[8] Wordbank; 2020. https://data.worldbank.org/indicator/AG.LND.ARBL.HA?locations=AL. (Access on 19/01/2021).

[9] OLIVE COUNCIL; 2020. https://www.internationaloliveoil.org/wp-content/uploads/2020/12/OT-W901-23-11-2020-C.pdf

[10] MACP (Ministry of Agriculture and Consumer Protection). Study on the actual olive tree cultivation and its perspectives in Albania. 2009. (in Albanian).

[11] Topi D, Thomaj F, Shabani M, Carvalho AP, Gomes AM: The analytical and nutritional study of the Albanian autochthonous table olive *Kokërmadh Berati*. *Proceedings of 6th Central European Congress on Food-CEFood Congress*. 2012a. Novi sad, Serbia.

[12] MAFCP; 2009: Study on actual Olive cultivation and its developing perspectives. Ed: Ministry of Agriculture, Food and Consumer Protection. Tirana. Albania.

[13] Topi D, Amanpour A, Kelebek H, and Selli S: Screening of aroma profiles in Albanian cvs. Kalinjot and Bardhi Tirana olive oils using purge and trap extraction technique. *RISG Rivista Italiana Sostanze Grasse*; 2019;96(2):101-108.

[14] Dermeche S, Nadour M, Larroche C, Moulti-Mati F, Michaud P: Olive mill wastes: Biochemical characterization and valorization strategies. *Process Biochemistry*; 2013; 48:1532-1552.

[15] Topi D, Beqiraj I, Seiti B, Halimi E: Environmental impact from olive mills waste disposal, chemical analysis of solid wastes and wastewaters. *Journal of Hygienic and Engineering Design*. 2014; 7: 44-48.

[16] Bendini A, Cerretani L, Carrasco-Pancorbo A, Gómez-Caravaca A. M, Segura-Carretero A, Fernández-Gutiérrez A: Phenolic Molecules in Virgin Olive Oils: A Survey of Their Sensory Properties, Health Effects, Antioxidant Activity, and Analytical Methods. An Overview of the Last Decade. *Molecules*; 2007; 12:1679-1719.

[17] Sindona G: A marker of Quality of Olive oils: The Expression of Oleuropein. In: Olives and Olive oil in Health and Disease Prevention. Editors V. R. Preedy and R. R. Watson. Elsevier. London, UK. 2010. pp. 95-100.

[18] Topi D, Thomaj F, Carvalho AP. Gomes A: Analytical Evaluation of Six

Monovarietal Virgin Olive Oils from Kruja Region in Albania. *2nd International ISEKI_ FOOD Conference*. 2011a. Milano, Italy.

[19] Topi D, Thomaj F, Halimi E: Virgin Olive Oil production from the major olive varieties in Albania. *Poljoprivreda i Sumarstvo*; 2012b; 58(2):87.

[20] Velo S. and Topi D: Study of *Kalinjot* extra virgin olive oil, fatty acids profiles, and trans-isomers. *Journal of Hygienic and Engineering Design,* 2015;12:129-135.

[21] Velo S. and Topi D: Analytical study of *Kalinjot* olive cultivar in the southern regions of Albania. III International Congress, "Food Technology, Quality, and Safety," 2016. 25-27.

[22] Velo S. and Topi D: Characterization of *Kalinjot* and *Nisiot* Monocultivar Virgin Olive Oils produced in Albania. *Asian Journal of Chemistry;* 2017; 29 (6), 1347-1350.

[23] Angerosa F, Campestre Ch, Giansante L: Analysis and Authentication. In Boskou B. *Olive Oil Chemistry and Technology,* Champaign, USA: AOCS Press; 2006; Vol. 1, pp. 450.

[24] Topi D, Thomaj F, Carvalho AP, Gomes A: Characterization of olive varieties from Albania: Fatty acid profile and total phenolic content. *Food Technologists, Biotechnologists and Nutritionists*; 2011b. 185.

[25] Aparicio R, and Luna. G: Characterization of monovarietal virgin olive oils. *European Journal of Lipid Science and Technology*. 2002; 104: 614–627.

[26] Pinelli P, Galardi C, Mulinacci N, Vincieri FF, Cimato A, Romani A: Minor polar compound and fatty acid analyses in monocultivar virgin olive oils from Tuscany. *Food Chemistry*; 2003; **80**: 331-336.

[27] Haddada M, Krichène Dh, Manai H, Oueslati I, Daoud D, Zarrouk M: Analytical evaluation of six Monovarietal virgin olive oils from Northern Tunisia. *European Journal of Lipid Science and Technology*; 2008; **110** (10):905–913.

[28] Kiritsakis AK, Nauos GG, Polymenoupoulos Z, Thomai T, Sfakiotakis EY: Effect of fruit storage conditions on olive oil quality. *Journal of American Oil Chemists Society*; 1998; **75**: 721-724.

[29] Servili M. Sordini B. Esposto S. Urbani S. Veneziani G. Di Maio I. Selvaggini R. Taticchi A: Biological Activities of Phenolic Compounds of Extra Virgin Olive Oil. *Antioxidants*, 2014;3:1-23. doi:10.3390/ antiox3010001.

[30] De Medina V, Priego-Capote F, de Castro L: Characterization of monovarietal virgin olive oils by phenols profiling. *Talanta*; 2015; 132:424–432.

[31] Del Monaco G, Officioso A, D'Angelo S, La Cara F, Ionata E, Marcolongo L, Squillaci G, Maurelli L, Morana A: Characterization of extra virgin olive oils produced with typical Italian varieties by their phenolic profile. *Food Chemistry*. 2015; 184:220–228.

[32] Seguera-Carretero A, Memendez-Menendez J, Fernandez-Gutierrez A: Polyphenols in Olive Oil: The importance of phenolic compounds in the chemical composition of olive oil. In: In Olives and Olive oil in Health and Disease Prevention. Editors: V. R. Preedy and R. R. Watson. Elsevier. London, UK. 2010; Pp. 167-175.

[33] El Riachy M, Priego-Capote F, Leon L, Rallo L, Luque de Castro MD: Hydrophilic antioxidants of virgin olive oil. Part 1: Hydrophilic phenols: A key factor for virgin olive oil quality. *European Journal of Lipid Science and Technology*. (2011; **113**:678–691

[34] Cicerale S, Conlan X.A, Sinclair AJ. Keast RS: Chemistry and health of olive

oil phenolics. *Critical Reviews in Food Science and Nutrition*. 2009; 49(3): 218-236. DOI: 10.1080/10408390701856223.

[35] EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA), *EFSA Journal*, 2011;9(4):2033 (25 pp.). doi: 10.2903/j.efsa.2011.2033. Available online: www.efsa.europa.eu/efsajournal.

[36] Kelebek, H., Kesen, S., & Selli, S. Comparative study of bioactive constituents in Turkish olive oils by LC-ESI/MS/MS. *International Journal of Food Properties*, 2015; **18**(10), 2231-2245.

[37] Montedoro, G, Servilli, M, Miniati, E: Simple and hydrolysable Phenolic Compounds in Virgin Olive oil. 1. Their extraction, separation, and quantitative and semi quantitative evaluation by HPLC. *Journal of Agriculture and Food Chemistry*. 1992;*40:*1571-1576.

[38] Topi D, Guclu G, Kelebek H, Selli S: Comparative elucidation of phenolic compounds in Albanian olive oils using LC-DAD-ESI-MS/MS. *Journal of Liquid Chromatography & Related Technologies;* 2020; 43(5-6):203-212.

[39] Oliveras-Lopez J, Innocenti M, Giaccherini C, Ieri F, Romani, A, Mulinacci N: Study of the phenolic composition of Spanish and Italian monocultivar Extra Virgin Olive Oils: Distribution of lignans, secoiridoidic, simple phenols, and flavonoids. *Talanta*. 2007; **73**:726–732

[40] Bayram B, Esatbeyoglu T, Schulze N, Ozcelik B, Frank J, Rimbach G: Comprehensive Analysis of Polyphenols in 55 Extra Virgin Olive Oils by HPLC-ECD and Their Correlation with Antioxidant Activities. *Plant Food Hum Nutr.* 2012; **67**:326–336

[41] Kulisić-Bilusić T, Melliou E, Giacometti J, Causević A, Corbo S, Landeka M, Magiatis P: Phenolics, fatty acids, and biological potential of selected Croatian EVOOs. *European Journal of Lipid Science and Technology*. 2017; **119**(10):1700108.

[42] Luna, G, Morales, MT, & Aparicio, R: Characterization of 39 varietal virgin olive oils by their volatile compositions. *Food Chemistry*. 2006;*98*:243–252.

[43] Sarolić M, Gugić M, Tuberoso G, Jerković I, Suste M, Marijanović Z, & Kuś M: Volatile Profile, Phytochemicals and Antioxidant Activity of Virgin Olive Oils from Croatian Autochthonous Varieties *Masnjaca* and *Krvavica* in comparison with Italian Variety Leccino. *Molecules*. 2014;*19*:881–895.

[44] Kesen S, Kelebek H, & Selli S: Characterization of the volatile, phenolic and antioxidant properties of monovarietal olive oil obtained from cv. *Halhali*. *Journal of American Oil Chemists' Society*. 2013;*90*:1685–1696.