Project co-financed by the European Regional Development Fund

ARISTOIL

"Reinforcement of Mediterranean olive oil sector competitiveness through development and application of innovative production and quality control methodologies related to olive oil health protecting properties"

PRIORITY AXIS:

OBJECTIVE: The guide for production and quality control of olive oil with increased health protecting properties, which will be published for use by all stakeholders.

Project website: http://aristoil.interreg-med.eu/

DELIVERABLE Number: 4.1.1
Title of DELIVERABLE: Testing report

ACTIVITY n.: 4.1

WP n.: 4

PARTNER IN CHARGE: University of Cordoba

PARTNERS INVOLVED: All partners

Status:

Draft ×	*Final* □	*Version n. 01*

Distribution:

Confidential □	*Public* ×	

Date: 15/01/2020

Introduction

This document summarizes the main results achieved during the Testing phase ascribed to WP4 "Testing" according to the activities developed by the two certification centers located at University of Athens (Greece) and University of Cordoba (Spain). In WP4 "Testing" one of the main purposes was the application of the guide for production of olive oil with increased healthy properties generated as deliverable in WP3 by producers for one harvest in order to detect an increase of phenolic content in olive oil. This pilot phase was initially executed with samples produced in the 2018/2019 agronomical season. Samples should be analyzed by the certification centers set up in 3.3 that also operated under pilot phase. The expected number of samples for this period was 1000, which should come from all participating countries. The obtained results should be used for the evaluation of the pilot phase and extraction of the final conclusions about the methods for production and analysis of olive oil.

However, two main aspects modified this previously planned scheme. These were:

- Substantial increase in the number of expected samples for this period. To evaluate the influence of agronomical and climatological factors on the phenolic content of olive oil, the number of samples was substantially increased from 1000 to 2469 samples. This increase was approved to extend and corroborate results obtained in the WP3 with a second agronomical season. Phenolic content in olive oil is strongly associated to stress conditions, which are directly linked to agronomical and climatological factors. This extension supported the results provided by the two certification centers in WP3, which were used to prepare the guide for production of olive oil with increased healthy properties. Thus, in Spain a total number of 1050 samples were analyzed in the 2018/2019 agronomical season while a total number of 1419 samples from Croatia (120), Italy (355), Cyprus (86) and Greece (858) were analyzed in Athens.
- Different factors were responsible for the reduction in the phenolic content of virgin olive oil in general terms. Thus, in Spain the average phenolic intake per 20 g of olive oil in the 17/18 season was 16.4 mg while the same parameter in the 18/19 season was reduced to 12.0. This reduction was attributed to a strong drought period in the Mediterranean area. In Greece, Cyprus and Italy a strong problem with the fly (*Bactrocera oleae*) decreased considerably the production and quality of olive oil. This problem led to a dramatic reduction in phenolic content of olive oils. For Greece the reduction was from average 454 mg/Kg in17/18 to 388 mg/Kg in 18/19. For this reason, the certification center at University of Athens extended the Testing phase with the analysis of samples processed in the 2019/2020 agronomical season.

- Delay in the WP4. Training seminars were held from April to December. In Spain all the training seminars were held in June, while in the other participating countries training seminars were organized until December. For this reason, a higher number of producers received the formation just before or during the collection period and they did not have time to implement the recommendations for the 2018/2019 season.

Despite these limitations, the Testing phase was programmed with an increased workload as compared to planned actions included in the project and a combination of results is presented for 2018/2019 and 2019/2020 seasons. For the first season, only results provided by the certification center in Spain are included. On the other hand, only results provided by the certification center in Greece are shown.

Results of the Testing phase

2018/2019 agronomical season: Certification center in University of Cordoba (Spain)

A total number of 1050 samples of extra virgin olive oil were analyzed in this season. A subset of 100 samples were selected for the Testing phase. These samples were filtered out according to the following criteria:

- Producers assisted to training seminars or they receive the guide with recommendations to increase the healthy properties of olive oil based on the phenolic content.
- Producers submitted the complete information regarding the production of olive oil in the two previous agronomical season.
- Producers were enrolled in the Aristoil project since the first agronomical season. Therefore, at least two samples were previously analyzed in the framework of the Aristoil project.
- Producers accepted to introduce some modifications in the production process according to the recommendations included in the guide.

With these premises, the results provided by this subset of samples were compared to those obtained previously in the previous season. 75% of the samples reported an increase of phenols concentration as compared to previous season. This increase ranged from 5 to 100%, and the average detected increase was around 20%.

2019/2020 agronomical season: Certification center in University of Athens (Greece)

As previously mentioned, the certification center at University of Athens analyzed a total number of 1419 samples in 2018/2019 season. However, the fly affected considerably to Greece, Italy and Cyprus and this problem led to a substantial reduction of the phenolic content in olive oil produced in these countries. That is why the results produced in 2018/2019 agronomical season were not useful for the Testing phase and WP4 was extended to January 2020 to include the results provided by samples analyzed in the 2019/2020 season. In this last season, 319 samples have been analyzed in Athens: 144 from Greece, 50 from Italy, 48 from Cyprus and 77 from Croatia.

In season 19/20 the samples from Greece showed an average phenolic content of 570 mg/Kg which corresponds to an increase +25% in comparison with 17/18 (452 mg/Kg, Table 64, Annex1). Similarly, in Italy the increase from 297 mg/Kg in 17/18 to 471 in 19/20 reached +58%. In Croatia the increase from 607 mg/Kg in 17/18 to 763 in 19/20 reached +26%. Finally in Cyprus we achieved an increase of +18% from 309 mg/kg in 17/18 to 366 mg/Kg in 19/20.

Detailed results with statistical evaluation is presented in ANNEX1

Conclusions

These values are quite significant and support the recommendations included in the Guide for producers. It is also worth mentioning that phenolic content in olive oil is affected by numerous factors, some of which cannot be controlled. Thus, in some cases, particular diseases such as the fly cause a dramatic effect. The climatological conditions are also relevant. On the one hand, an intense drought can avoid the normal ripening of olive fruits. On the other hand, adverse climatological conditions can promote the fall of most fruits and, therefore, the quality of olive oil should be considerably affected. In fact, phenolic concentration is not a parameter used to monitor the quality of olive oil, but it can be considerably affected when quality is reduced or minimized. However, when the producers follow the ARISTOIL recommendations they can achieve a significant increase in the phenolic content of the produced olive oil.

ANNEX 1

Aristoil Statistics

Introduction

The following statistic results concerns the main factors influencing the phenolic content of olive oil. The statistic evaluation has been based on the analysis of 4461 samples that have been analyzed by the NMR method in the University of Athens during the years 2016-2017, 2017-2018 and 2018-2019 coming mainly (but not exclusively) from the ARISTOIL project and has been accomplished by 2153 samples that had been collected and analyzed by the same method before the beginning of the project. The statistic evaluation is mainly focused on the Greek samples (due to their largest number) and mainly evaluates the role of variety, harvest time and olive mill type and confirms the guidelines that had been proposed from WP3 and were applied during WP4.

Statistics for all samples

Country of Origin of Samples

The country of origin of the olive oil samples is presented in Table 1. Of the 6,614 samples, 4,778 relate to olive oils originating from Greek olive groves. A significant number of samples was originated from Italy (n=906), Croatia (n=406) and Cyprus (n=303), while a small number of samples originated from countries outside European Union (South America, Africa and Middle East). About 2.3% (n=151) of the analyzed samples were from the USA and included samples from American olive groves and bottled olive oils found in stores.

Table 1. ***The country of origin of the olive oil samples.***

Country of Origin of Samples	*n*	*Percent (%)*	*Cumulative Percent (%)*
Greece	4,778	72.2	72.2

Cyprus	303	4.6	76.8
Italy	906	13.7	90.5
Croatia	406	6.1	96.7
Spain	59	0.9	97.6
Portugal	1	0.0	97.6
USA	151	2.3	99.8
Argentina	1	0.0	99.9
Chile	1	0.0	99.9
Lebanon	3	0.0	99.9
Syria	2	0.0	100.0
Morocco	2	0.0	100.0
Tunisia	1	0.0	100.0
Total	**6,614**	**100.0**	

**bottled olive oils found in stores*

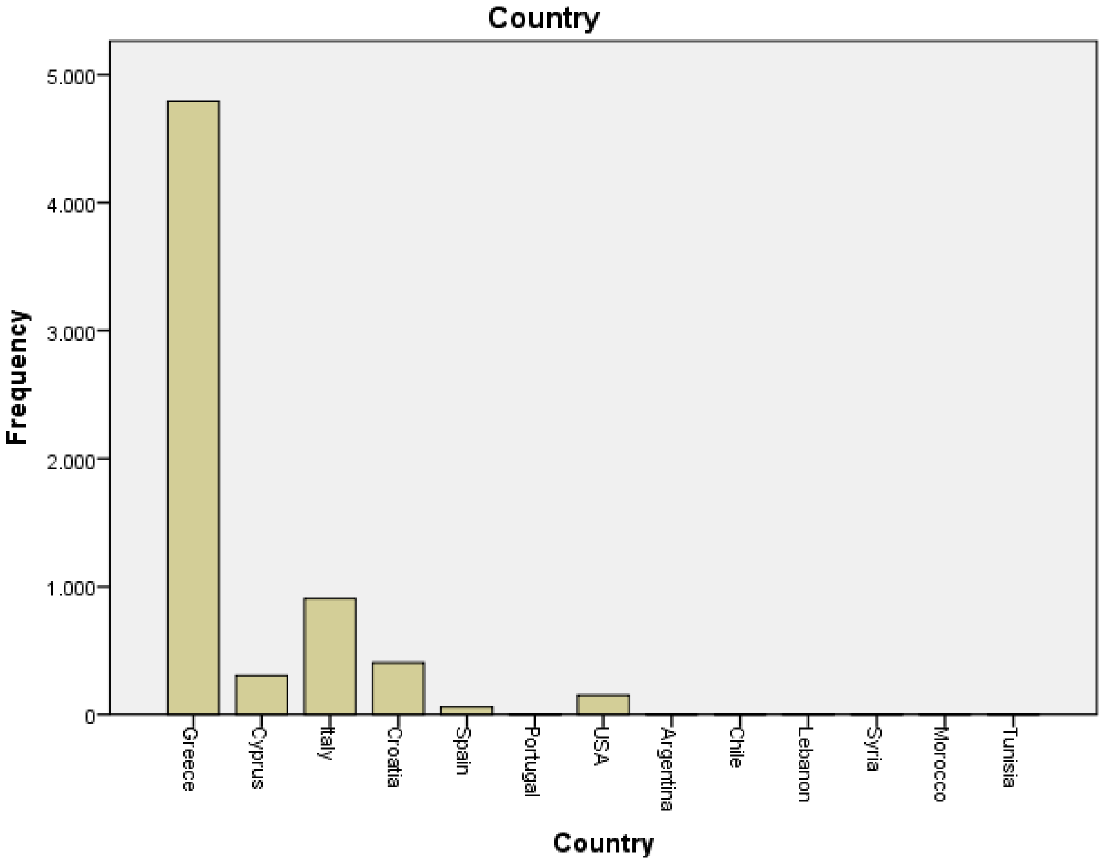


Diagram 1. The distribution of the analyzed olive oil samples according to country of origin.

Harvest Year – Harvest Month

The harvest years of the analyzed olive oil samples were referred to 2014 to 2019 (Table 2). For 3,743 samples there is no information on years of harvest (Table 2).

Table 2. The harvest years of the analyzed olive oil samples.

Harvest Year	n	Percent (%)	Cumulative Percent (%)
2009-2013 or No Data	1,693	25.6	25.6
2014-2015	162	2.4	28.0
2015-2016	298	4.5	32.6
2016-2017	966	14.6	47.2
2017-2018	2,137	32.3	79.5
2018-2019	1,358	20.5	100.0
Total	**6,614**	**100.0**	

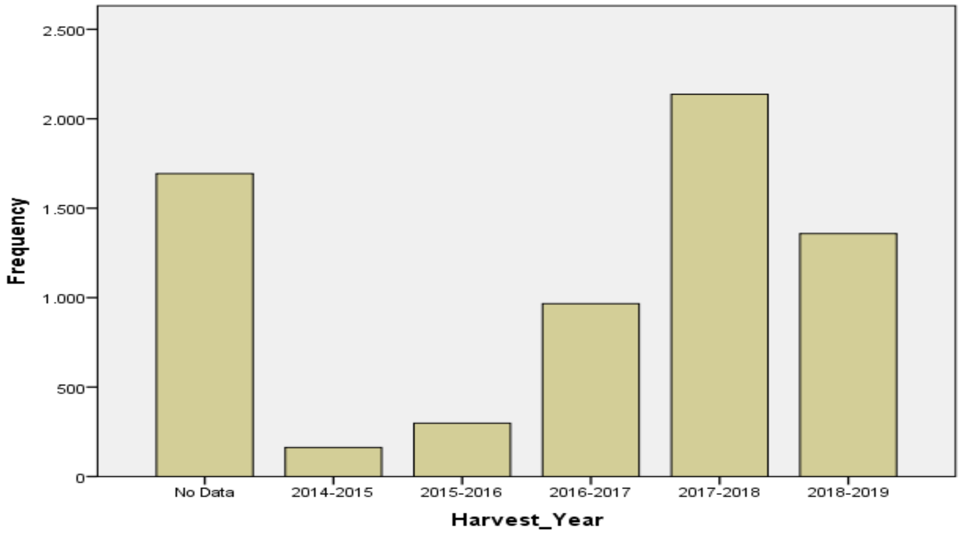


Diagram 2. The distribution of the analyzed olive oil samples according to harvest years.

The harvest month of the olive oil samples is presented in Table 3.

Table 3. The harvest month of the olive oil samples.

Harvest Month	n	Percent (%)	Cumulative Percent (%)
No Data	3,736	56.5	56.5
September	128	1.9	58.4
October	652	9.9	68.3
November	1,105	16.7	85.0

December	913	13.8	98.8
January	79	1.2	100.0
February	1	0.0	100.0
Total	**6,614**	**100.0**	

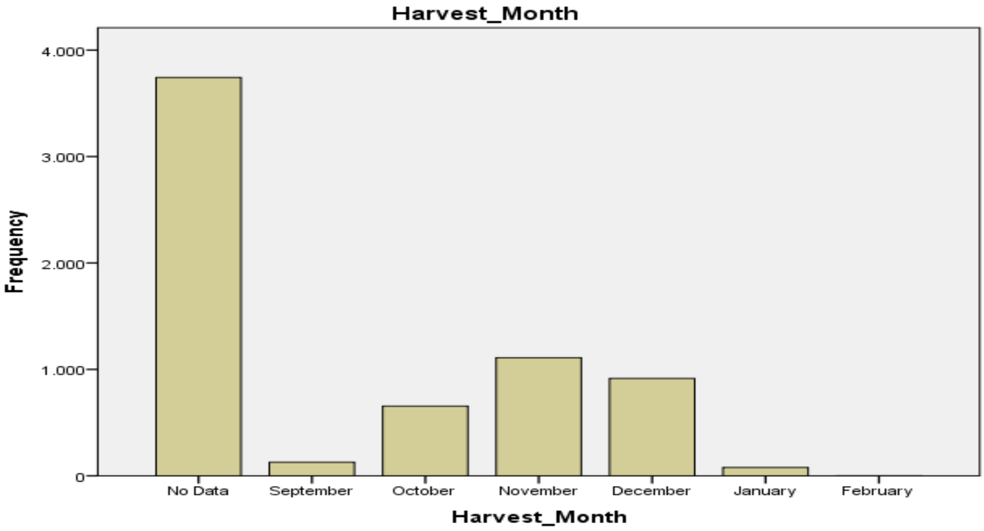


Diagram 3. The distribution of the analyzed olive oil samples according to the harvest month.

Olive oil varieties

Diagram 4 and Table 4 presents the variety samples distribution. The major quantity of the samples was concerned Koroneiki variety (n=2,217) comprising the one third of total samples (33.5%). The rest samples concerned less popular varieties such as Chalkidikis (n=312 samples, 4.7%), Athinolia (n=233, 3.5%), Lianolia (n=283, 4.3%), Manaki (n=222, 3.4%) and Olympia (n=216, 3.3%). A large portion of the analyzed samples (n=2,399) that counted for the 33.3% were of unknown variety (Table 4, Diagram 4).

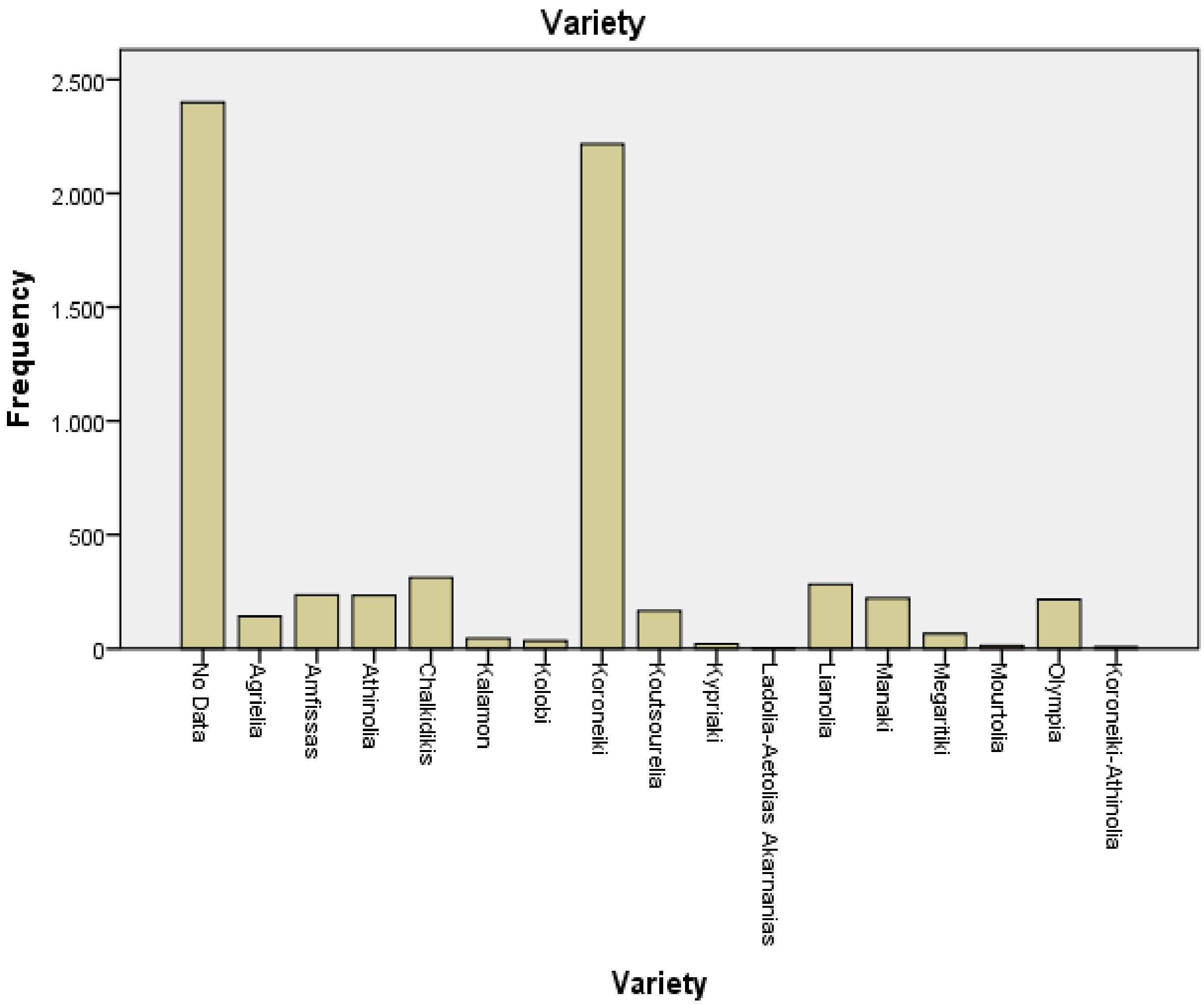


Diagram 4. The distribution of the analyzed olive oil samples according to the variety.

Table 4. ***The varieties of the olive oil samples.***

Variety	n	Percent	Cumulative Percent
No Data	2,399	36.3	36.3
Agrielia	142	2.1	38.4
Amfissas	235	3.6	42.0
Athinolia	233	3.5	45.5
Chalkidikis	312	4.7	50.2
Kalamon	45	0.7	50.9

Kolobi	34	0.5	51.4
Koroneiki	2,217	33.5	84.9
Koutsourelia	166	2.5	87.4
Kypriaki	22	0.3	87.8
Ladolia-Aetolias Akarnanias	2	0.0	87.8
Lianolia	283	4.3	92.1
Manaki	222	3.4	95.4
Megaritiki	65	1.0	96.4
Mourtolia	13	0.2	96.6
Olympia	216	3.3	99.9
Koroneiki-Athinolia	8	0.1	100.0
Total	**6,614**	**100.0**	

Olive oil press type

Table 5 presents the olive oil press type used in oiling process. The major quantity of the samples was originated from olives pressed in a two phase olive oil press type (n=1,655) comprising almost the two thirds (63.56%) of total samples for which data were available. For most samples (n=4,010, 60.6%) the used olive oil press type was unknown (Diagram 5).

Table 5. ***The olive oil samples of the analyzed according to the mill type.***

Oil press type	**n**	**Percent**	**Cumulative Percent**
No data	4,010	60.6	60.6
Two-Phase	1,655	25.0	85.7
Three-Phase	949	14.3	100.0
Total	**6,614**	**100.0**	

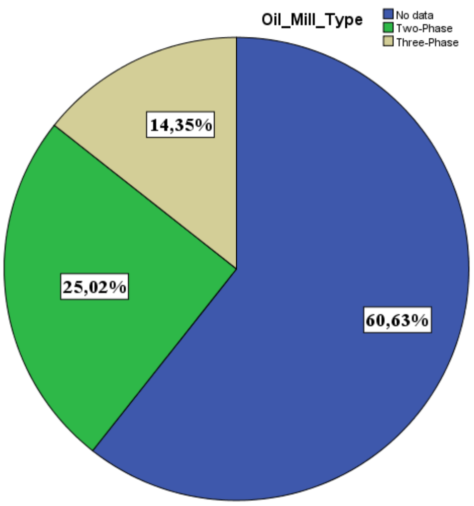


Diagram 5. The distribution of the analyzed olive oil samples according to the mill type used.

Chemical analysis

The oil samples chemical composition was compared among countries with at least 30 samples (Table 5, Table 7, Diagram 6).

Table 6.

Country	**n**
Greece	4,791
Cyprus	305
Italy	906
Croatia	406
Spain	59
USA	*151*

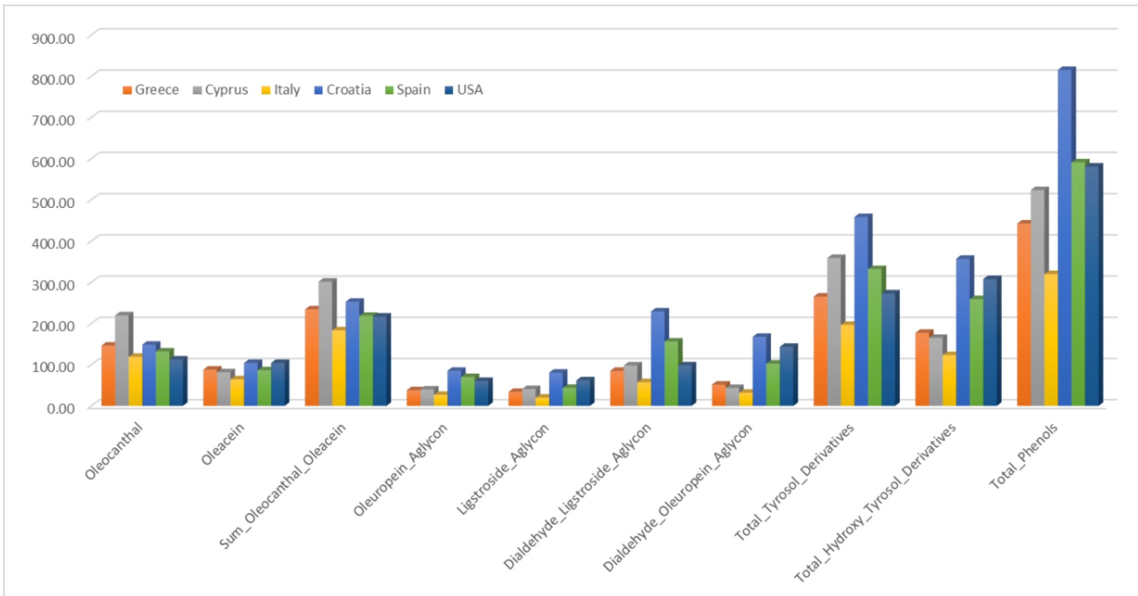


Diagram 6. Chemical composition compared among countries

Table 7.

Component (mg/g)	**Oleocanthal**		**Oleacein**		**Sum_Oleocanthal_ Oleacein**		**Oleuropein_ Aglycon**		**Ligstroside_ Aglycon**	
Country	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std Erro
Greece	146.25	1.587	87.89	1.126	234.13	2.542	37.89	.548	34.03	.4
Cyprus	219.78	24.824	81.59	5.491	301.38	29.771	39.81	2.369	40.88	2.5
Italy	118.95	2.502	64.39	1.868	183.34	4.126	26.91	1.160	20.10	.9
Croatia	148.51	4.311	104.14	2.930	252.66	6.650	85.10	3.816	80.66	5.2
Spain	132.08	14.439	86.44	10.219	218.52	23.436	69.93	8.156	43.71	4.5
USA	112.54	7.863	104.14	5.460	216.68	11.758	60.43	5.786	61.95	9.9

Component (mg/g)	**Dialdehyde_ Ligstroside_Aglycon**		**Dialdehyde_ Oleuropein_Aglycon**		**Total_Tyrosol_ Derivatives**		**Total_Hydroxy_ Tyrosol_Derivatives**		**Total_ Phenols**	
Country	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std Erro
Greece	84.91	1.534	51.49	1.127	265.18	2.759	177.27	2.244	442.45	4.8
Cyprus	98.11	8.484	43.49	5.101	358.77	30.030	164.90	9.843	523.67	37.7
Italy	57.41	3.282	31.90	2.343	196.47	5.333	123.19	4.129	319.66	8.9
Croatia	229.07	7.981	167.55	6.656	458.24	13.951	356.79	10.668	815.03	22.2
Spain	156.18	22.145	102.68	12.854	331.97	34.570	259.05	24.641	591.02	56.4
USA	98.45	9.784	143.22	15.188	272.94	20.190	307.79	20.493	580.74	38.0

Statistics for Greek samples

The statistical analysis is related only to olive oil samples originated from Greece. From the analysis were eliminated varieties numbered less than 10 samples.

Olive oil varieties

Table 8 presents the variety samples distribution. The major quantity of the samples was concerned Koroneiki variety (n=2,183) comprising the one third of total Greek samples (45.7%). The rest samples concerned less popular varieties such as Chalkidikis (n=312 samples, 6.5%), Athinolia (n=2228, 4.8%), Lianolia (n=283, 5.9%), Manaki (n=222, 4.6%) and Olympia (n=213, 4.5%). A large portion of the analyzed samples (n=642) that counted for the 13.4% were unknown variety (Table 8, Diagram 7).

Table 8.

Variety	n	Percent (%)	Cumulative Percent (%)
No Data	642	13.4	13.4
Agrielia	142	3.0	16.4
Amfissas	235	4.9	21.3
Athinolia	228	4.8	26.1
Chalkidikis	312	6.5	32.6
Kalamon	29	0.6	33.2
Kolobi	34	0.7	33.9
Koroneiki	2,183	45.7	79.6
Koutsourelia	166	3.5	83.1
Kypriaki	1	0.0	83.1
Ladolia-Aetolias Akarnanias	2	0.0	83.2
Lianolia	283	5.9	89.1
Manaki	222	4.6	93.7
Megaritiki	65	1.4	95.1
Mourtolia	13	0.3	95.4
Olympia	213	4.5	99.8
Koroneiki-Athinolia	8	0.2	100.0
Total	**4,778**	**100.0**	

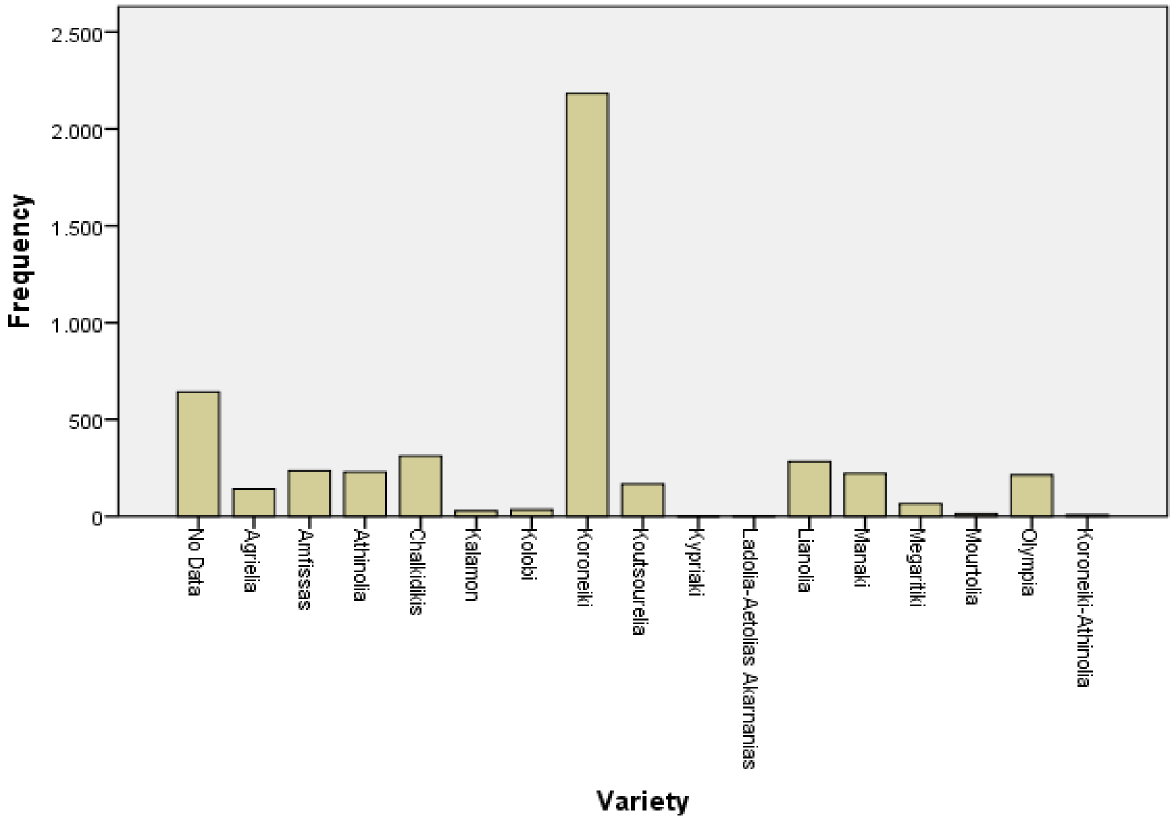


Diagram 7. The distribution of the analyzed olive oil samples according to the variety.

Harvest Year – Harvest Month – Harvest Week

The harvest years of the analyzed olive oil samples were referred to 2014 to 2019 (Table 9). Table 9 presents the samples' harvest year distribution. The major quantity of the samples was harvested in 2017-2018 (n=977) comprising the 20.4% of all samples. For 2,109 samples (44.1%) there was no information on years of harvest (Table 9).

Table 9.

Harvest_Year	n	Percent	Cumulative Percent
No Data	1,419	29.7	29.7
2014-2015	161	3.4	33.1
2015-2016	292	6.1	39.2
2016-2017	703	14.7	53.9
2017-2018	1,308	27.4	81.3
2018-2019	895	18.7	100.0

Total	4,778	100.0

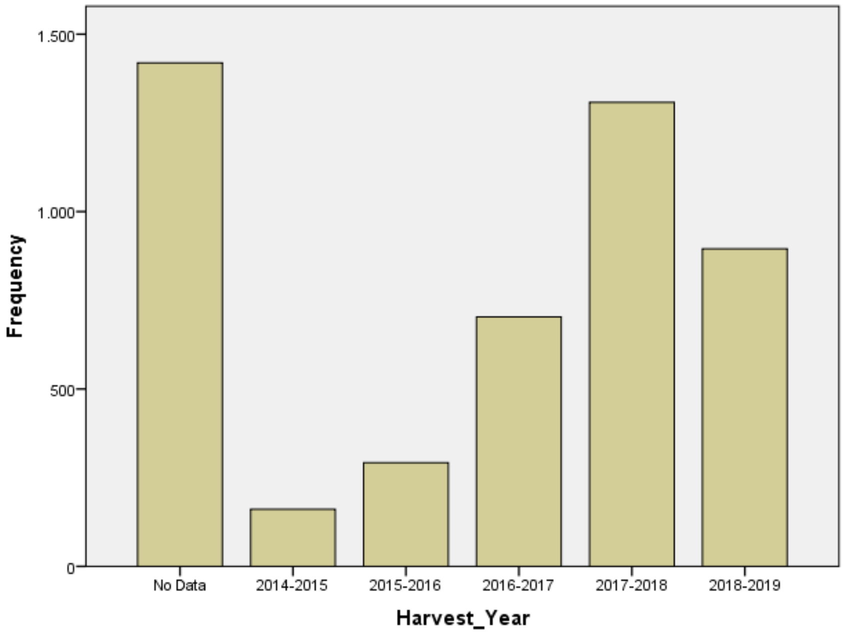


Diagram 8. The distribution of the analyzed olive oil samples according to the year harvest.

The olive of oil samples was harvested during September to February (Table 10), and were sent for analysis from September to March. Table 10 presents the samples' harvest month distribution. The major quantity of the samples was harvested in November (n=1,013) comprising the 21.2% of all samples. For 2,109 samples (44.1%) there was no information on month of harvest (Table 10).

Table 10.

Harvest Month	*n*	*Percent*	*Cumulative Percent*
No Data	2,109	44.1	44.1
September	111	2.3	46.5
October	610	12.8	59.2
November	1,013	21.2	80.4
December	862	18.0	98.5
January	72	1.5	100.0
February	1	.0	100.0
Total	***4,778***	***100.0***	

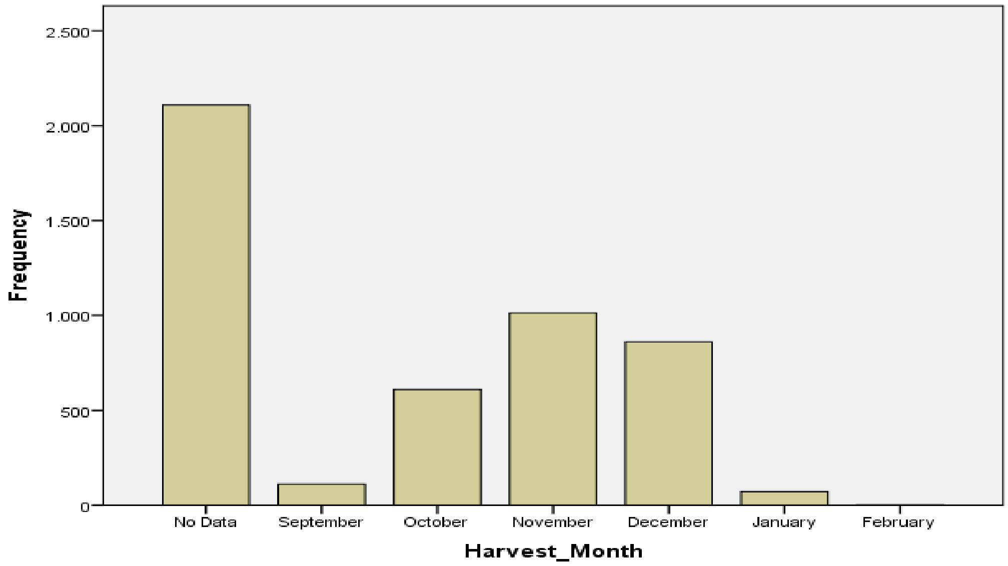


Diagram 9. The distribution of the analyzed olive oil samples according to the month harvest.

In order to assess the impact of harvest time, it was divided into shorter intervals of weeks. The first harvest week was the first week of September. Olive of oil samples was harvested during September to March (Table 10). Few samples that were harvested on August were eliminated from the analysis due to their limited number. Diagram 10 and Table 11 presents the samples' harvest week distribution. For 2,109 samples (44.1%) there was no information on week of harvest (Table 11).

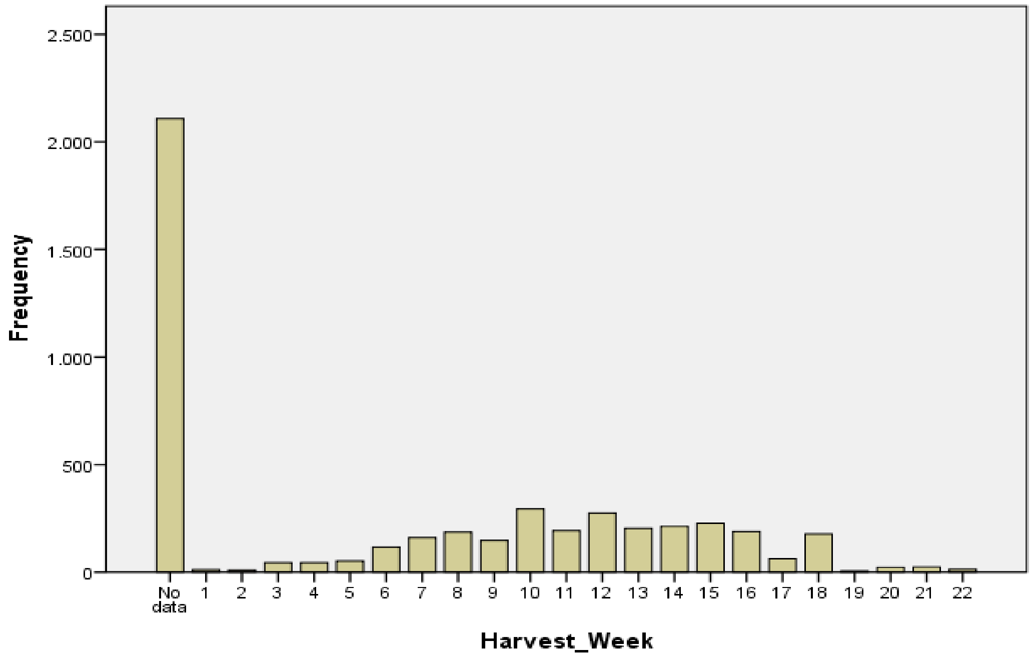


Diagram 10. The distribution of the analyzed olive oil samples according to harvest week.

Table 11.

Harvest_Week	n	Percent	Cumulative Percent
No data	2,109	44.1	44.1
1	11	0.2	44.4
2	9	0.2	44.6
3	44	0.9	45.5
4	44	0.9	46.4
5	52	1.1	47.5
6	116	2.4	49.9
7	160	3.3	53.3
8	186	3.9	57.2
9	147	3.1	60.2
10	294	6.2	66.4
11	193	4.0	70.4
12	275	5.8	76.2
13	203	4.2	80.4
14	213	4.5	84.9
15	228	4.8	89.7
16	189	4.0	93.6
17	62	1.3	94.9
18	178	3.7	98.6
19	5	0.1	98.7
20	23	0.5	99.2
21	24	0.5	99.7
22	13	0.3	100.0
Total	***4,778***	***100.0***	

Geographic distribution of the samples

Region

Most of the analyzed samples were from the Peloponnese (n=1,849) comprising the 38.7% of all Greek samples (Table 12, Diagram 11). A significant amount of samples was from Ionian Islands (n=710, 14.9%) and Crete (n=438, 9.2%). For 689 samples (14.4%) there was no information about the region originated from (Table 12).

Table 12.

Region	***Frequency***	***Percent***	***Cumulative Percent***
No Data	689	14.4	14.4
Eastern Macedonia and Thrace	75	1.6	16.0
Attica	101	2.1	18.1
North Aegean	49	1.0	19.1
Crete	438	9.2	28.3
Western Greece	295	6.2	34.5
Western Macedonia	28	0.6	35.1
Ionian Islands	710	14.9	49.9
Epirus	52	1.1	51.0
Central Macedonia	281	5.9	56.9
South Aegean	53	1.1	58.0
Peloponnese	1849	38.7	96.7
Central Greece	62	1.3	98.0
Thessaly	96	2.0	100.0
Total	***4,778***	***100.0***	

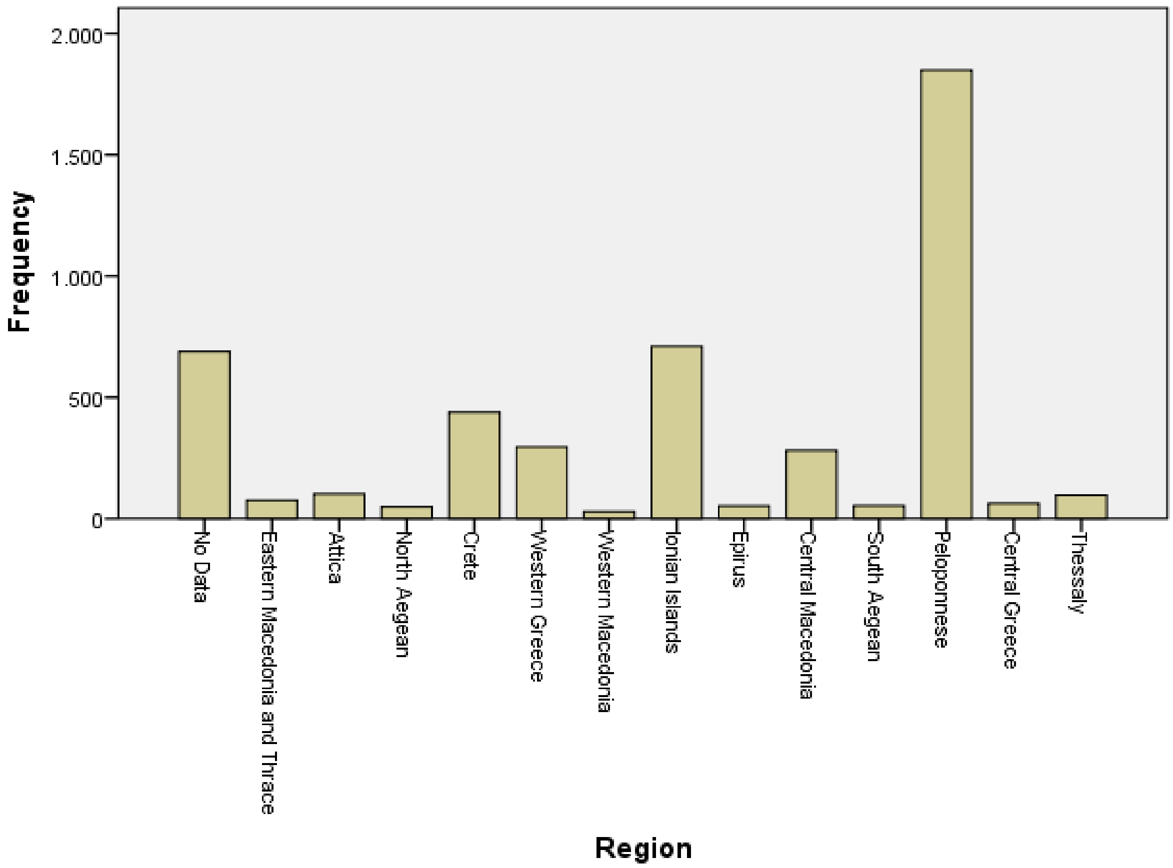


Diagram 11. The distribution of the analyzed olive oil samples according to Greek Region.

County

For 711 samples (14.8%) there was no information about the county originated from (Table 13). Most of the analyzed samples were from Messinia (n=786) and Lakonia (n=513), both counties from the Peloponnese, representing 16.5% and 10.7% of all Greek samples (Table 13, Diagram 12). A significant amount of samples was from Kerkyra (n=307, 6.4%), Zakynthos (n=237, 5%), both counties from Ionian Islands, Argolida (n=256, 5.4%) and Chalkidiki (n=264, 5.5%).

Table 13.

County	*Frequency*	*Percent*	*Cumulative Percent*
No Data	710	14.9	14.9
Achaia	82	1.7	16.6
Aetolia and Akarnania	82	1.7	18.3
Argolida	256	5.4	23.7
Arkadia	149	3.1	26.8
Attica	101	2.1	28.9
Boeotia	23	0.5	29.4
Chalkidiki	264	5.5	34.9
Chania	196	4.1	39.0
Chios	6	0.1	39.1
Cyclades	48	1.0	40.1
Dodecanesos	5	0.1	40.2
Drama	2	0.0	40.3
Evia	22	0.5	40.7
Evros	4	0.1	40.8
Fokida	2	0.0	40.9
Ilia	130	2.7	43.6
Irakleio	76	1.6	45.2
Kavala	53	1.1	46.3
Kefalonia	107	2.2	48.5
Kerkyra	307	6.4	54.9
Korinthos	145	3.0	58.0
Kozani	28	0.6	58.6
Lakonia	513	10.7	69.3
Larisa	7	0.1	69.4
Lasithi	136	2.8	72.3
Lefkada	59	1.2	73.5
Lesvos	40	0.8	74.4
Magnessia	63	1.3	75.7
Messinia	786	16.5	92.1
Phthiotida	15	0.3	92.4
Preveza	46	1.0	93.4
Rethymno	25	0.5	93.9
Rodopi	2	0.0	94.0
Samos	3	0.1	94.0
Thesprotia	6	0.1	94.2

Thessaloniki	17	0.4	94.5
Trikala	11	0.2	94.7
Xanthi	14	0.3	95.0
Zakynthos	237	5.0	100.0
Total	***4,778***	***100.0***	

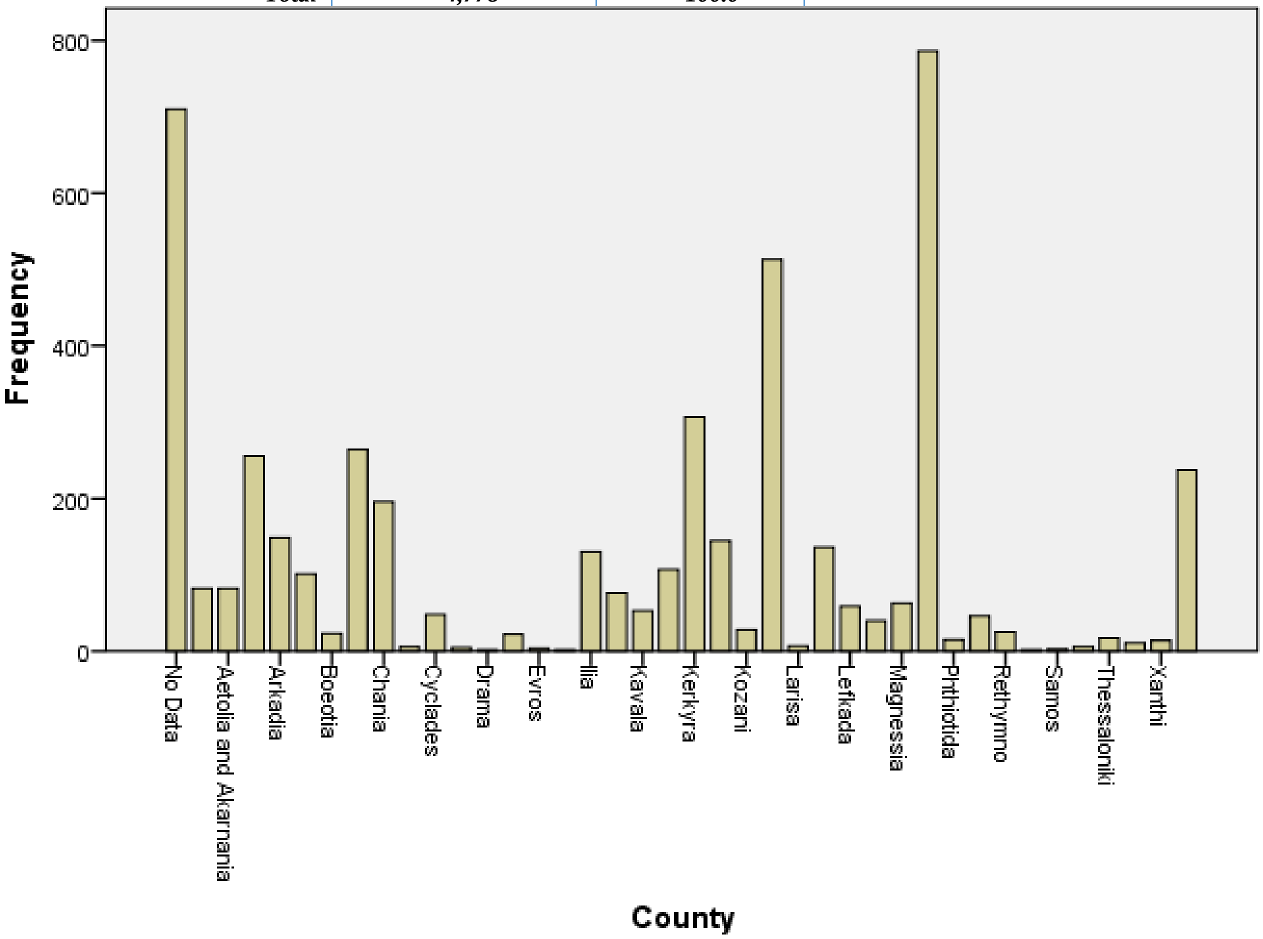


Diagram 12. The distribution of the analyzed olive oil samples according to County.

Municipality

For 691 samples (14.5%) there was no information about the municipality originated from (Table 14). Most of the analyzed samples were from Kerkyra (n=306, 6.3%) %), Zakynthos (n=237, 5%), both municipalities from Ionian Islands, Pylou-Nestoros (n=249, 5.2%), Sparti (n=216, 4.5%) and Kalamata (n=188, 3.9%), municipalities from the Peloponnese (Table 14, Diagram 13). Significant amount of samples was from Gortynia and Messini (n=147, 3.1% and n=149, 3.1%, respectively), both municipalities from the Peloponnese, too.

Table 14.

Municipality	Frequency	Percent	Cumulative Percent	Municipality	Frequency	Percent	Cumulative Percent
No Data	691	14.5	14.5	Lavreotiki	6	0.1	54.8
Abdira	14	0.3	14.8	Lefkada	57	1.2	55.9
Aegialeia	33	0.7	15.4	Lesbou	40	0.8	56.8
Ag. Nikolaou	23	0.5	15.9	Libadeia	3	0.1	56.8
Agia	1	0.0	15.9	Lokroi	7	0.1	57.0
Agrinio	24	0.5	16.5	Loutraki-Ag. Theodoroi	35	0.7	57.7
Aharnes-Asterousia	9	0.2	16.6	Makris	2	0.0	57.8
Aktio-Vonitsa	3	0.1	16.7	Marathonas	2	0.0	57.8
Alexandroupoli	2	0.0	16.7	Megalopoli	1	0.0	57.8
Almyros	15	0.3	17.1	Megara	7	0.1	58.0
Amario	1	0.0	17.1	Mesologi	12	0.3	58.2
Amfikleia-Elateia	1	0.0	17.1	Messini	149	3.1	61.3
Amfilohia	9	0.2	17.3	Mikris Volvis	4	0.1	61.4
Anatoliki Mani	108	2.3	19.5	Minoa Pediada	4	0.1	61.5
Andravida-Kyllini	5	0.1	19.7	Molos-Ag. Konstantinos	1	0.0	61.5
Andritsena-Krestena	29	0.6	20.3	Monembasia	123	2.6	64.1
Antiparos	6	0.1	20.4	Mylopotamos	5	0.1	64.2
Apokoronou	2	0.0	20.4	Nafplio	17	0.4	64.6
Archea Olympia	47	1.0	21.4	Naxos	17	0.4	64.9
Argos-Mykines	25	0.5	21.9	Nea Propontida	124	2.6	67.5
Biannou	36	0.8	22.7	Nemea	9	0.2	67.7
Bolbi	12	0.3	22.9	Notio Pilio	62	1.3	69.0
Chania	44	0.9	23.9	Oihalia	29	0.6	69.6
Chios	6	0.1	24.0	Oropos	1	0.0	69.6
Delfi	1	0.0	24.0	Pageo	1	0.0	69.7
Distomo-Arachova	13	0.3	24.3	Parga	2	0.0	69.7
Drama	2	0.0	24.3	Paros	24	0.5	70.2
Dytiki Achaia	29	0.6	24.9	Patra	9	0.2	70.4
Dytiki Mani	44	0.9	25.8	Paxoi	4	0.1	70.5
Elassona	4	0.1	25.9	Pineiou	1	0.0	70.5
Epidavros	21	0.4	26.4	Platania	54	1.1	71.6
Eretria	3	0.1	26.4	Polygyros	112	2.3	74.0
Ermionida	193	4.0	30.5	Preveza	44	0.9	74.9
Erymanthos	1	0.0	30.5	Prosotsani	2	0.0	74.9
Evia	1	0.0	30.5	Pylou-Nestoros	249	5.2	80.1
Evrota	66	1.4	31.9	Pyrgos	23	0.5	80.6
Festos	38	0.8	32.7	Rethymno	20	0.4	81.0
Gortynia	147	3.1	35.8	Salamina	9	0.2	81.2
Halkida	6	0.1	35.9	Samos	3	0.1	81.3
Ierapetra	2	0.0	35.9	Saronikou	23	0.5	81.8
Igoumenitsa	6	0.1	36.1	Sikyonion	45	0.9	82.7
Ilida	22	0.5	36.5	Siteia	111	2.3	85.0
Irakleio	29	0.6	37.1	Sithonia	2	0.0	85.1
Istiea-Edipsos	1	0.0	37.1	Sparti	216	4.5	89.6
Itea	1	0.0	37.2	Spata-Artemida	16	0.3	89.9
Ithaki	2	0.0	37.2	Spetses	1	0.0	90.0
Kalamata	188	3.9	41.1	Stylida	1	0.0	90.0
Kalavryta	10	0.2	41.4	Tembi	1	0.0	90.0
Kalymnos	59	1.2	42.6	Thassos	49	1.0	91.0
Karpathos	3	0.1	42.7	Thermou	17	0.4	91.4
Karystos	3	0.1	42.7	Thiva	6	0.1	91.5
Kassandra	26	0.5	43.3	Trifylia	127	2.7	94.2
Kea	1	0.0	43.3	Trikala	11	0.2	94.4
Kefalonia	107	2.2	45.5	Troizina	3	0.1	94.5
Kerkyra	303	6.3	51.9	Velo-Vocha	1	0.0	94.5

Kissamos	3	0.1	51.9	*Volos*	1	0.0	94.5
Korinthos	53	1.1	53.0	*Voria Kynouria*	1	0.0	94.5
Kozani	28	0.6	53.6	*Xiromero*	14	0.3	94.8
Kropia	14	0.3	53.9	*Xylokastro Evrostyni*	4	0.1	94.9
Kymi-Aliveri	8	0.2	54.1	*Zacharo*	4	0.1	95.0
Kythira	19	0.4	54.5	*Zakynthos*	237	5.0	99.9
Lamia	6	0.1	54.6	*Zerou*	3	0.1	100.0
Larisa	1	0.0	54.6	***Total***	***4,778***	***100.0***	

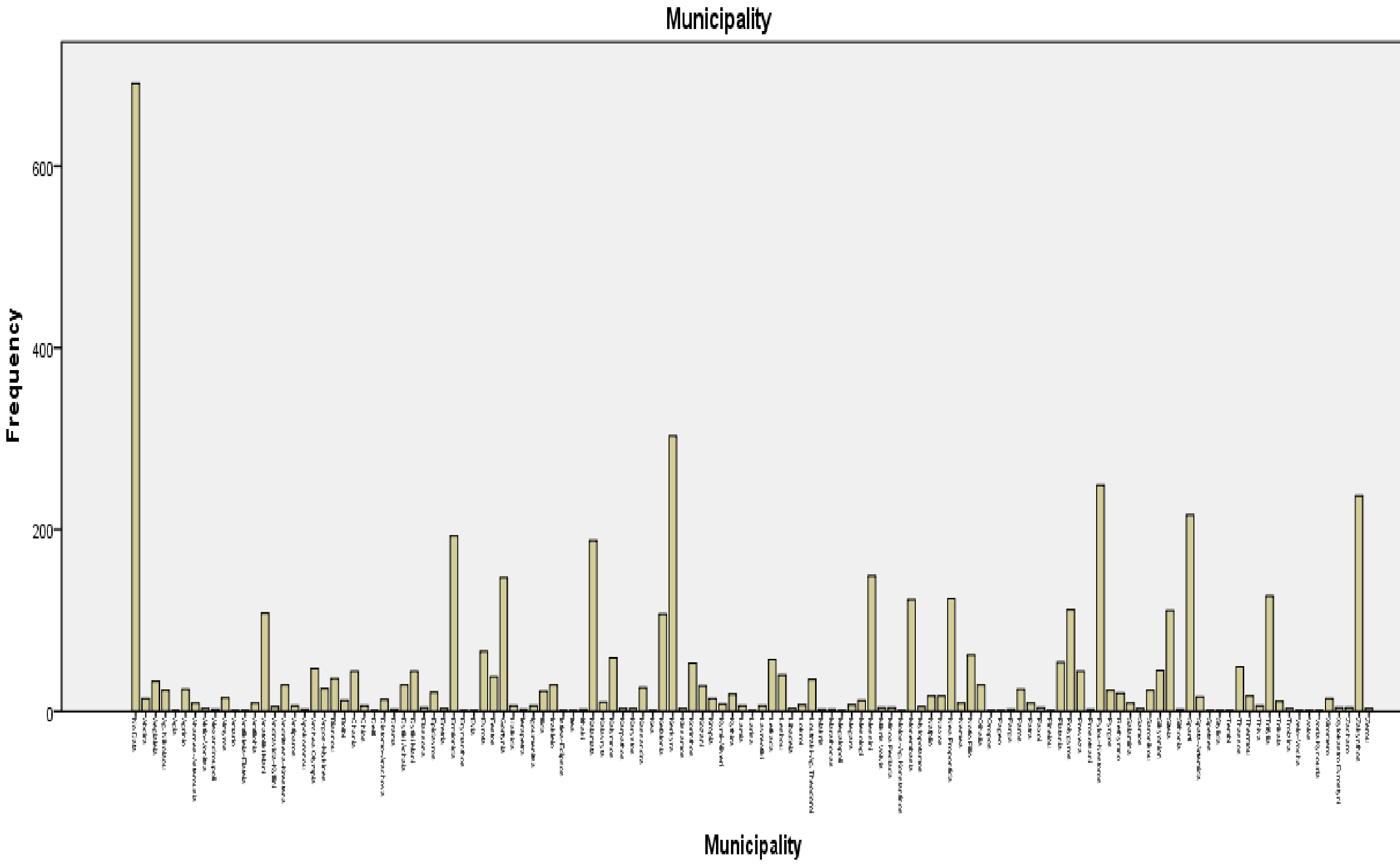


Diagram 13. The distribution of the analyzed olive oil samples according to Municipality.

Olive oil press type

Half of the samples (50%) it was unknown what type of olive oil mill press was used (Table 15, Diagram 14). The two phase olive oil mill was the most used type (n=1,488) accounting for 31.1% of all samples, while the 18.9% of the olive oils were pressed in three phase mill press types.

Table 15. ***Distribution of samples according the used olive oil mill type.***

Oil_Mill_Type	*Frequency*	*Percent*	*Cumulative Percent*
No data	2,389	50.0	50.0
Two-Phase	1,488	31.1	81.1
Three-Phase	901	18.9	100.0
Total	***4,778***	***100.0***	

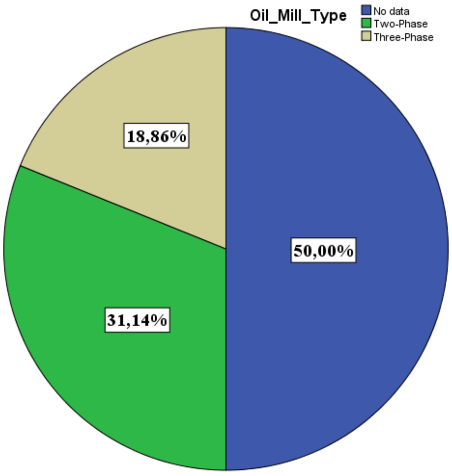


Diagram 14. The distribution of the analyzed olive oil samples according to oil mill type.

Chemical analysis

Overall analysis

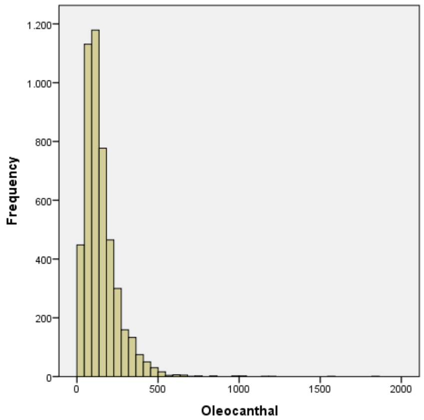
All the olive oil samples were analyzed to determine the chemical profile of the following target phenolic substances: oleocanthal, oleacein, oleuropein aglycon, ligstroside aglycon, dialdehyde ligstroside aglycon, dialdehyde oleuropein aglycon, total tyrosol derivatives, total hydroxy tyrosol derivatives and total phenols.

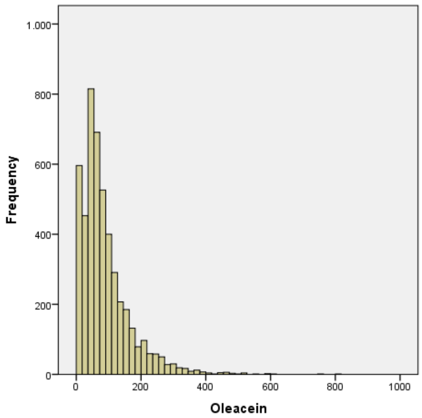
Total tyrosol derivatives comprise the sum of the following substances: oleocanthal, dialdehyde ligstroside aglycon and ligstroside aglycon. Total hydroxy-tyrosol derivatives comprise the sum of the following substances: oleacein, dialdehyde oleuropein aglycon and oleuropein aglycon. Total phenols constitute the sum of the following substances: oleocanthal, oleacein, oleuropein aglycon, ligstroside aglycon, dialdehyde ligstroside aglycon, dialdehyde oleuropein aglycon. Table 16 shows the mean concentrations of the studied substances for the Greek analyzed samples.

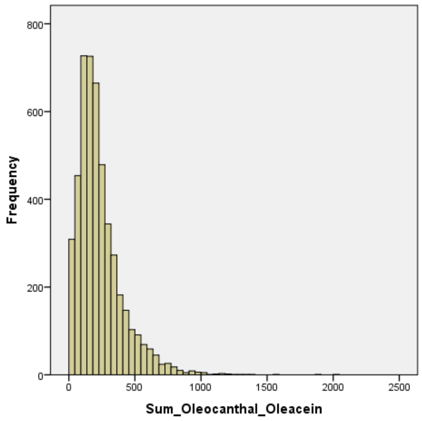
Table 16.

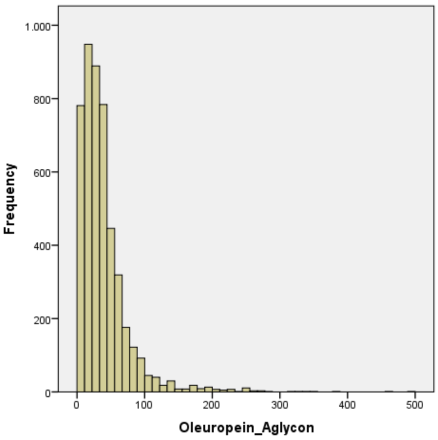
n=4,778 (mg/g)	*Maximum*	*Mean*	*Std. Error*	*Std. Deviation*
Oleocanthal	1,821	146.26	1.590	109.881
Oleacein	809	87.90	1.127	77.923
Sum_Oleocanthal_Oleacein	2,045	234.16	2.545	175.922
Oleuropein_Aglycon	494	37.93	.550	37.993
Ligstroside_Aglycon	421	34.05	.487	33.697
Dialdehyde_Ligstroside_Aglycon	833	85.07	1.537	106.225
Dialdehyde_Oleuropein_Aglycon	867	51.58	1.130	78.089
Total_Tyrosol_Derivatives	2,072	265.37	2.765	191.106
Total_Hydroxy_Tyrosol_Derivatives	1,305	177.41	2.249	155.463
Total_Phenols	2,442	442.78	4.814	332.792

Diagrams 15 to 23 show the distribution of the analyzed olive oil samples according to phenol studied substance, while Diagram 24 the total phenol content distribution.





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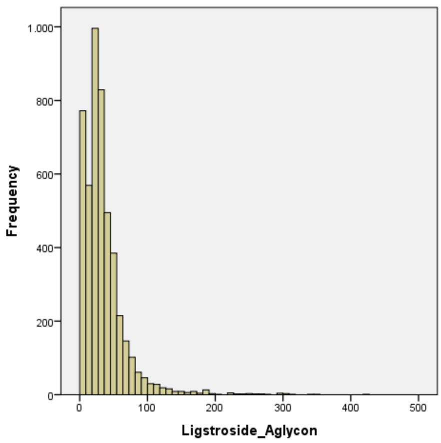
400
200
0
0 100 200 300 400 500
Oleuropein_Aglycon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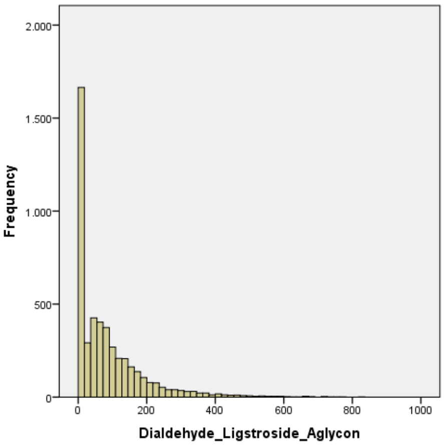
Ligstroside_Aglycon


Frequency
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1.500
1.000
500
0
0 200 400 600 800 1000
Dialdehyde_Ligstroside_Aglycon

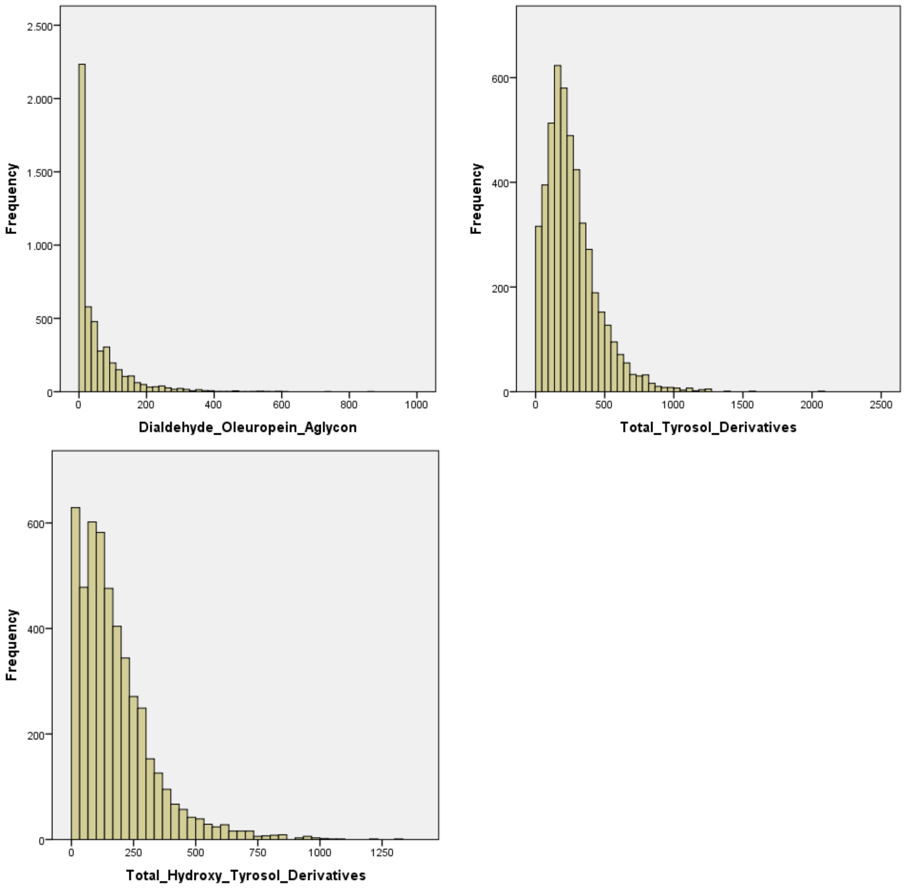

Diagram 15-23. The distribution of the analyzed olive oil samples according to phenol studied substance.

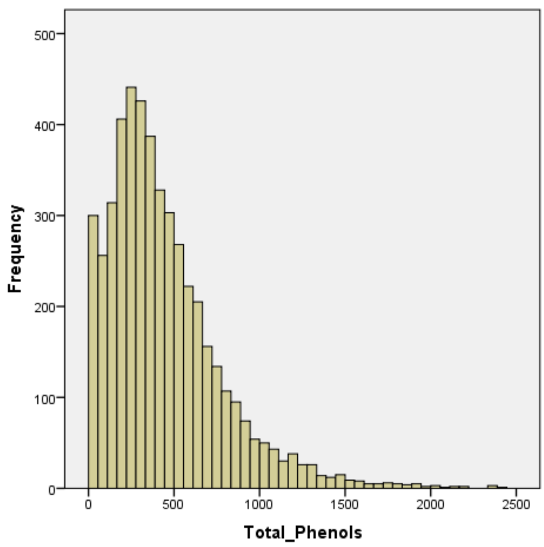

Diagram 24. The total phenol content distribution of the analyzed olive oil samples.

In the data, analysis of variance was applied to control the significance of differences among varieties, olive oil mill types, harvest year, month and week as well as in geographical origin of the samples. All groups were tested for normality using the Shapiro-Wilk and the Kolmogorov-Smirnov tests, measures of skewness and kurtosis and visual inspection of histograms, QQ plots and boxplots (Shapiro and Wilk 1965, Cramer 1998, Cramer and Howitt 2004, Doane and Seward 2011, Razali and Wah 2011). Groups were tested for homogeneity by the Levene test (Martin and Bridgmon 2012). Group's data deviated from normality were log transformed (Chambers et al. 1983), although, generally speaking, the analysis of variance is a method that is not significantly affected by the samples' deviations from normality, even when the populations of the different operations follow qualitatively different distributions (Sokal and Rohlf 1981, Kaltsikis 1989). Duncan's Multiple Range Test (MRT) was used for the multiple comparisons. The sample size in every analysis of variance was not the same due to outliers exclusion from the data. All analysis' were performed at a significance level of a=0.05, using SPSS v.20 software for Windows (IBM SPSS Statistics 2011, IBM Corp.).

Differences among varieties

Tables 17-26 show the mean concentrations as some other descriptive statistics of the studied phenols for the various varieties.

Table 17. ***Ranking of variety mean's concentration of Oleocanthal per variety.***

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Kalamon	29	363.15	400.294	74.333	0	1,559
Lianolia	283	303.25	130.566	7.761	0	750
Mourtolia	13	193.69	150.984	41.875	76	641
Olympia	213	190.88	114.249	7.828	0	1,188
Agrielia	142	181.69	119.914	10.063	0	974
Chalkidikis	312	179.70	105.839	5.992	0	658
Amfissas	235	149.42	102.549	6.690	0	531
Total	4,778	146.26	109.881	1.590	0	1,821
Athinolia	228	143.73	73.918	4.895	0	379
Koutsourelia	166	138.18	70.250	5.452	0	409
Koroneiki	2,183	125.11	79.765	1.707	0	1,022
Kolobi	34	119.65	51.452	8.824	28	237
Manaki	222	91.24	55.422	3.720	0	348

Megaritiki	65	88.16	55.132	6.838	0	330

Table 18. ***Mean concentration of Oleacein per variety.***

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Lianolia	283	206.79	120.715	7.176	0	758
Olympia	213	123.31	80.484	5.515	0	563
Kalamon	29	104.25	109.011	20.243	0	404
Chalkidikis	312	96.53	70.654	4.000	0	387
Kolobi	34	94.93	72.353	12.408	0	269
Athinolia	228	93.06	63.129	4.181	0	303
Mourtolia	13	89.45	53.079	14.721	0	208
Total	4,778	87.90	77.923	1.127	0	809
Agrielia	142	83.79	70.810	5.942	0	368
Amfissas	235	81.95	68.723	4.483	0	373
Koroneiki	2,183	77.52	64.019	1.370	0	809
Koutsourelia	166	69.70	51.253	3.978	0	300
Manaki	222	65.60	67.387	4.523	0	370
Megaritiki	65	43.10	49.502	6.140	0	267

Table 19. ***Mean concentration of the Sum_Oleocanthal_Oleacein per variety.***

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Lianolia	283	510.04	235.977	14.027	0	1,343
Kalamon	29	467.40	491.386	91.248	0	1,898
Olympia	213	314.19	176.602	12.101	0	1,373
Mourtolia	13	283.14	192.534	53.399	119	849
Chalkidikis	312	276.23	169.018	9.569	0	972
Agrielia	142	265.47	174.560	14.649	0	1,262
Athinolia	228	236.78	128.625	8.518	0	619
Total	4,778	234.16	175.922	2.545	0	2,045
Amfissas	235	231.36	163.385	10.658	0	904
Kolobi	34	214.58	118.105	20.255	28	501
Koutsourelia	166	207.88	111.617	8.663	0	659
Koroneiki	2,183	202.63	133.888	2.866	0	1,301
Manaki	222	156.84	117.049	7.856	0	613
Megaritiki	65	131.26	99.881	12.389	0	597

Table 20. ***Mean concentration of Oleuropein_Aglycon per variety.***

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Olympia	213	102.46	84.288	5.775	0	494
Athinolia	228	44.73	32.517	2.154	0	146
Chalkidikis	312	40.99	32.784	1.856	0	248
Total	4,778	37.93	37.993	.550	0	494
Amfissas	235	37.57	32.267	2.105	0	190
Koroneiki	2,183	36.23	27.911	.597	0	263
Lianolia	283	36.12	28.376	1.687	0	224
Kolobi	34	31.02	21.101	3.619	0	95
Koutsourelia	166	30.24	29.583	2.296	0	187
Kalamon	29	27.96	34.808	6.464	0	165
Agrielia	142	27.73	24.025	2.016	0	133

Megaritiki	65	19.58	19.297	2.393	0	92
Manaki	222	17.16	15.891	1.067	0	112
Mourtolia	13	11.79	21.229	5.888	0	78

Table 21. Mean concentration of Ligstroside_Aglycon per variety.

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Olympia	213	90.56	79.336	5.436	0	421
Athinolia	228	38.10	30.093	1.993	0	224
Chalkidikis	312	36.29	27.450	1.554	0	185
Total	4,778	34.05	33.697	.487	0	421
Lianolia	283	32.16	20.942	1.245	0	197
Koroneiki	2,183	31.95	23.464	.502	0	204
Amfissas	235	31.76	27.764	1.811	0	148
Agrielia	142	30.31	28.801	2.417	0	271
Koutsourelia	166	28.89	29.357	2.279	0	190
Kolobi	34	24.22	16.156	2.771	0	60
Kalamon	29	24.00	27.237	5.058	0	114
Megaritiki	65	17.45	16.147	2.003	0	72
Manaki	222	17.32	17.274	1.159	0	80
Mourtolia	13	9.41	12.360	3.428	0	39

Table 22. Mean concentration of Dialdehyde_Ligstroside_Aglycon per variety.

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Olympia	213	239.86	196.560	13.468	0	833
Athinolia	228	149.97	134.493	8.907	0	716
Total	4,778	85.07	106.225	1.537	0	833
Chalkidikis	312	83.28	84.504	4.784	0	460
Koroneiki	2,183	83.01	91.533	1.959	0	721
Lianolia	283	82.78	96.467	5.734	0	570
Amfissas	235	80.16	96.267	6.280	0	465
Kolobi	34	63.29	93.118	15.970	0	330
Agrielia	142	53.90	84.967	7.130	0	665
Koutsourelia	166	52.85	67.235	5.218	0	316
Megaritiki	65	49.32	78.554	9.743	0	328
Kalamon	29	43.05	72.252	13.417	0	228
Mourtolia	13	32.70	108.594	30.119	0	393
Manaki	222	28.36	50.491	3.389	0	405

Table 23. Mean concentration of Dialdehyde_Oleuropein_Aglycon per variety.

Variety	*n*	*Mean*	*Std. Dev.*	*Std. Er.*	*Min.*	*Max.*
Olympia	213	148.51	142.867	9.789	0	589
Athinolia	228	90.76	101.442	6.718	0	543
Total	4,778	51.58	78.089	1.130	0	867
Koroneiki	2,183	50.53	66.633	1.426	0	516
Lianolia	283	49.86	72.232	4.294	0	535
Kolobi	34	49.03	85.914	14.734	0	382
Mourtolia	13	46.99	169.429	46.991	0	611
Amfissas	235	44.51	65.223	4.255	0	309
Chalkidikis	312	40.98	55.645	3.150	0	384
Agrielia	142	33.99	82.272	6.904	0	867

Megaritiki	65	28.44	55.973	6.943	0	219
Kalamon	29	26.70	56.275	10.450	0	212
Koutsourelia	166	24.70	39.376	3.056	0	248
Manaki	222	19.84	60.472	4.059	0	735

Table 24. *Mean concentration of Total_Tyrosol_Derivatives per variety.*

Variety	n	Mean	Std. Dev.	Std. Er.	Min.	Max.
Olympia	213	521.30	308.264	21.122	0	1,244
Kalamon	29	430.20	402.497	74.742	0	1,559
Lianolia	283	418.19	195.159	11.601	0	1,391
Athinolia	228	331.80	199.743	13.228	0	930
Chalkidikis	312	299.26	174.264	9.866	0	837
Agrielia	142	265.89	178.622	14.990	0	1,077
Total	4,778	265.37	191.106	2.765	0	2,072
Amfissas	235	261.34	185.946	12.130	0	831
Koroneiki	2,183	240.07	149.435	3.198	0	1,249
Mourtolia	13	235.80	168.053	46.609	81	641
Koutsourelia	166	219.93	138.832	10.775	0	621
Kolobi	34	207.17	130.258	22.339	28	530
Megaritiki	65	154.93	113.694	14.102	0	515
Manaki	222	136.92	98.062	6.582	0	810

Table 25. *Mean concentration of Total_Hydroxy_Tyrosol_Derivatives per variety.*

Variety	n	Mean	Std. Dev.	Std. Er.	Min.	Max.
Olympia	213	374.28	267.201	18.308	0	1,217
Lianolia	283	292.78	165.760	9.853	0	1,051
Athinolia	228	228.55	175.710	11.637	0	783
Chalkidikis	312	178.50	133.211	7.542	0	722
Total	4,778	177.41	155.463	2.249	0	1,305
Kolobi	34	174.99	148.272	25.428	0	674
Koroneiki	2,183	164.28	127.786	2.735	0	955
Amfissas	235	164.02	139.652	9.110	0	684
Kalamon	29	158.92	163.145	30.295	0	590
Mourtolia	13	148.23	193.964	53.796	14	771
Agrielia	142	145.51	147.252	12.357	0	1,305
Koutsourelia	166	124.64	93.947	7.292	0	438
Manaki	222	102.59	120.169	8.065	0	1,023
Megaritiki	65	91.12	99.199	12.304	0	348

Table 26. *Mean concentration of Total_Phenols per variety.*

Variety	n	Mean	Std. Dev.	Std. Er.	Min.	Max.
Olympia	213	895.58	559.274	38.321	0	2,343
Lianolia	283	710.97	342.185	20.341	0	2,442
Kalamon	29	589.12	523.149	97.146	0	1,898
Athinolia	228	560.35	361.752	23.958	0	1,712
Chalkidikis	312	477.76	298.189	16.882	0	1,468
Total	4,778	442.78	332.792	4.814	0	2,442
Amfissas	235	425.36	312.446	20.382	0	1,438
Agrielia	142	411.40	307.541	25.808	0	2,382
Koroneiki	2,183	404.35	265.570	5.684	0	2,079
Mourtolia	13	384.04	328.859	91.209	153	1,287

Kolobi	34	382.15	271.916	46.633	28	1,204
Koutsourelia	166	344.57	221.867	17.220	0	1,059
Megaritiki	65	246.05	206.540	25.618	0	849
Manaki	222	239.51	203.785	13.677	0	1,396

All the subsets from the post-hoc multiple comparisons for the chemical studied traits are presented in Tables 27 to 36. Kalamon and Lianolia varieties were the outstanding varieties in the concentration of Oleocanthal and Oleacein respectively (Tables 27, 28, 29), while Olympia, which ranked fourth and second for the above corresponding substances, together with the varieties of Chalkidikis and Mourtolia formed the second subgroup with the highest concentrations for the respective compounds.

Table 27. Comparisons of variety's oleocanthal means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Oleocanthal (mg/g)								
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Kalamon	29	363.15						
Lianolia	283		303.25					
Mourtolia	13			193.69				
Olympia	213			190.88				
Agrielia	142			181.69	181.69			
Chalkidikis	312			179.70	179.70			
Amfissas	235				149.42	149.42		
Athinolia	228					143.73		
Koutsourelia	166					138.18		
Koroneiki	2183					125.11	125.11	
Kolobi	34					119.65	119.65	119.65
Manaki	222						91.24	91.24
Megaritiki	65							88.16

Table 28. Comparisons of variety's oleacein means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Oleacein (mg/g)							
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***
Lianolia	283	206.79					
Olympia	213		123.31				
Kalamon	29		104.25	104.25			
Chalkidikis	312			96.53	96.53		
Kolobi	34			94.93	94.93		
Athinolia	228			93.06	93.06		

Mourtolia	13			89.45	89.45	89.45	
Agrielia	142			83.79	83.79	83.79	
Amfissas	235			81.95	81.95	81.95	
Koroneiki	2183			77.52	77.52	77.52	
Koutsourelia	166				69.70	69.70	
Manaki	222					65.60	65.60
Megaritiki	65						43.10

Table 29. ***Comparisons of variety's Sum_Oleocanthal_Oleacein means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).***

Sum_Oleocanthal_Oleacein (mg/g)								
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Lianolia	283	510.04						
Kalamon	29	467.40						
Olympia	213		314.19					
Mourtolia	13		283.14	283.14				
Chalkidikis	312		276.23	276.23				
Agrielia	142		265.47	265.47	265.47			
Athinolia	228			236.78	236.78	236.78		
Amfissas	235			231.36	231.36	231.36		
Kolobi	34				214.58	214.58		
Koutsourelia	166					207.88	207.88	
Koroneiki	2183					202.63	202.63	
Manaki	222						156.84	156.84
Megaritiki	65							131.26

Olympia variety was the outstanding variety in the concentration of oleuropein aglycon, ligstroside aglycon, dialdehyde ligstroside aglycon, dialdehyde oleuropein aglycon, total tyrosol derivatives, total hydroxy tyrosol derivatives and total phenols (Tables 30-36). The varieties Athinolia, Lianolia, Mourtolia, Kalamon and Chalkidikis were classified in the following places depending to the substance being measured (Tables 30-36).

Table 30. ***Comparisons of variety's Oleuropein_Aglycon means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).***

Oleuropein_Aglycon (mg/g)							
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***
Olympia	213	102.46					
Athinolia	228		44.73				
Chalkidikis	312		40.99	40.99			
Amfissas	235		37.57	37.57			

Koroneiki	2183		36.23	36.23			
Lianolia	283		36.12	36.12			
Kolobi	34			31.02	31.02		
Koutsourelia	166			30.24	30.24		
Kalamon	29			27.96	27.96	27.96	
Agrielia	142			27.73	27.73	27.73	
Megaritiki	65				19.58	19.58	19.58
Manaki	222					17.16	17.16
Mourtolia	13						11.79

Table 31. Comparisons of variety's Ligstroside_Aglycon means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Ligstroside_Aglycon (mg/g)						
Variety	***n***	***1***	***2***	***3***	***4***	***5***
Olympia	213	90.56				
Athinolia	228		38.10			
Chalkidikis	312		36.29			
Lianolia	283		32.16	32.16		
Koroneiki	2183		31.95	31.95		
Amfissas	235		31.76	31.76		
Agrielia	142		30.31	30.31		
Koutsourelia	166		28.89	28.89		
Kolobi	34			24.22	24.22	
Kalamon	29			24.00	24.00	
Megaritiki	65				17.45	17.45
Manaki	222				17.32	17.32
Mourtolia	13					9.41

Table 32. Comparisons of variety's Dialdehyde_Ligstroside_Aglycon means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Dialdehyde_Ligstroside_Aglycon (mg/g)						
Variety	***n***	***1***	***2***	***3***	***4***	***4***
Olympia	213	239.86				
Athinolia	228		149.97			
Chalkidikis	312			83.28		
Koroneiki	2183			83.01		

Lianolia	283			82.78		
Amfissas	235			80.16	80.16	
Kolobi	34			63.29	63.29	63.29
Agrielia	142			53.90	53.90	53.90
Koutsourelia	166			52.85	52.85	52.85
Megaritiki	65			49.32	49.32	49.32
Kalamon	29				43.05	43.05
Mourtolia	13					32.70
Manaki	222					28.36

Table 33. Comparisons of variety's Dialdehyde_Oleuropein_Aglycon means using Duncan's multiple range test (a=0.05) (varieties under reside in the same subset are not statistically different).

Dialdehyde_Oleuropein_Aglycon (mg/g)					
Variety	***n***	***1***	***2***	***3***	***4***
Olympia	213	148.51			
Athinolia	228		90.76		
Koroneiki	2183			50.53	
Lianolia	283			49.86	
Kolobi	34			49.03	
Mourtolia	13			46.99	46.99
Amfissas	235			44.51	44.51
Chalkidikis	312			40.98	40.98
Agrielia	142			33.99	33.99
Megaritiki	65			28.44	28.44
Kalamon	29			26.70	26.70
Koutsourelia	166			24.70	24.70
Manaki	222				19.84

Table 34. Comparisons of variety's Total_Tyrosol_Derivatives means using Duncan's multiple range test (a=0.05) (varieties under reside in the same subset are not statistically different).

Total_Tyrosol_Derivatives (mg/g)								
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Olympia	213	521.30						
Kalamon	29		430.20					
Lianolia	283		418.19					
Athinolia	228			331.80				

Chalkidikis	312			299.26	299.26			
Agrielia	142				265.89	265.89		
Amfissas	235				261.34	261.34		
Koroneiki	2183				240.07	240.07		
Mourtolia	13				235.80	235.80		
Koutsourelia	166					219.93		
Kolobi	34					207.17	207.17	
Megaritiki	65						154.93	154.93
Manaki	222							136.92

Table 35. Comparisons of variety's Total_Hydroxy_Tyrosol_Derivatives means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Total_Hydroxy_Tyrosol_Derivatives (mg/g)							
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***
Olympia	213	374.28					
Lianolia	283		292.78				
Athinolia	228			228.55			
Chalkidikis	312				178.50		
Kolobi	34				174.99		
Koroneiki	2183				164.28		
Amfissas	235				164.02		
Kalamon	29				158.92		
Mourtolia	13				148.23	148.23	
Agrielia	142				145.51	145.51	
Koutsourelia	166				124.64	124.64	124.64
Manaki	222					102.59	102.59
Megaritiki	65						91.12

Table 36. Comparisons of variety's Total_Phenols means using Duncan's multiple range test (a=0.05) (varieties reside in the same subset are not statistically different).

Total_Phenols (mg/g)								
Variety	***n***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Olympia	213	895.58						
Lianolia	283		710.97					
Kalamon	29			589.12				
Athinolia	228			560.35	560.35			

Chalkidikis	312				477.76	477.76		
Amfissas	235					425.36	425.36	
Agrielia	142					411.40	411.40	
Koroneiki	2183					404.35	404.35	
Mourtolia	13					384.04	384.04	
Kolobi	34					382.15	382.15	
Koutsourelia	166						344.57	344.57
Megaritiki	65							246.05
Manaki	222							239.51

Overall, we can argue that the variety with highest phenolic concentrations is Olympia, followed by the variety Lianolia (Tables 27-36).

Differences between olive oil mill types

Examining the phenols concentrations between the olive oil mill type, without taking into account the variety, it was found that they were influenced by the mill type, as there were statistically significant differences in their concentrations. Table 37 shows the concentrations of chemical substances depending on the olive oil mill type. In the statistical analysis was included all the samples for which there were data on the mill type (n=2,034). In the two-phase mills there is a higher concentration of the substances: Oleuropein Aglycon, Ligstroside Aglycon, Dialdehyde Ligstroside Aglycon and Dialdehyde Oleuropein Aglycon. In contrast, the concentrations of Oleocanthal, Oleacein as well as their sum are higher when three phase olive oil mills were used.

Table 37. Comparisons of mill type's phenols means using Duncan's multiple range test (a=0.05) (phenols followed by * presented statistically difference in their concentration between the two mill type).

Oil Press Type	(mg/g)	Oleocanthal*	Oleacein*	Sum Oleocanthal Oleacein*	Oleuropein Aglycon	Ligstroside Aglycon
Two-Phase n=1,359	Mean	148.77	87.35	236.11	35.35	31.41
	Std. Dev.	106.634	71.992	164.878	28.054	25.536
Three-Phase n=675	Mean	133.79	78.62	212.41	33.09	30.90
	Std. Dev.	92.009	64.956	146.102	32.466	26.885
Oil Press Type	**(mg/g)**	**Dialdehyde Ligstroside Aglycon***	**Dialdehyde Oleuropein Aglycon***	**Total Tyrosol Derivatives***	**Total Hydroxy Tyrosol Derivatives***	**Total Phenols***
Two-Phase n=1,359	Mean	84.30	48.65	264.48	171.35	435.83
	Std. Dev.	100.917	73.773	177.118	142.217	303.166
Three-Phase n=675	Mean	74.57	41.12	239.25	152.83	392.08
	Std. Dev.	93.364	63.491	163.528	131.146	284.243

Table 38 shows the chemical substances that are and are not influenced by olive oil mill type.

Table 38. Phenols that are and are not influenced by olive oil mill type.

Influenced	Not Influenced
Oleocanthal	*Oleuropein Aglycon*
Oleacein	*Ligstroside Aglycon*
Dialdehyde Ligstroside Aglycon	
Dialdehyde Oleuropein Aglycon	
Total Tyrosol Derivatives	
Total Hydroxy Tyrosol Derivatives	
Total Phenols	

In order to test if there were a difference between the used mill type, taking into account the variety, correspondence bar charts were built (Diagrams 25-34), for all phenols substances (Table 37-38).

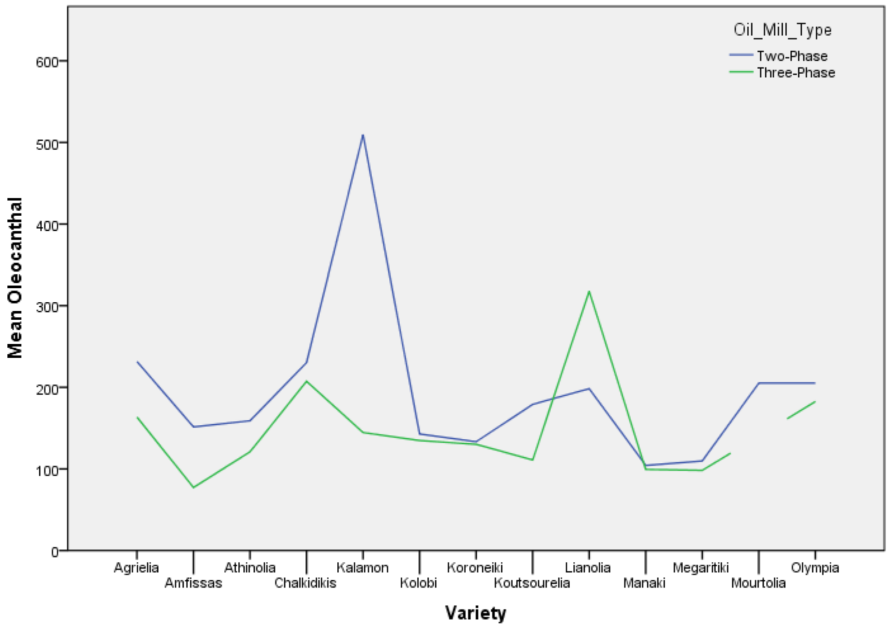

Diagram 25. Difference in oleocanthal concentration between the used mill type, of several varieties.

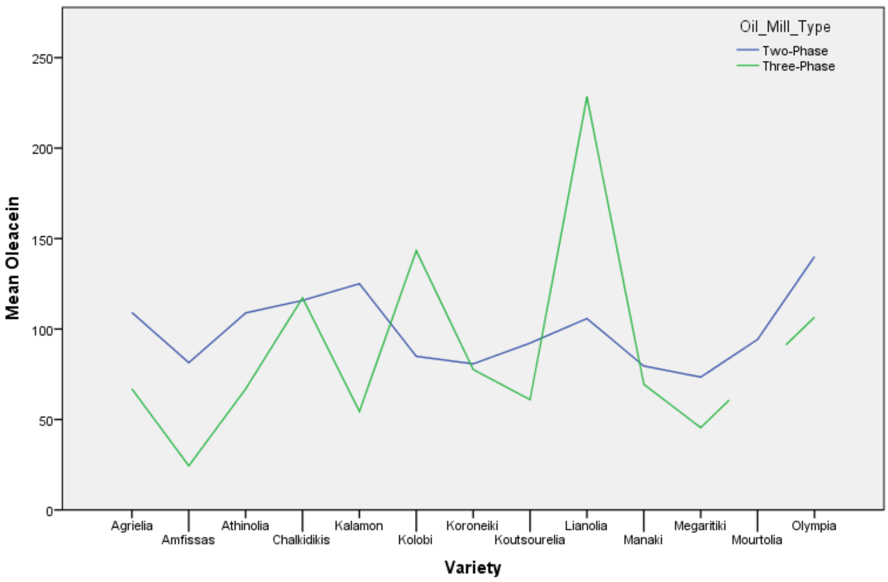

Diagram 26. Difference in oleacein concentration between the used mill type, of several varieties.

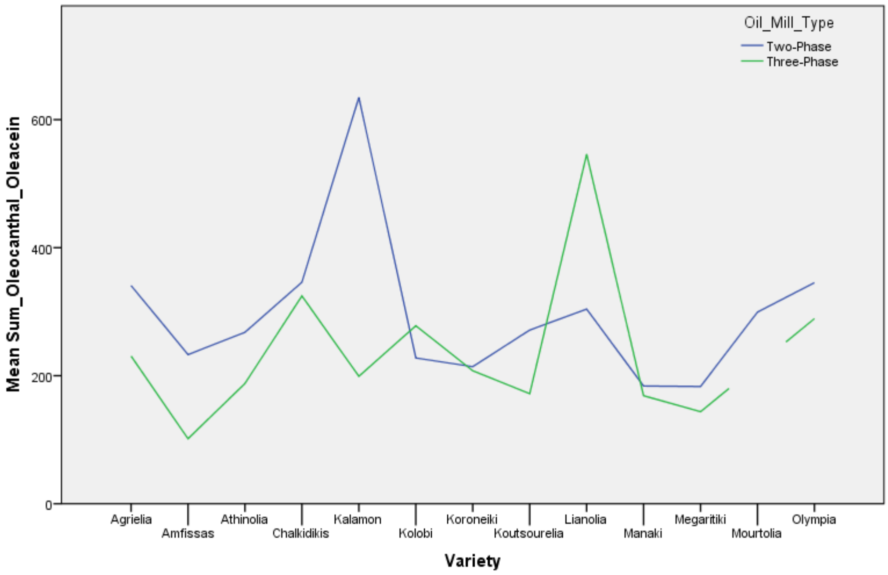

Diagram 27. Difference in sum oleacein-oleocanthal concentration between the used mill type, of several varieties.

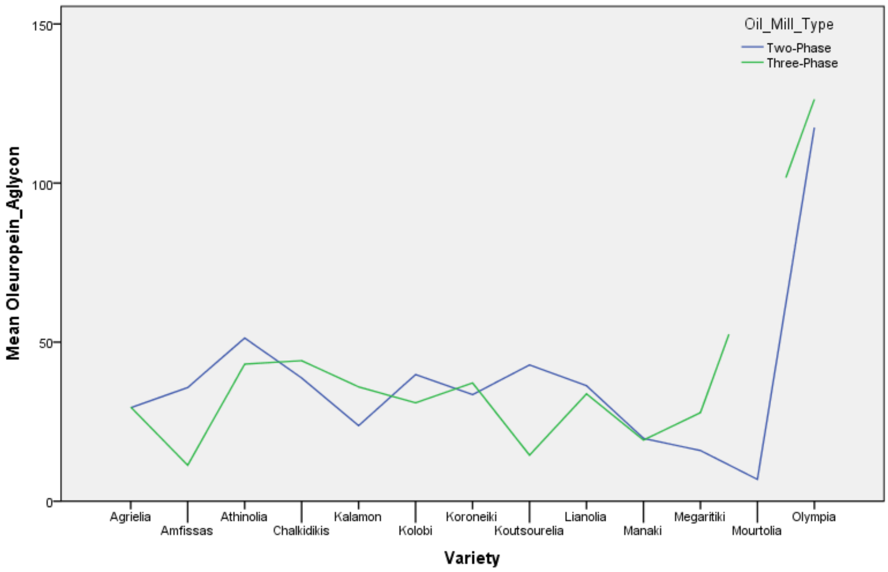

Diagram 28. Difference in oleuropein aglycon concentration between the used mill type, of several varieties.

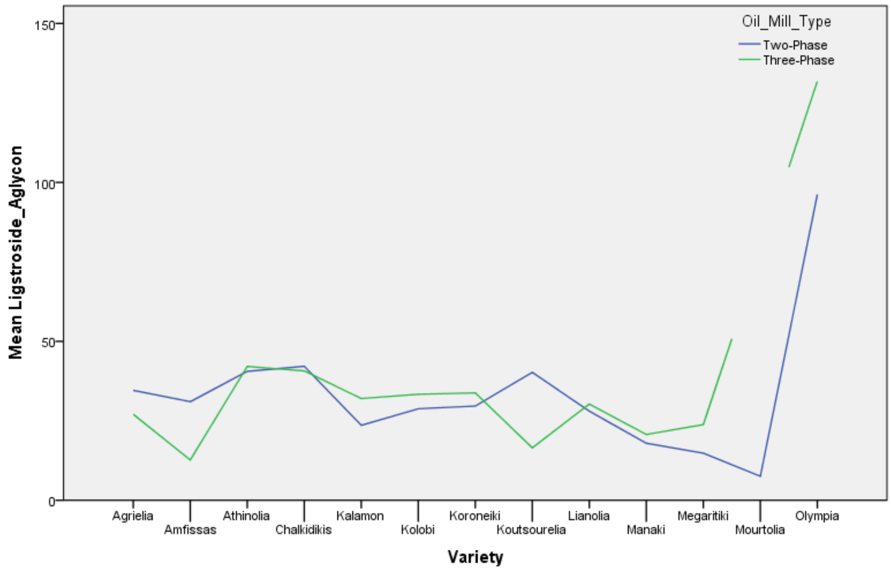

Diagram 29. Difference in ligstroside aglycon concentration between the used mill type, of several varieties.

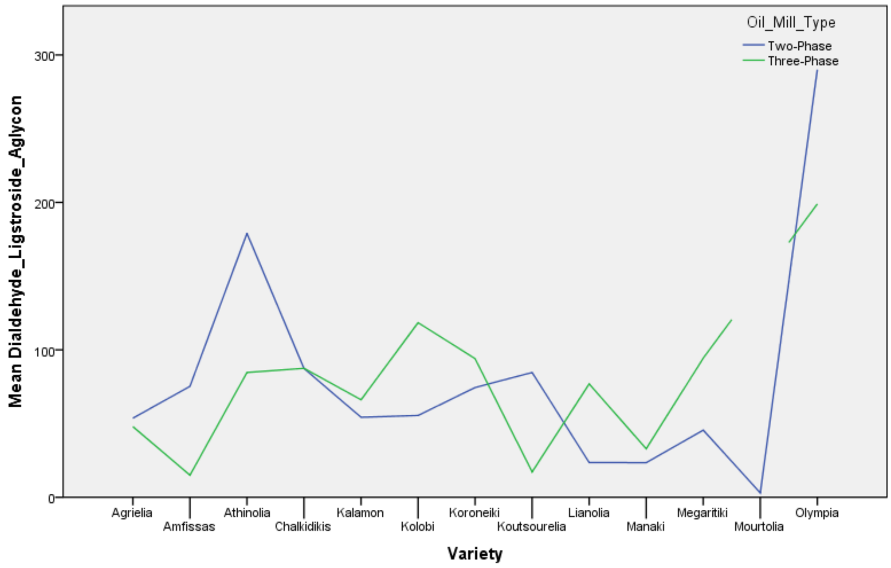

Diagram 30. Difference in dialdehyde ligstroside aglycon concentration between the used mill type, of several varieties.

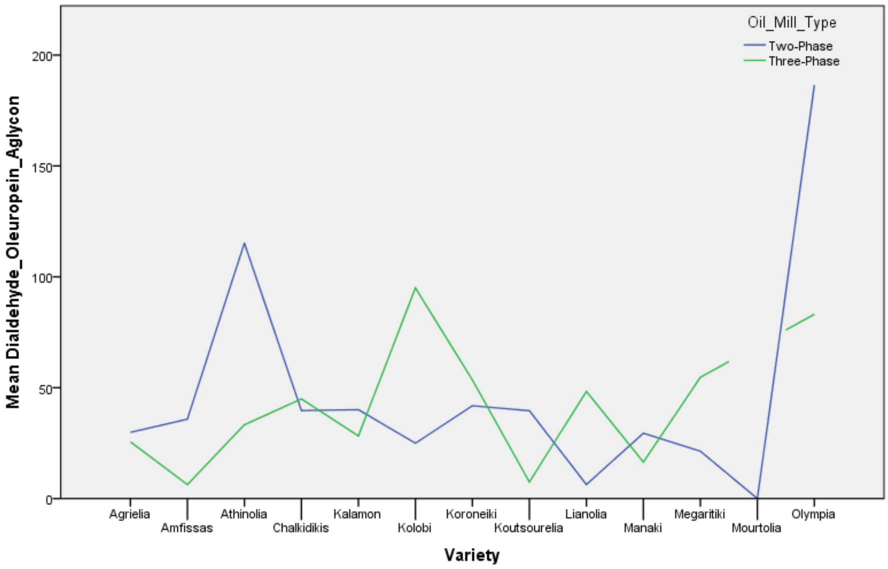

Diagram 31. Difference in dialdehyde oleuropein aglycon concentration between the used mill type, of several varieties.

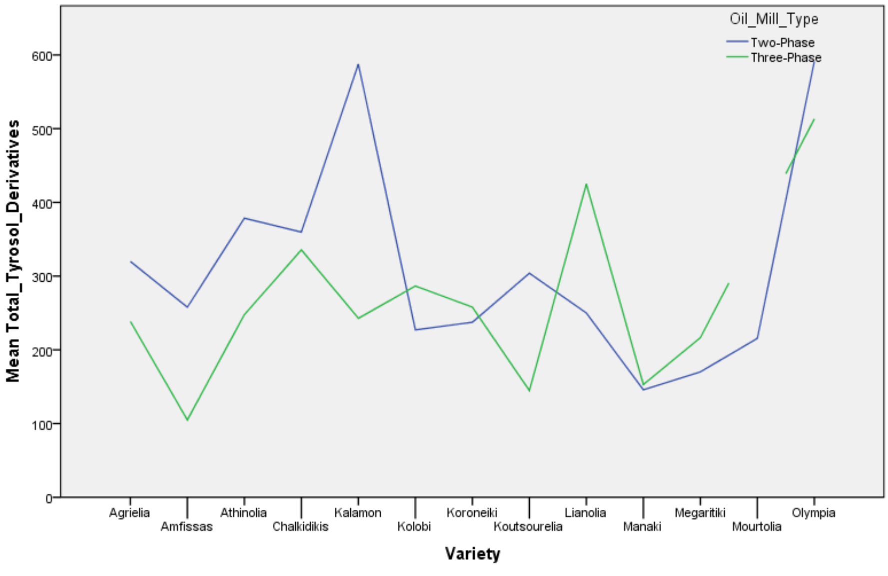

Diagram 32. Difference in total tyrosol derivatives concentration between the used mill type, of several varieties.

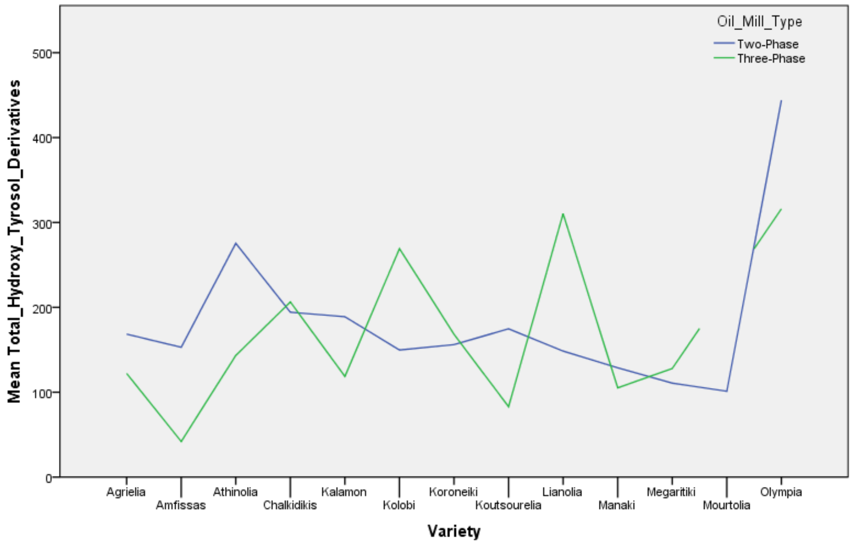

Diagram 33. Difference in total hydroxy tyrosol derivatives concentration between the used mill type, of several varieties.

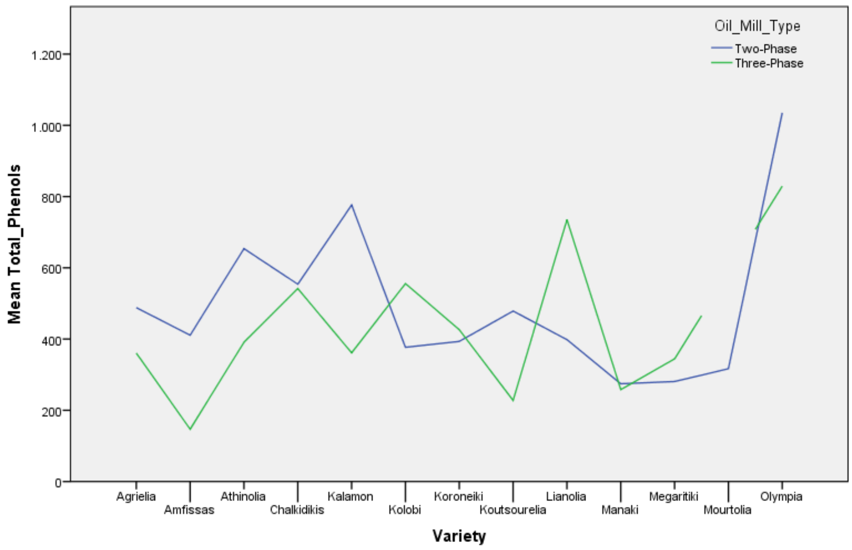

Diagram 34. Difference in total phenols concentration between the used mill type, of several varieties.

As shown in Diagrams 25-34, mill type plays an important role in presence of phenol substances in each variety individually. Overall, the three-phase mill type seemed to led to lower phenols concentrations. In contrast, when in the analysis variety was taken into account, the results were differentiated.

In order to determine to what extent mill type played an important role in the presence of phenol substances in each variety individually, independent sample t-test was performed. Through the analysis the means of the phenols concentrations between the mill type compared for each variety for which there were sufficient data, in order to determine whether there was statistical significantly difference between the corresponding means. The statistical analysis included sufficient number of samples (n=2,026) for which there were complete data for varieties and mill type (Table 39-40). The results are presented in Tables 41-53.

Table 39. Varieties (shaded lines) excluded from the GLM analysis.

Variety	*Oil_Mill_Type*		*Total*
	Two-Phase	*Three-Phase*	
No Data	39	21	60
Agrielia	48	20	68
Amfissas	112	15	127
Athinolia	152	16	168
Chalkidikis	41	91	132
Kalamon	10	6	16
Kolobi	3	10	13
Koroneiki	836	339	1175
Koutsourelia	42	43	85
Kypriaki	0	1	1
Ladolia-Aetolias Akarnanias	0	0	0
Lianolia	0	0	0
Manaki	47	97	144
Megaritiki	11	15	26
Mourtolia	11	0	11
Olympia	0	0	0
Throuba	0	0	0
Tsounati	0	0	0
Zakynthou	0	0	0
Koroneiki-Athinolia	0	0	0

Table 40. Varieties included in the GLM analysis.

Variety	**Oil Mill Type**		**Total**
	Two-Phase	***Three-Phase***	
Agrielia	48	20	68
Amfissas	112	15	127
Athinolia	152	16	168
Chalkidikis	41	91	132
Kalamon	10	6	16
Kolobi	3	10	13
Koroneiki	836	339	1175
Koutsourelia	42	43	85
Manaki	47	97	144
Megaritiki	11	15	26

Table 41. *t-test results for the Agrielia variety.*

Oil_Mill_Type		Oleocanthal	Oleacein	Sum Oleocanthal Oleacein	Oleuropein Aglycon	Ligstroside Aglycon	Dialdehyde Ligstroside Aglycon	Dialdehyde Oleuropein Aglycon	Total Tyrosol Derivatives	Total Hydroxy Tyrosol Derivatives	Total Phenols
Two-Phase	Mean	231.66	109.16	340.82	29.39	34.58	53.63	29.88	319.86	168.43	488.29
	n	48	48	48	48	48	48	48	48	48	48
	Std. Dev.	152.094	72.262	208.848	21.114	27.179	75.944	43.559	193.703	114.457	289.971
Three-Phase	Mean	163.57	66.98	230.55	29.59	27.05	47.96	25.57	238.57	122.14	360.72
	n	20	20	20	20	20	20	20	20	20	20
	Std. Dev.	110.147	59.223	154.226	22.722	12.991	57.492	39.666	153.419	108.701	247.522

Table 42. *t-test results for the Amfissas variety.*

Oil_Mill_Type		Oleocanthal	Oleacein	Sum Oleocanthal Oleacein	Oleuropein Aglycon	Ligstroside Aglycon	Dialdehyde Ligstroside Aglycon	Dialdehyde Oleuropein Aglycon	Total Tyrosol Derivatives	Total Hydroxy Tyrosol Derivatives	Total Phenols
Two-Phase	Mean	95.15	28.26	123.41	15.37	17.52	58.00	22.48	170.67	66.11	236.78
	n	112	112	112	112	112	112	112	112	112	112
	Std. Dev.	43.487	27.470	55.834	13.996	15.407	83.406	38.952	97.233	66.795	153.524
Three-Phase	Mean	55.86	10.78	66.64	6.31	5.53	4.81	1.66	66.20	18.75	84.95
	n	15	15	15	15	15	15	15	15	15	15
	Std. Dev.	53.223	16.927	57.690	12.706	11.124	17.327	5.995	64.207	24.143	81.108

Table 43. *t-test results for the Athinolia variety.*

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	Mean	158.98	108.88	267.86	51.30	40.57	178.99	115.21	378.54	275.40	653.94
	n	152	152	152	152	152	152	152	152	152	152
	Std. Dev.	75.862	63.698	130.871	33.416	31.313	139.342	111.998	203.217	188.212	376.974
Three-Phase	Mean	121.00	66.89	187.89	43.11	42.11	84.67	33.29	247.78	143.29	391.08
	n	16	16	16	16	16	16	16	16	16	16
	Std. Dev.	47.002	39.866	80.774	35.286	34.416	87.584	46.349	139.629	90.031	217.984

Table 44. *t-test results for the Chalkidikis variety.*

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	Mean	230.20	115.84	346.04	38.73	42.14	87.36	39.68	359.70	194.26	553.95
	n	41	41	41	41	41	41	41	41	41	41
	Std. Dev.	121.271	66.595	181.086	26.418	34.897	91.481	73.800	186.290	125.624	303.494
Three-Phase	Mean	207.35	117.24	324.59	44.18	40.71	87.47	44.94	335.54	206.35	541.89
	n	91	91	91	91	91	91	91	91	91	91
	Std. Dev.	112.002	83.440	185.384	33.945	28.718	80.943	60.594	176.681	155.493	321.400

Table 45. ***t-test results for the Kalamon variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	509.63	125.06	634.70	23.77	23.60	54.27	40.09	587.51	188.92	776.43
	n	10	10	10	10	10	10	10	10	10	10
	Std. Dev.	478.714	115.033	572.892	26.684	18.589	84.333	79.286	454.766	175.777	563.157
Three-Phase	**Mean**	144.60	54.45	199.05	35.94	32.01	66.14	28.26	242.75	118.64	361.39
	n	6	6	6	6	6	6	6	6	6	6
	Std. Dev.	74.358	41.102	103.880	23.310	25.608	80.378	35.700	106.795	79.546	181.104

Table 46. ***t-test results for the Kolobi variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	142.80	84.90	227.70	39.83	28.80	55.49	24.96	227.09	149.70	376.79
	n	3	3	3	3	3	3	3	3	3	3
	Std. Dev.	31.666	12.828	42.448	18.062	3.492	28.595	22.458	32.889	39.823	63.469
Three-Phase	**Mean**	134.78	143.30	278.08	30.93	33.35	118.43	95.00	286.57	269.22	555.79
	n	10	10	10	10	10	10	10	10	10	10
	Std. Dev.	44.915	67.846	110.073	15.149	19.571	137.084	135.415	152.657	186.835	332.299

Table 47. ***t-test results for the Koroneiki variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	133.32	80.78	214.10	33.50	29.65	74.44	41.86	237.41	156.14	393.55
	n	836	836	836	836	836	836	836	836	836	836
	Std. Dev.	85.378	71.972	146.372	25.269	22.001	87.642	59.714	151.025	126.164	264.599
Three-Phase	**Mean**	130.12	77.64	207.76	37.17	33.79	94.05	53.48	257.96	168.29	426.25
	n	339	339	339	339	339	339	339	339	339	339
	Std. Dev.	91.369	58.683	138.098	32.715	25.886	104.189	70.444	166.720	130.536	285.201

Table 48. ***t-test results for the Koutsourelia variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	162.73	86.47	249.20	26.22	21.60	41.78	27.16	226.11	139.86	365.97
	n	42	42	42	42	42	42	42	42	42	42
	Std. Dev.	82.040	82.306	147.643	29.071	26.474	58.563	58.983	131.778	133.384	240.234
Three-Phase	**Mean**	109.24	60.32	169.56	13.96	15.81	15.70	7.44	140.75	81.72	222.47
	n	43	43	43	43	43	43	43	43	43	43
	Std. Dev.	45.197	29.483	66.126	12.934	12.363	40.155	20.069	65.430	44.376	103.849

Table 49. ***t-test results for the Manaki variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	104.30	79.56	183.85	19.76	17.94	23.47	29.47	145.71	128.79	274.50
	n	47	47	47	47	47	47	47	47	47	47
	Std. Dev.	52.514	57.800	104.268	13.922	14.705	43.750	109.639	77.995	152.444	196.531
Three-Phase	**Mean**	99.31	69.45	168.76	19.23	20.70	32.94	16.48	152.94	105.16	258.10
	n	97	97	97	97	97	97	97	97	97	97
	Std. Dev.	59.279	66.806	120.526	13.344	17.318	52.674	30.769	102.452	94.243	190.493

Table 50. ***t-test results for the Megaritiki variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	109.75	73.41	183.16	15.93	14.82	45.57	21.36	170.13	110.71	280.84
	n	11	11	11	11	11	11	11	11	11	11
	Std. Dev.	77.831	76.143	151.403	15.655	17.650	65.118	35.341	98.152	86.188	176.766
Three-Phase	**Mean**	98.27	45.48	143.74	27.84	23.82	94.37	54.71	216.46	128.02	344.48
	n	15	15	15	15	15	15	15	15	15	15
	Std. Dev.	63.374	43.602	100.059	25.515	20.192	108.748	77.797	141.524	117.720	251.694

Table 51. ***t-test results for the Patrinia variety.***

Oil_Mill_Type		*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Total Phenols*
Two-Phase	**Mean**	203.00	100.78	303.78	67.27	67.69	147.63	57.92	418.32	225.96	644.28
	n	17	17	17	17	17	17	17	17	17	17
	Std. Dev.	80.072	56.046	132.337	37.393	36.767	84.115	51.367	142.198	108.298	241.834
Three-Phase	**Mean**	134.56	69.52	204.08	21.48	25.77	37.00	8.02	197.33	99.02	296.35
	n	3	3	3	3	3	3	3	3	3	3
	Std. Dev.	41.105	5.494	46.324	18.749	22.320	32.376	13.885	14.201	25.220	36.253

Table 52. Varieties influenced and not by oil mill type.

Influenced	***Not influenced***
Agrielia	*Chalkidikis*
Amfissas	*Kalamon*
Athinolia	*Kolobi*
Koroneiki	*Manaki*
Koutsourelia	*Megaritiki*
Patrinia	
Piliou	

Table 53. ***Statistical significance of the mill type effect on phenols production in different varieties.***

	Agrielia	Amfissas	Athinolia	Chalkidikis	Kalamon	Kolobi	Koroneiki	Koutsourelia	Manaki	Megaritiki	Patrinia
Oleocanthal	ns	**	*	ns	ns	ns	ns	**	ns	ns	ns
Oleacein	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns
Sum Oleocanthal Oleacein	*	**	*	ns	ns	ns	ns	**	ns	ns	ns
Oleuropein Aglycon	ns	*	ns	ns	ns	ns	*	*	ns	ns	ns
Ligstroside Aglycon	ns	*	ns	ns	ns	ns	**	ns	ns	ns	ns
Dialdehyde Ligstroside Aglycon	ns	*	**	ns	ns	ns	**	*	ns	ns	*
Dialdehyde Oleuropein Aglycon	ns	ns	**	ns	ns	ns	**	ns	ns	ns	ns
Total Tyrosol Derivatives	ns	**	*	ns	ns	ns	*	**	ns	ns	*
Total Hydroxy Tyrosol Derivatives	ns	*	**	ns	ns	ns	ns	*	ns	ns	ns
Total Phenols	ns	**	**	ns	ns	ns	ns	**	ns	ns	*

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

In order to test if there was an interaction between the variety and the mill type, a simple general linear model applied. Analysis was based on individual values and performed using the General Linear Model (GLM) type III hypothesis testing, that is best suited to unbalanced samples or missing observations in experiments (Searle 1987, Milliken and Johnson 1992). The following linear models was used:

$$y_{ijk} = \mu + v_j + m_i + v_j * m_i + e_{ijk}$$

y_{ijk} = phenol concentration of k^{th} sample of j^{th} variety and i^{th} mill type, as dependent variable

μ = fixed population mean of all samples averaged across all the data

v_j = random effect of the j^{th} = 1 ... 11 variety

m_i = fixed effect of the i^{th} = 1… 2 mill type

$v_j * m_i$ = random effect of interaction between the i^{th} mill type and j^{th} variety

e_{ijk} = random residual error of k[th] sample of j[th] variety and i[th] mill type.

Both statistical analyses included sufficient number of samples (n=1,973) for which there were complete data for varieties and mill type (Table 39-40).

Table 53. Statistical significance of the mill type-variety interaction in phenols production.

Source	*Oleocanthal*	*Oleacein*	*Sum Oleocanthal Oleacein*	*Oleuropein Aglycon*	*Ligstroside Aglycon*	*Dialdehyde Ligstroside Aglycon*	*Dialdehyde Oleuropein Aglycon*	*Total Tyrosol Derivatives*	*Total Hydroxy Tyrosol Derivatives*	*Tot Phen*
*Oil_Mill_Type*Variety interaction*	***	ns	***	ns	*	***	***	**	***	**

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Differences among years, months and weeks of harvest

In order to test if there was difference among harvest years, months and weeks, three general linear models were applied. Analysis was based on individual values and performed using the General Linear Model (GLM) type III hypothesis testing, that is best suited to unbalanced samples or missing observations in experiments (Searle 1987, Milliken and Johnson 1992). The first linear model was used in order to examine if there were statistical differences among years and months (overall) of olive harvest in the production of the studied phenol substances:

$$y_{ijk} = \mu + y_j + m_i(y_j) + e_{ijk} \qquad \textit{(GLM 1)}$$

y_{ijk} = phenol concentration of k[th] sample of j[th] year and i[th] month, as dependent variable

μ = fixed population mean of all samples averaged across all the data

y_j = random effect of the j[th] = 1 ... 5 year

$m_i(y_j)$ = random effect of the i[th] = 1… 5 month nested in the j[th] = 1 … 5 year

e_{ijk} = random residual error of k[th] sample, j[th] year and i[th] month.

The next linear model was used in order to examine if there were statistical differences among months overall and within each harvest year in the production of the studied phenol substances:

$$y_{ik} = \mu + m_i + e_k \qquad \textit{(GLM2)}$$

y_{ik} = phenol concentration of k[th] sample of i[th] month, as dependent variable

μ = fixed population mean of all samples averaged across all the data

m_i = random effect of the i^{th} = 1… 5 month

e_{ik} = random residual error of k^{th} sample of i^{th} month.

The last linear model was used in order to examine if there were statistical differences among weeks overall and within each harvest year in the production of the studied phenol substances:

$$y_{kl} = \mu + w_k + e_{kl} \qquad \text{(GLM 3)}$$

y_{kl} = phenol concentration of l^{th} sample of k^{th} week, as dependent variable

μ = fixed population mean of all samples averaged across all the data

w_k = random effect of the k^{th} = 1… 22 week

e_{lk} = random residual error of l^{th} sample of k^{th} week.

Differences among years (GLM 1)

The statistical significance in phenol concentrations among harvest years is presented in Table 54. Although there was no statistically significant difference for oleacein and sum of oleocanthal and oleacein, post hoc were performed. All the results of the post hoc tests for the multiple comparisons, using Duncan's Multiple Range Test (MRT), are presented in Tables 55- 64. The 2014-2015 harvest period was observed the highest oleocanthal concentration (Table 55, Diagram 35). The 2016-2017 harvest period was the best for oleacein as for the sum of oleocanthal and oleacein (Tables 56-57, Diagram 35), while the next (2017-2018) was for the oleuropein aglycon and ligstroside aglycon (Tables 58-59, Diagram 35). During the 2015-2016 harvest period, was observed the highest concentration for dialdehyde oleuropein aglycon and dialdehyde ligstroside aglycon, total tyrosol derivatives, total hydroxy tyrosol derivatives and total phenols (Tables 60-64, Diagram 35).

Table 54. Statistical significance of phenol concentrations among harvest years.

Oleocanthal	***
Oleacein	ns*
Sum_Oleocanthal_Oleacein	**
Oleuropein_Aglycon	ns*

Ligstroside_Aglycon	***
Dialdehyde_Ligstroside_Aglycon	*
Dialdehyde_Oleuropein_Aglycon	*
Total_Tyrosol_Derivatives	**
Total_Hydroxy_Tyrosol_Derivatives	ns*
Total_Phenols	ns*
****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***	
ns : although the model showed non-significant differences we proceed in MRT*	

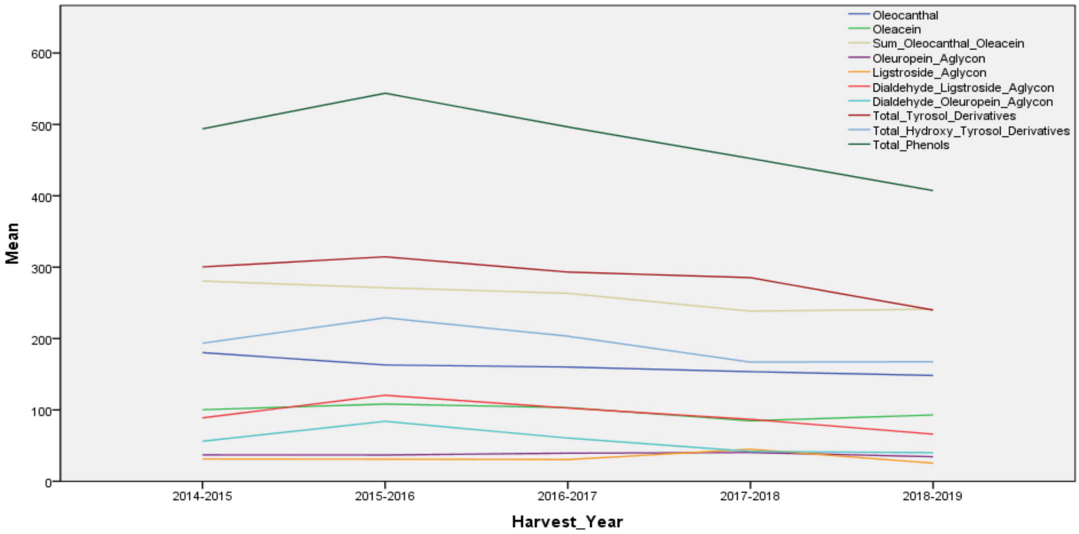

Diagram 35. Difference in the concentration of the mean concentration phenols among the studied years in relation of harvest month.

***Table 55.* Comparisons of oleocanthal means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).**

Harvest Year	**n**	**1**	**2**
2014-2015	161	180.23	
2015-2016	292		163.00
2016-2017	703		160.11
2017-2018	1,308		153.56
2018-2019	895		148.32

***Table 56.* Comparisons of oleacein means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).**

Harvest Year	**N**	**1**	**2**	**3**
2015-2016	292	108.18		
2016-2017	703	103.31	103.31	
2014-2015	161	100.32	100.32	
2018-2019	895		92.92	92.92
2017-2018	1,308			84.77

Table 57. ***Comparisons of sum oleocanthal oleacein means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	**N**	**1**	**2**
2014-2015	161	*280.55*	
2015-2016	292	271.19	
2016-2017	703	*263.42*	*263.42*
2018-2019	895		241.24
2017-2018	1,308		*238.33*

Table 58. ***Comparisons of oleuropein aglycon means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	**N**	**1**
2017-2018	1,308	40.35
2016-2017	703	39.42
2014-2015	161	36.98
2015-2016	292	36.89
2018-2019	895	34.49

Table 59. ***Comparisons of ligstroside aglycon means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	**n**	**1**	**2**	**3**
2017-2018	1,308	44.93		
2014-2015	161		31.25	
2015-2016	292		30.99	
2016-2017	703		30.46	
2018-2019	895			25.45

Table 60. ***Comparisons of dialdehyde ligstroside aglycon means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	**n**	**1**	**2**	**3**
2015-2016	292	120.56		
2016-2017	703		102.58	
2014-2015	161		88.86	
2017-2018	1,308		86.83	
2018-2019	895			66.09

Table 61. ***Comparisons of dialdehyde oleuropein aglycon means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	n	1	2	3
2015-2016	292	84.03		
2016-2017	703		60.60	
2014-2015	161		56.15	
2017-2018	1,308			41.87
2018-2019	895			40.05

Table 62. ***Comparisons of total tyrosol derivatives means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	n	1	2
2015-2016	292	314.55	
2014-2015	161	300.34	
2016-2017	703	293.15	
2017-2018	1,308	285.32	
2018-2019	895		239.86

Table 63. ***Comparisons of total hydroxy tyrosol derivatives means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	n	1	2	3
2015-2016	292	229.10		
2016-2017	703		203.33	
2014-2015	161		193.44	
2018-2019	895			167.47
2017-2018	1,308			166.99

Table 64. ***Comparisons of total phenols means (mg/g) among harvest years using Duncan's multiple range test (a=0.05) (harvest years reside in the same subset are not statistically different).***

Harvest Year	n	1	2	3
2015-2016	292	543.65		
2016-2017	703	496.48	496.48	
2014-2015	161	493.78	493.78	
2017-2018	1,308		452.31	452.31
2018-2019	895			407.33

Differences among months of harvest overall (ANOVA)

The statistical significance in phenol concentrations among harvest months is presented in Table 65. Although there was no statistically significant difference for oleuropein aglycon and ligstroside aglycon, post hoc were performed. All the results of the post hoc tests for the multiple comparisons, using Duncan's Multiple Range Test (MRT), are presented in Tables 66-75. September was the best month for oleocanthal, the sum of oleocanthal and oleacein, total tyrosol derivatives and total phenols production (Tables 66, 68,73, 75), while October was for the oleacein dialdehyde oleuropein aglycon and total hydroxy tyrosol derivatives (Tables 67, 72, 74). In November, oleuropein aglycon, ligstroside aglycon and dialdehyde ligstroside aglycon presented the higher concentrations (Tables 69-71).

Table 65. Statistical significance of phenol concentrations among harvest months (overall).

Oleocanthal	***
Oleacein	***
Sum_Oleocanthal_Oleacein	***
Oleuropein_Aglycon	***
Ligstroside_Aglycon	ns
Dialdehyde_Ligstroside_Aglycon	***
Dialdehyde_Oleuropein_Aglycon	***
Total_Tyrosol_Derivatives	***
Total_Hydroxy_Tyrosol_Derivatives	***
Total_Phenols	***

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Table 66. Comparisons of oleocanthal means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Month	**n**	**1**	**2**	**3**	**4**
September	111	251.06			
October	613		191.34		
November	1017			159.35	
December	864				131.84
January	72				111.95

Table 67. ***Comparisons of oleacein means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Month	n	1	2	3
October	613	117.95		
September	111	116.12		
November	1017		98.22	
December	864			80.20
January	72			68.97

Table 68. ***Comparisons of sum oleocanthal oleacein means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Month	n	1	2	3	4
September	111	367.18			
October	613		309.29		
November	1017			257.57	
December	864				212.04
January	72				180.92

Table 69. ***Comparisons of oleuropein aglycon means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Month	n	1	2
November	1017	40.76	
October	613	39.40	
September	111	37.82	37.82
December	864	33.26	33.26
January	72		30.85

Table 70. ***Comparisons of ligstroside aglycon means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Month	n	1

November	1017	35.68
September	111	34.20
January	72	33.41
December	864	32.95
October	613	32.40

Table 71. Comparisons of dialdehyde ligstroside aglycon means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Month	n	1	2
November	1017	98.85	
October	613	97.24	
September	111	80.94	
December	864	77.58	
January	72		54.33

Table 72. Comparisons of dialdehyde oleuropein aglycon means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Month	n	1	2
October	613	58.51	
November	1017	55.98	
December	864	45.19	45.19
September	111	41.61	41.61
January	72		28.41

Table 73. Comparisons of total tyrosol derivatives means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Month	n	1	2	3	4
September	111	366.20			
October	613		320.97		
November	1017		293.88		
December	864			242.38	
January	72				199.70

Table 74. Comparisons of total hydroxy tyrosol derivatives means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Month	n	1	2

October	613	215.86	
September	111	195.55	
November	1017	194.96	
December	864		158.64
January	72		128.22

Table 75. ***Comparisons of total phenols means (mg/g) among harvest months using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Month	n	1	2	3
September	111	561.75		
October	613	536.84		
November	1017	488.84		
December	864		401.02	
January	72			327.92

Differences among months of harvest in each year (GLM 2)

The results of the ANOVA for the studied phenols' concentrations among harvest months in each year are presented in Tables 76-86.

Table 76. ***Statistical significance of phenol concentrations among harvest months in each year.***

ANOVA	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Oleocanthal	***	**	***	***	***
Oleacein	**	ns	***	***	ns
Sum_Oleocanthal_Oleacein	***	*	***	***	***
Oleuropein_Aglycon	ns	ns	**	***	ns
Ligstroside_Aglycon	ns	ns	***	***	**
Dialdehyde_Ligstroside_Aglycon	ns	ns	***	***	*
Dialdehyde_Oleuropein_Aglycon	ns	ns	***	***	*
Total_Tyrosol_Derivatives	*	ns	***	***	***
Total_Hydroxy_Tyrosol_Derivatives	*	ns	***	***	ns
Total_Phenols	*	ns	***	***	***

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Table 77. ***Comparisons of oleocanthal means (mg/g) among harvest months in each year using Duncan's mul range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015				*2015-2016*				*2016-2017*				*2017-2018*					*2018-2019*			
Harvest Month	*n*			*Harvest Month*	*n*			*Harvest Month*	*n*			*Harvest Month*	*n*				*Harvest Month*	*n*		
		1	2			1	2			1	2			1	2	3			1	
Oct	26	261		**Oct**	32	224		**Sep**	15	218		**Sept**	21	392			**Sep**	73	222	
Nov	78		178	**Nov**	145	167	167	**Oct**	129	211		**Oct**	136		201		**Oct**	290	168	[illegible]

Dec	59		151	**Dec**	108	145	145	**Nov**	235	174		**Nov**	311		171		**Dec**	133	
				Sep	2		72	**Dec**	93		116	**Dec**	471			129	**Nov**	248	
				Jan	5		71	**Jan**	19		106	**Jan**	42			122	**Jan**	6	

Table 78. ***Comparisons of oleacein means (mg/g) among harvest months in each year using Duncan's multi range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015				*2015-2016*			*2016-2017*					*2017-2018*						*2018-2019*	
Harvest Month	*n*	*Subset*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*				*Harvest Month*	*1*
		1	2			1			1	2	3		n	1	2	3	4		n
Oct	26	142		Oct	32	131	**Oct**	129	155			**Sep**	21	150				**Sep**	73
Nov	78		98	Nov	145	109	**Sep**	15	114	114		**Oct**	136		108			**Oct**	290
Dec	59		87	Dec	108	103	**Nov**	235		109		**Nov**	311		98	98		**Dec**	133
				Sep	2	80	**Dec**	93		72	72	**Jan**	42			75	75	**Nov**	248
				Jan	5	54	**Jan**	19			59	**Dec**	471				72	**Jan**	6

Table 79. ***Comparisons of sum oleocanthal oleacein means (mg/g) among harvest months in each year u Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015				*2015-2016*				*2016-2017*				*2017-2018*					*2018-2019*		
Harvest Month	*n*	*Subset*		*Harvest Month*	*n*	*Subset*		*Harvest Month*	*n*	*Subset*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Su*
		1	2			1	2			1	2			1	2	3			1
Oct	26	403		**Oct**	32	355		**Oct**	129	366		**Sep**	21	542			**Sep**	73	330
Nov	78		276	**Nov**	145	276	276	**Sep**	15	332		**Oct**	136		309		**Oct**	290	271
Dec	59		237	**Dec**	108	249	249	**Nov**	235	283		**Nov**	311		269		**Dec**	133	229
				Sep	2	152	152	**Dec**	93		188	**Dec**	471			200	**Nov**	248	
				Jan	5		125	**Jan**	19		165	**Jan**	42			197	**Jan**	6	

Table 80. ***Comparisons of oleuropein aglycon means (mg/g) among harvest months in each year using Dunc multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015			*2015-2016*			*2016-2017*					*2017-2018*				*2018-2019*	
Harvest Month	*n*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*		*Harvest Month*	*n*
		1			1			1	2	3			1	2		
Dec	59	38	Oct	32	42	**Sep**	15	62			**Nov**	311	56		**Jan**	6
Oct	26	37	Dec	108	39	**Oct**	129		44		**Oct**	136	44	44	**Oct**	290
Nov	78	36	Sep	2	39	**Nov**	235		39	39	**Sep**	21	40	40	**Sep**	73
			Nov	145	34	**Dec**	93		36	36	**Dec**	471		32	**Dec**	133
			Jan	5	30	**Jan**	19			26	**Jan**	42		32	**Nov**	248

Table 81. ***Comparisons of ligstroside aglycon means (mg/g) among harvest months in each year using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015			*2015-2016*			*2016-2017*					*2017-2018*				*2018-2019*		
Harvest Month	*n*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*		*Harvest Month*	*n*	
		1			1			1	2	3			1	2			1

Oct	26	34	Oct	32	40	**Sep**	15	50			**Nov**	311	55		**Sep**	73	30
Nov	78	32	Dec	108	30	**Oct**	129		35		**Jan**	42	44	44	**Oct**	290	27
Dec	59	29	Nov	145	30	**Nov**	235		31		**Oct**	136	39	39	**Jan**	6	21
			Sep	2	21	**Dec**	93		25	25	**Dec**	471	39	39	**Nov**	248	21
			Jan	5	20	**Jan**	19			17	**Sep**	21		37	**Dec**	133	20

Table 82. ***Comparisons of dialdehyde ligstroside aglycon means (mg/g) among harvest months in each year using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015			*2015-2016*			*2016-2017*					*2017-2018*					*2018-2019*		
Harvest Month	*n*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	
		1			1			1	2	3			1	2	3			1
Dec	59	99	Dec	108	126	Sep	15	184			Nov	311	133			Oct	290	73
Oct	26	84	Sep	2	124	Oct	129	143	143		Sep	21	109	109		Dec	133	58
Nov	78	81	Nov	145	122	Nov	235		97	97	Oct	136	105	105		Sep	73	50
			Oct	32	109	Dec	93		96	96	Dec	471		66	66	Nov	248	50
			Jan	5	52	Jan	19			47	Jan	42			59	Jan	6	50

Table 83. ***Comparisons of dialdehyde oleuropein aglycon means (mg/g) among harvest months in each year using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015			*2015-2016*			*2016-2017*					*2017-2018*				*2018-2019*		
Harvest Month	*n*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*			*Harvest Month*	*n*	
		1			1			1	2	3			1	2			1
Oct	26	76	**Sep**	2	156	**Sep**	15	103			**Nov**	311	66		**Jan**	6	48
Dec	59	57	**Dec**	108	93	**Oct**	129	95	95		**Sep**	21	56	56	**Oct**	290	43
Nov	78	48	**Nov**	145	83	**Dec**	93	61	61	61	**Oct**	136	53	53	**Dec**	133	38
			Oct	32	63	**Nov**	235		55	55	**Dec**	471		32	**Nov**	248	31
			Jan	5	34	**Jan**	19			26	**Jan**	42		26	**Sep**	73	22

Table 84. ***Comparisons of total tyrosol derivatives means (mg/g) among harvest months in each year using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015				*2015-2016*			*2016-2017*					*2017-2018*					*2018-2019*			
Harvest Month	*n*	*Subset*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*	
		1	2			1			1	2	3			1	2	3			1	2
Oct	26	380		**Oct**	32	373	**Sep**	15	452			**Sep**	21	538			**Sep**	73	303	
Nov	78		290	**Nov**	145	319	**Oct**	129	389			**Nov**	311		358		**Oct**	290	268	268
Dec	59		279	**Dec**	108	302	**Nov**	235		302		**Oct**	136		345		**Dec**	133	214	214
				Sep	2	218	**Dec**	93		237	237	**Dec**	471			233	**Nov**	248		192
				Jan	5	144	**Jan**	19			170	**Jan**	42			225	**Jan**	6		168

Table 85. ***Comparisons of total hydroxy tyrosol derivatives means (mg/g) among harvest months in each y using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistic different).***

2014-2015	*2015-2016*	*2016-2017*	*2017-2018*	*2018-2019*

Harvest Month	*n*	*Subset*		*Harvest Month*	*n*		*Harvest Month*	*n*	*Subset*			*Harvest Month*	*n*	*Subset*		*Harvest Month*	*n*
		1	2			1			1	2	3			1	2		
Oct	26	255		**Sep**	2	274	**Oct**	129	293			**Sep**	21	245		**Oct**	290
Nov	78		183	**Oct**	32	236	**Sep**	15	280			**Nov**	311	220		**Sep**	73
Dec	59		181	**Dec**	108	236	**Nov**	235		203		**Oct**	136	205		**Dec**	133
				Nov	145	226	**Dec**	93		169	169	**Dec**	471		135	**Jan**	6
				Jan	5	118	**Jan**	19			111	**Jan**	42		133	**Nov**	248

Table 86. ***Comparisons of total phenols means (mg/g) among harvest months in each year using Dunc multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

2014-2015				**2015-2016**			**2016-2017**					**2017-2018**					**2018-2019**	
Harvest Month	**n**	**Subset**		**Harvest Month**	**n**		**Harvest Month**	**n**	**Subset**			**Harvest Month**	**n**	**Subset**			**Harvest Month**	**n**
		1	2			1			1	2	3			1	2	3		
Oct	26	634		Oct	32	610	Sep	15	732			Sep	21	783			Sep	73
Nov	78		473	Nov	145	544	Oct	129	683			Nov	311		578		Oct	290
Dec	59		460	Dec	108	537	Nov	235		505		Oct	136		550		Dec	133
				Sep	2	492	Dec	93		406	406	Dec	471			369	Nov	248
				Jan	5	262	Jan	19			281	Jan	42			357	Jan	6

The concentrations of the studied phenol substances among harvest months, for each year, are presented in Diagrams 36-45. In general, the phenols concentrations are higher when olives were harvested during the first months of the olive harvest period e.g. oleocanthal, oleacein, the sum of oleocanthal and oleacein, total hydroxy tyrosol derivatives, total tyrosol derivatives and total phenols. The concentration of oleuropein aglycon, ligstroside aglycon, dialdehyde oleuropein aglycon and dialdehyde ligstroside aglycon usually followed the above rule but were more depended on harvest year.

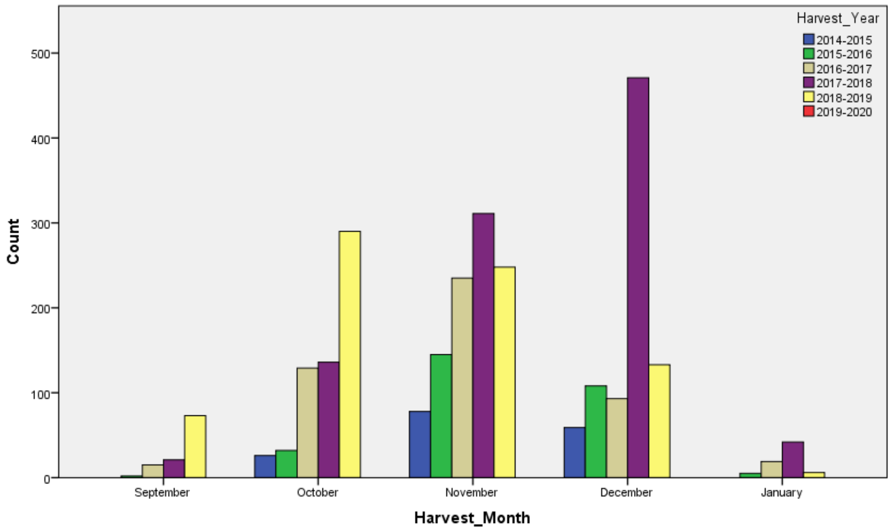

Diagram 36. The distribution of the analyzed olive oil samples in relation to harvest month and year.

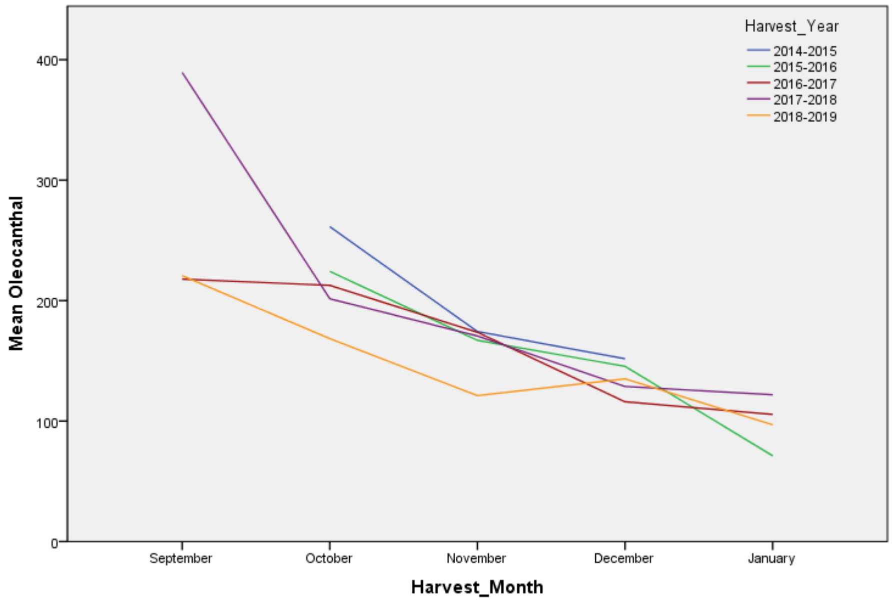

Diagram 37. Difference in the concentration of oleocanthal (mg/g) among the studied years in relation of harvest month.

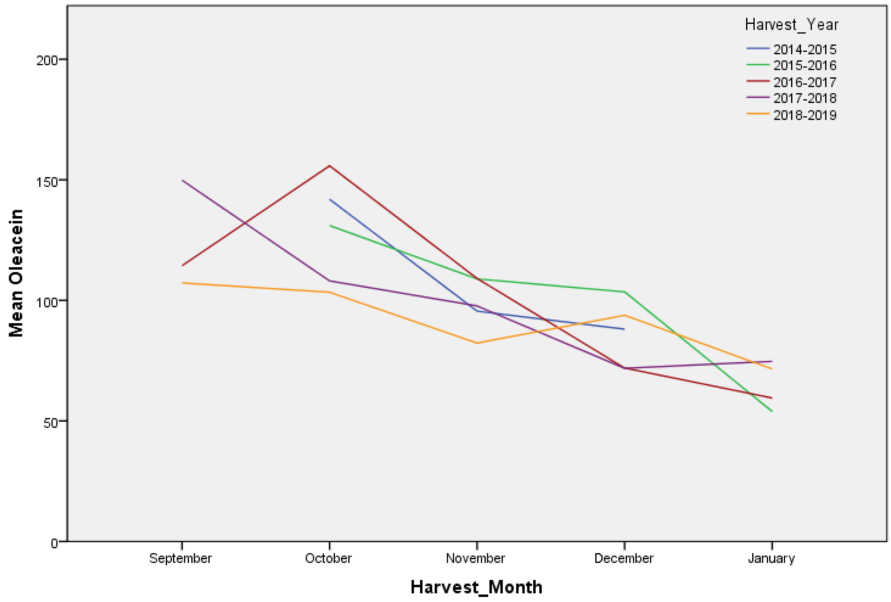

Diagram 38. Difference in the concentration of oleacein (mg/g) among the studied years in relation of harvest month.

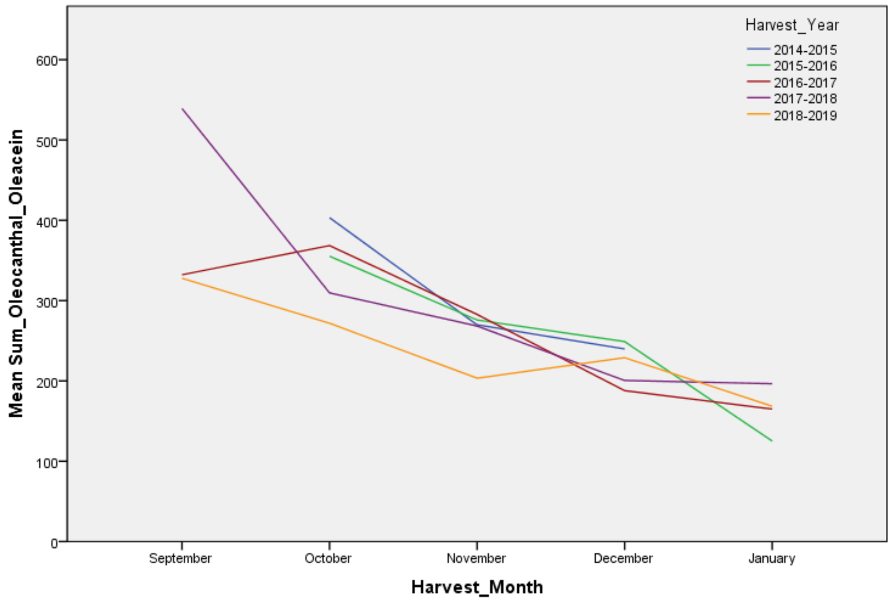

Diagram 39. Difference in the concentration of the sum oleocanthal and oleacein (mg/g) among the studied years in relation of harvest month.

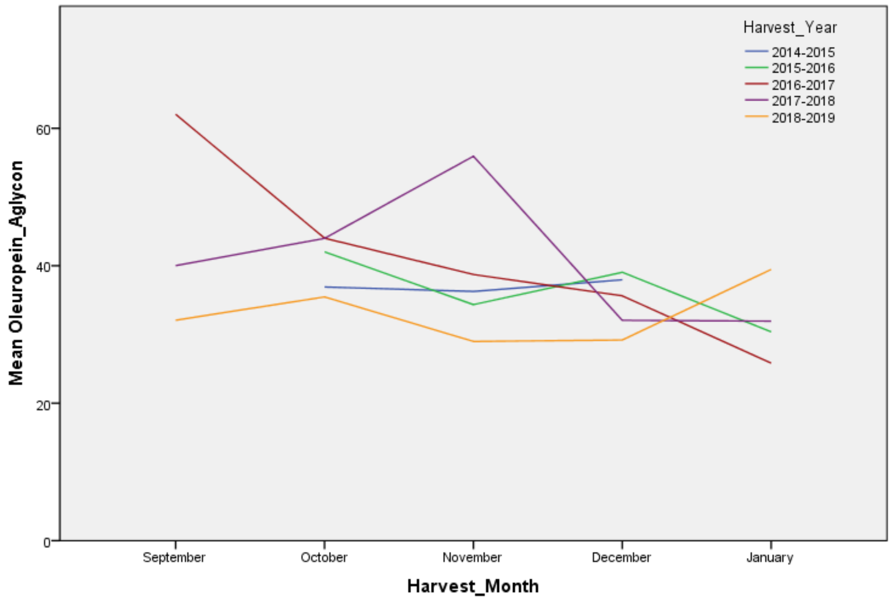

Diagram 40. Difference in the concentration of oleuropein aglycon (mg/g) among the studied years in relation of harvest month.

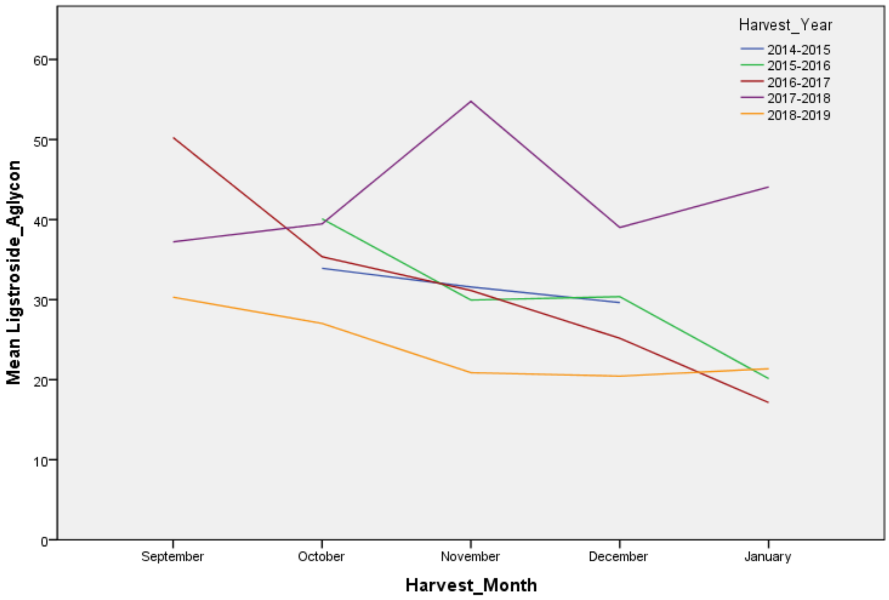

Diagram 41. Difference in the concentration of ligstroside aglycon (mg/g) among the studied years in relation of harvest month.

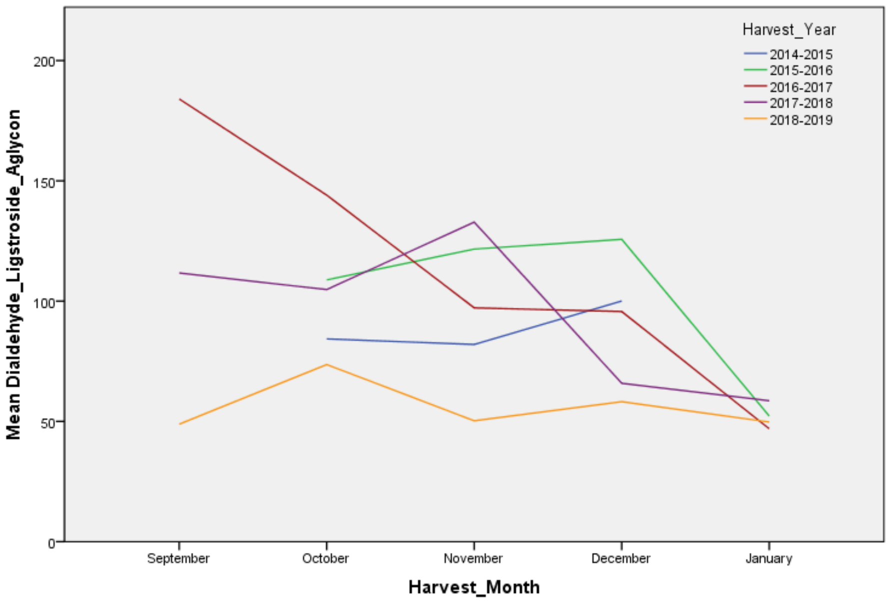

Diagram 42. Difference in the concentration of dialdehyde ligstroside aglycon (mg/g) among the studied years in relation of harvest month.

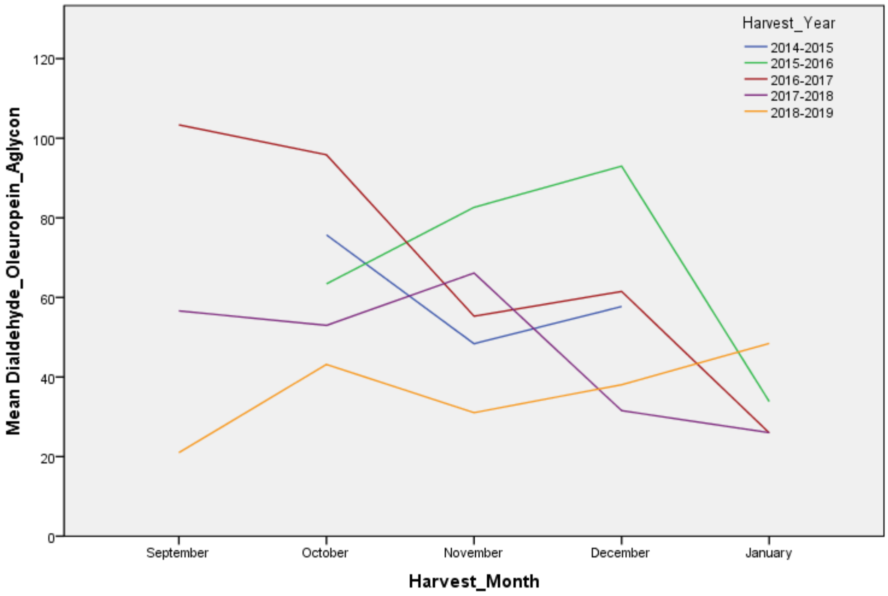

Diagram 43. Difference in the concentration of dialdehyde oleuropein aglycon (mg/g) among the studied years in relation of harvest month.

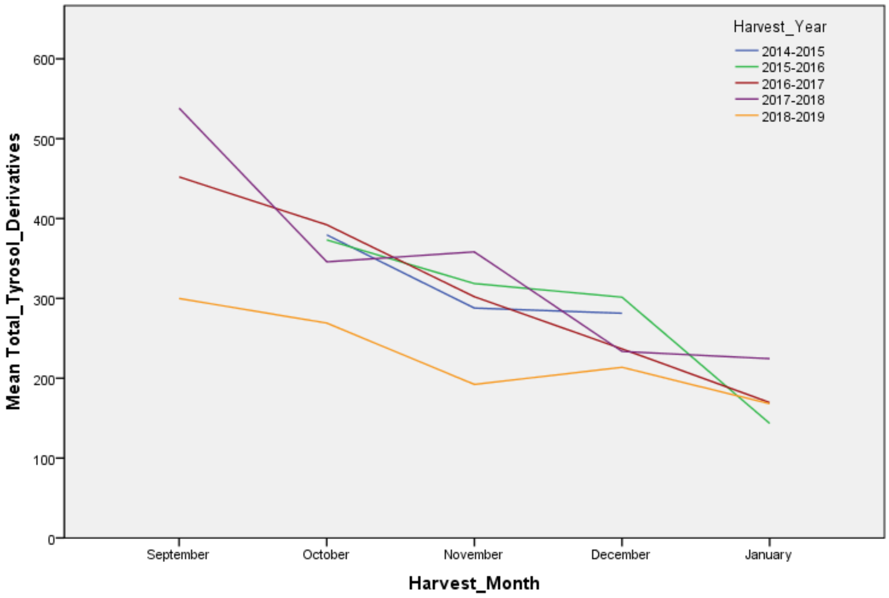

Diagram 44. Difference in the concentration of total tyrosol derivatives (mg/g) among the studied years in relation of harvest month.

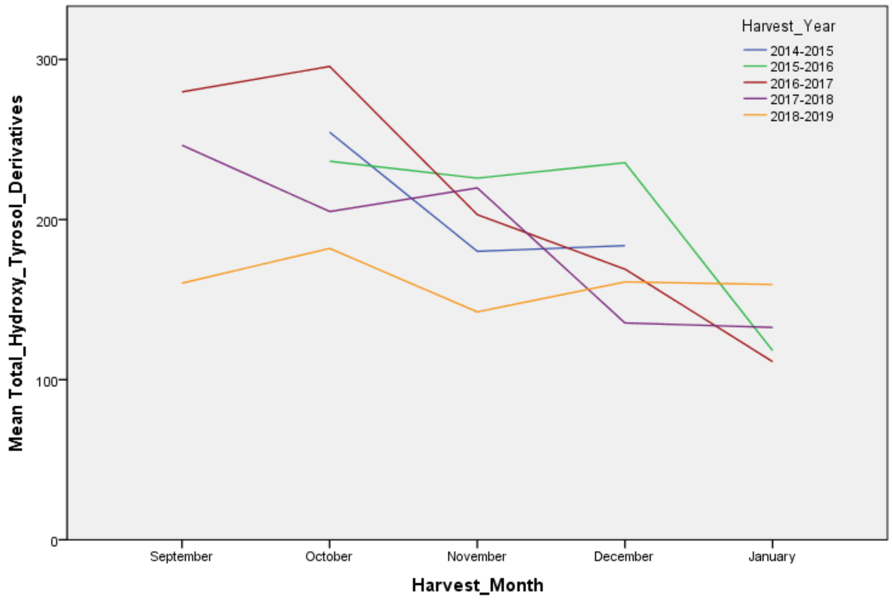

Diagram 45. Difference in the concentration of total hydroxy tyrosol derivatives (mg/g) among the studied years in relation of harvest month.

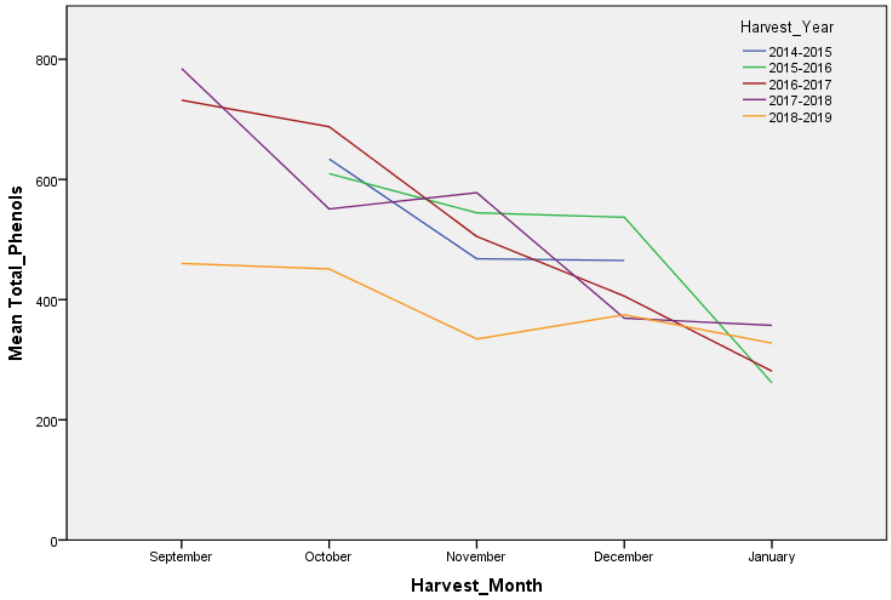

Diagram 46. Difference in the concentration of total phenols (mg/g) among the studied years in relation of harvest month.

Differences among weeks of harvest overall (ANOVA)

The statistical significance in phenol concentrations among harvest weeks is presented in Table 87. Although there was no statistically significant difference for ligstroside aglycon, post hoc were performed. All the results of the post hoc tests for the multiple comparisons, using Duncan's Multiple Range Test (MRT), are presented in Tables 88-97.

Table 87. Statistical significance of phenol concentrations among harvest weeks.

Oleocanthal	***
Oleacein	***
Sum_Oleocanthal_Oleacein	***
Oleuropein_Aglycon	***
Ligstroside_Aglycon	ns
Dialdehyde_Ligstroside_Aglycon	***
Dialdehyde_Oleuropein_Aglycon	***
Total_Tyrosol_Derivatives	***
Total_Hydroxy_Tyrosol_Derivatives	***
Total_Phenols	***

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Table 88. Comparisons of oleocanthal means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Week	n	1	2	3	4	5	6	7	8
1	11	564.41							
4	44		238.50						
5	52		227.09	227.09					
7	161		202.20	202.20	202.20				
2	9		199.19	199.19	199.19				
3	44		196.38	196.38	196.38	196.38			
6	118		184.78	184.78	184.78	184.78			
8	186		182.32	182.32	182.32	182.32	182.32		
10	295			175.79	175.79	175.79	175.79		
9	147			171.99	171.99	171.99	171.99	171.99	
13	204				158.25	158.25	158.25	158.25	158.25
14	214				154.75	154.75	154.75	154.75	154.75
12	277				154.56	154.56	154.56	154.56	154.56
11	193				143.85	143.85	143.85	143.85	143.85
15	228				143.33	143.33	143.33	143.33	143.33
16	190					134.26	134.26	134.26	134.26
21	24						119.11	119.11	119.11
22	12							110.81	110.81
20	23								105.17
17	62								105.08
19	5								96.23
18	178								95.88

Table 89. ***Comparisons of oleacein means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Week	n	1	2	3	4	5
1	11	136.74				
7	161	135.78				
5	52	133.46	133.46			
4	44	126.14	126.14	126.14		
6	118	110.24	110.24	110.24	110.24	
10	295	107.93	107.93	107.93	107.93	
3	44	106.71	106.71	106.71	106.71	
8	186	105.02	105.02	105.02	105.02	
9	147	104.42	104.42	104.42	104.42	
13	204	102.10	102.10	102.10	102.10	
12	277	97.28	97.28	97.28	97.28	97.28
14	214	97.06	97.06	97.06	97.06	97.06
15	228	91.23	91.23	91.23	91.23	91.23
2	9		85.09	85.09	85.09	85.09
11	193		84.26	84.26	84.26	84.26
16	190			81.62	81.62	81.62
21	24				73.84	73.84
22	12				70.61	70.61
20	23				68.40	68.40
17	62				66.09	66.09
19	5				65.88	65.88
18	178					48.08

Table 90. ***Comparisons of sum oleocanthal oleacein means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Week	n	1	2	3	4	5	6	7	8	9
1	11	701.16								
4	44		364.65							
5	52		360.55							
7	161		337.98	337.98						
3	44		303.08	303.08	303.08					
6	118		295.02	295.02	295.02	295.02				
8	186		287.34	287.34	287.34	287.34	287.34			
2	9		284.28	284.28	284.28	284.28	284.28			
10	295		283.72	283.72	283.72	283.72	283.72			
9	147		276.41	276.41	276.41	276.41	276.41	276.41		
13	204		260.36	260.36	260.36	260.36	260.36	260.36	260.36	
12	277			251.84	251.84	251.84	251.84	251.84	251.84	
14	214			251.80	251.80	251.80	251.80	251.80	251.80	
15	228			234.56	234.56	234.56	234.56	234.56	234.56	234.56
11	193				228.11	228.11	228.11	228.11	228.11	228.11
16	190				215.87	215.87	215.87	215.87	215.87	215.87
21	24					192.96	192.96	192.96	192.96	192.96
22	12						181.42	181.42	181.42	181.42
20	23							173.57	173.57	173.57
17	62							171.17	171.17	171.17
19	5								162.10	162.10

18	178									143.96

Table 91. Comparisons of oleuropein aglycon means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Week	***n***	***1***	***2***
2	9	67.37	
7	161		45.74
10	295		43.45
13	204		41.58
19	5		41.53
12	277		41.34
9	147		41.32
6	118		38.55
15	228		37.15
14	214		36.45
8	186		36.12
1	11		35.84
3	44		35.82
5	52		34.72
4	44		34.22
17	62		33.78
22	12		33.60
11	193		33.48
16	190		33.05
20	23		29.49
21	24		28.68
18	178		24.33

Table 92. Comparisons of ligstroside aglycon means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Week	***n***	***1***	***2***	***3***
19	5	60.09		
2	9	48.29	48.29	
10	295		38.41	38.41
22	12		36.88	36.88
12	277		36.42	36.42
13	204		36.36	36.36
17	62		36.05	36.05
1	11		35.88	35.88
7	161		35.74	35.74
15	228		35.39	35.39
9	147		34.40	34.40
3	44		34.09	34.09
16	190		33.15	33.15
14	214		32.56	32.56
6	118		32.33	32.33
21	24		31.54	31.54
4	44		31.45	31.45
5	52		31.40	31.40
8	186		29.89	29.89
18	178		29.19	29.19
11	193		28.90	28.90

20	23			26.31

Table 93. ***Comparisons of dialdehyde ligstroside aglycon means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Week	n	1	2	3
2	9	117.11		
7	161	116.26		
12	277	109.23	109.23	
10	295	108.23	108.23	
6	118	96.73	96.73	
4	44	96.38	96.38	
8	186	96.21	96.21	
14	214	92.38	92.38	92.38
13	204	90.63	90.63	90.63
15	228	90.25	90.25	90.25
9	147	89.36	89.36	89.36
16	190	82.52	82.52	82.52
11	193	80.23	80.23	80.23
3	44	69.40	69.40	69.40
21	24	63.95	63.95	63.95
17	62	62.53	62.53	62.53
5	52	61.14	61.14	61.14
19	5	56.42	56.42	56.42
22	12	55.81	55.81	55.81
20	23		46.89	46.89
18	178		42.01	42.01
1	11			24.90

Table 94. ***Comparisons of dialdehyde oleuropein aglycon means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Week	n	1	2	3
7	161	84.90		
2	9	73.66	73.66	
12	277	62.39	62.39	62.39
10	295	59.53	59.53	59.53
13	204	56.01	56.01	56.01
15	228	55.38	55.38	55.38
6	118	51.85	51.85	51.85
14	214	51.60	51.60	51.60
9	147	50.26	50.26	50.26
8	186	50.09	50.09	50.09
16	190	47.68	47.68	47.68
4	44	47.59	47.59	47.59
11	193	44.82	44.82	44.82
19	5	36.77	36.77	36.77
17	62		34.17	34.17
3	44		33.65	33.65
22	12		32.90	32.90
20	23		31.35	31.35
5	52		30.89	30.89
21	24		27.14	27.14

18	178		24.09	24.09
1	11			14.36

Table 95. Comparisons of total tyrosol derivatives means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Week	***n***	***1***	***2***	***3***	***4***	***5***	***6***
1	11	625.19					
4	44		366.34				
2	9		364.59				
7	161		354.20				
10	295		322.43	322.43			
5	52		319.64	319.64	319.64		
6	118		313.84	313.84	313.84		
8	186		308.42	308.42	308.42		
12	277		300.21	300.21	300.21		
3	44		299.87	299.87	299.87		
9	147		295.75	295.75	295.75		
13	204		285.24	285.24	285.24	285.24	
14	214		279.69	279.69	279.69	279.69	279.69
15	228		268.97	268.97	268.97	268.97	268.97
11	193		252.98	252.98	252.98	252.98	252.98
16	190		249.93	249.93	249.93	249.93	249.93
21	24			214.60	214.60	214.60	214.60
19	5			212.74	212.74	212.74	212.74
17	62				203.66	203.66	203.66
22	12				203.50	203.50	203.50
20	23					178.36	178.36
18	178						167.08

Table 96. Comparisons of total hydroxy tyrosol derivatives means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Harvest Week	***n***	***1***	***2***	***3***
7	161	266.43		
2	9	226.13	226.13	
10	295	210.91	210.91	
4	44	207.95	207.95	
12	277	201.01	201.01	
6	118	200.65	200.65	
13	204	199.69	199.69	
5	52	199.06	199.06	
9	147	196.00	196.00	
8	186	191.24	191.24	191.24
1	11	186.94	186.94	186.94
14	214	185.11	185.11	185.11
15	228	183.76	183.76	183.76
3	44	176.18	176.18	176.18
11	193		162.56	162.56
16	190		162.35	162.35
19	5		144.18	144.18
22	12		137.11	137.11
17	62		134.03	134.03

21	24		129.66	129.66
20	23		129.25	129.25
18	178			96.50

Table 97. ***Comparisons of total phenols means (mg/g) among harvest weeks using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Harvest Week	*n*	*1*	*2*	*3*	*4*	*5*	*6*
1	11	812.14					
7	161		620.63				
2	9		590.72	590.72			
4	44		574.28	574.28			
10	295		533.34	533.34	533.34		
5	52		518.70	518.70	518.70		
6	118		514.49	514.49	514.49	514.49	
12	277		501.22	501.22	501.22	501.22	
8	186		499.66	499.66	499.66	499.66	
9	147		491.75	491.75	491.75	491.75	
13	204		484.94	484.94	484.94	484.94	
3	44		476.05	476.05	476.05	476.05	
14	214		464.80	464.80	464.80	464.80	
15	228		452.73	452.73	452.73	452.73	452.73
11	193		415.53	415.53	415.53	415.53	415.53
16	190			412.28	412.28	412.28	412.28
19	5				356.92	356.92	356.92
21	24				344.27	344.27	344.27
22	12				340.61	340.61	340.61
17	62				337.70	337.70	337.70
20	23					307.60	307.60
18	178						263.58

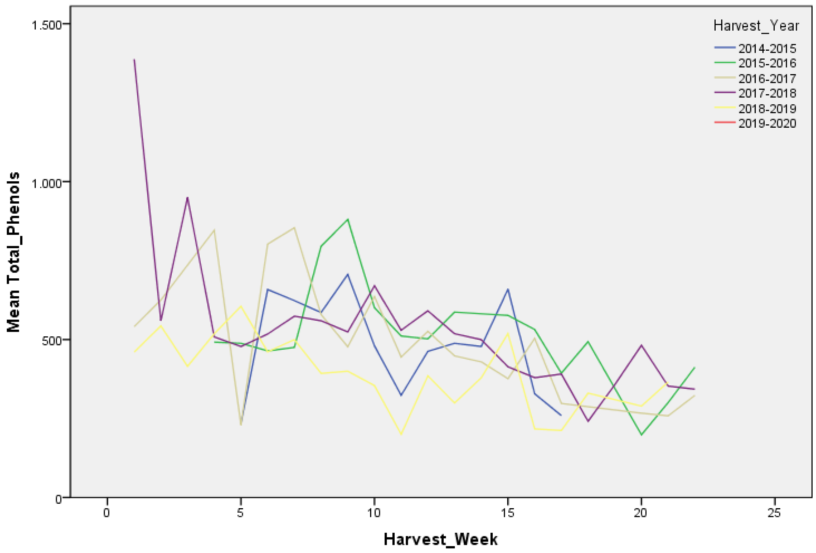

Diagram 46. Difference in the concentration of total phenols (mg/g) among the studied years in relation of harvest month.

Differences among weeks of harvest in each year (GLM 3)

The results of the ANOVA for the studied phenols' concentrations among harvest weeks in each year are presented in Table 98.

Table 98. ***Statistical significance of phenol concentrations among harvest weeks in each year.***

ANOVA	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Oleocanthal	***	**	***	***	***
Oleacein	*	ns	***	***	***
Sum_Oleocanthal_Oleacein	***	ns	***	***	***
Oleuropein_Aglycon	ns	ns	***	***	ns
Ligstroside_Aglycon	ns	ns	***	***	**
Dialdehyde_Ligstroside_Aglycon	ns	ns	***	***	*
Dialdehyde_Oleuropein_Aglycon	*	ns	***	***	ns
Total_Tyrosol_Derivatives	ns	ns	***	***	***
Total_Hydroxy_Tyrosol_Derivatives	ns	ns	***	***	**
Total_Phenols	ns	ns	***	***	***

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Differences among regions (ANOVA)

The results of the ANOVA for the studied phenols' concentrations among harvest regions in each year are presented in Table 99-109.

Table 99. ***Statistical significance of phenol concentrations among harvest regions.***

Oleocanthal	***	Dialdehyde_Ligstroside_Aglycon	***
Oleacein	***	Dialdehyde_Oleuropein_Aglycon	***
Sum_Oleocanthal_Oleacein	***	Total_Tyrosol_Derivatives	***
Oleuropein_Aglycon	***	Total_Hydroxy_Tyrosol_Derivatives	***
Ligstroside_Aglycon	***	Total_Phenols	***

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Table 100. ***Comparisons of oleocanthal means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Region	n	1	2	3	4
Ionian Islands	710	206.10			
Epirus	52	199.75			
Central Macedonia	281	188.91			

South Aegean	53		156.28		
Eastern Macedonia and Thrace	75		151.72		
Western Greece	295		142.52		
Peloponnese	1861		135.98	135.98	
Crete	438		133.08	133.08	
Western Macedonia	28		127.75	127.75	
North Aegean	49			106.68	106.68
Thessaly	96			103.35	103.35
Attica	101			100.22	100.22
Central Greece	62				86.15

Table 101. Comparisons of oleacein means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Region	***n***	***1***	***2***	***3***	***4***	***5***
Ionian Islands	710	134.53				
Central Macedonia	281		103.60			
Epirus	52		97.36	97.36		
Western Macedonia	28		96.80	96.80		
Crete	438		90.08	90.08		
South Aegean	53		88.72	88.72		
Western Greece	295		83.33	83.33		
Peloponnese	1861		81.73	81.73		
North Aegean	49		77.16	77.16		
Eastern Macedonia and Thrace	75			72.15	72.15	
Attica	101				51.29	51.29
Thessaly	96					35.48
Central Greece	62					28.99

Table 102. Comparisons of sum oleocanthal oleacein means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Region	***n***	***1***	***2***	***3***	***4***	***5***	***6***
Ionian Islands	710	340.63					
Epirus	52	297.12	297.12				
Central Macedonia	281	292.51	292.51				
South Aegean	53		245.00	245.00			
Western Greece	295			225.85	225.85		
Western Macedonia	28			224.55	224.55		
Eastern Macedonia and Thrace	75			223.86	223.86		
Crete	438			223.16	223.16		
Peloponnese	1861			217.71	217.71		
North Aegean	49				183.84	183.84	
Attica	101					151.51	151.51
Thessaly	96					138.84	138.84
Central Greece	62						115.15

Table 103. Comparisons of oleuropein aglycon means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Region	*n*	*1*	*2*	*3*	*4*	*5*	*6*
Eastern Macedonia and Thrace	75	50.66					
Crete	438	50.48					
Western Greece	295	46.46	46.46				
Central Macedonia	281	41.84	41.84	41.84			
South Aegean	53	39.34	39.34	39.34	39.34		
Western Macedonia	28		37.84	37.84	37.84		
Ionian Islands	710		37.32	37.32	37.32		
Peloponnese	1861		35.65	35.65	35.65		
Epirus	52			29.76	29.76	29.76	
North Aegean	49				28.47	28.47	
Attica	101				26.54	26.54	
Thessaly	96					18.00	18.00
Central Greece	62						11.58

Table 104. Comparisons of ligstroside aglycon means (mg/g) harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Region	*n*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Eastern Macedonia and Thrace	75	46.00							
Western Greece	295	43.28	43.28						
Crete	438	38.98	38.98	38.98					
Central Macedonia	281	37.76	37.76	37.76	37.76				
Ionian Islands	710		33.99	33.99	33.99	33.99			
Peloponnese	1861		33.55	33.55	33.55	33.55			
South Aegean	53			31.77	31.77	31.77	31.77		
Epirus	52				26.99	26.99	26.99	26.99	
Attica	101					25.41	25.41	25.41	
North Aegean	49					23.09	23.09	23.09	23.09
Western Macedonia	28						22.16	22.16	22.16
Thessaly	96							18.04	18.04
Central Greece	62								13.22

Table 105. Comparisons of dialdehyde ligstroside aglycon means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).

Region	*n*	*1*	*2*	*3*	*4*	*5*
South Aegean	53	146.11				
Crete	438	135.03				
Western Greece	295	118.71	118.71			
Eastern Macedonia and Thrace	75		96.92	96.92		
Western Macedonia	28			82.83	82.83	
Central Macedonia	281			81.93	81.93	
Peloponnese	1861			78.22	78.22	
Ionian Islands	710			77.08	77.08	
Attica	101			63.81	63.81	
North Aegean	49				48.73	48.73
Thessaly	96				48.18	48.18
Epirus	52				47.02	47.02
Central Greece	62					15.56

Table 106. *Comparisons of dialdehyde oleuropein aglycon means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).*

Region	n	1	2	3	4	5
Crete	438	86.15				
Western Greece	295	70.22	70.22			
South Aegean	53	66.74	66.74			
Western Macedonia	28		56.91	56.91		
Eastern Macedonia and Thrace	75		48.70	48.70	48.70	
Peloponnese	1861		45.74	45.74	45.74	
Ionian Islands	710		44.93	44.93	44.93	
Central Macedonia	281			39.77	39.77	
North Aegean	49			36.74	36.74	
Attica	101			31.63	31.63	31.63
Thessaly	96				27.88	27.88
Epirus	52				25.58	25.58
Central Greece	62					9.08

Table 107. *Comparisons of total tyrosol derivatives means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).*

Region	n	1	2	3	4	5	6	7
South Aegean	53	334.16						
Ionian Islands	710	317.17						
Central Macedonia	281	308.60	308.60					
Crete	438	307.09	307.09					
Western Greece	295	304.51	304.51					
Eastern Macedonia and Thrace	75	294.63	294.63					
Epirus	52	273.76	273.76	273.76				
Peloponnese	1861		247.75	247.75	247.75			
Western Macedonia	28			232.75	232.75	232.75		
Attica	101				189.45	189.45	189.45	
North Aegean	49					178.50	178.50	
Thessaly	96						169.57	169.57
Central Greece	62							114.93

Table 108. *Comparisons of total hydroxy tyrosol derivatives means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).*

Region	n	1	2	3	4	5	6	7
Crete	438	226.71						
Ionian Islands	710	216.78	216.78					
Western Greece	295	200.01	200.01	200.01				
South Aegean	53	194.80	194.80	194.80	194.80			
Western Macedonia	28	191.55	191.55	191.55	191.55			
Central Macedonia	281	185.20	185.20	185.20	185.20			
Eastern Macedonia and Thrace	75		171.50	171.50	171.50			
Peloponnese	1861			163.11	163.11			
Epirus	52			152.70	152.70	152.70		
North Aegean	49				142.37	142.37		
Attica	101					109.46	109.46	
Thessaly	96						81.36	81.36

Central Greece	62							49.65

Table 109. ***Comparisons of total phenols means (mg/g) among harvest regions using Duncan's multiple range test (a=0.05) (harvest months reside in the same subset are not statistically different).***

Region	***n***	***1***	***2***	***3***	***4***	***5***
Ionian Islands	710	533.95				
Crete	438	533.81				
South Aegean	53	528.96				
Western Greece	295	504.52	504.52			
Central Macedonia	281	493.80	493.80			
Eastern Macedonia and Thrace	75	466.13	466.13			
Epirus	52	426.47	426.47	426.47		
Western Macedonia	28	424.29	424.29	424.29		
Peloponnese	1861		410.87	410.87		
North Aegean	49			320.88	320.88	
Attica	101				298.91	
Thessaly	96				250.93	250.93
Central Greece	62					164.58

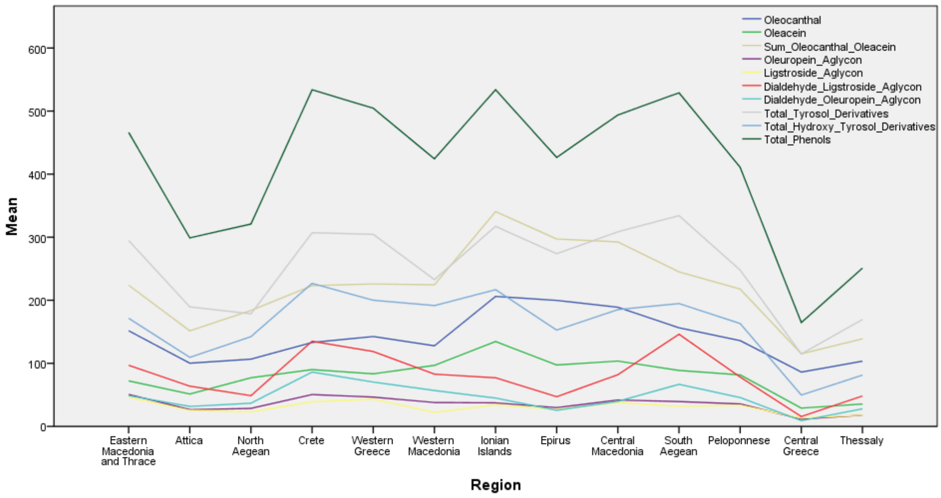

Diagram 47. Difference in the concentration of total phenols (mg/g) among the studied regions.

Relation between variety and region

The χ^2 (chi-square) test of independence is used to determine if there was a significant relationship between the variety and region (Diagram 48). The results are presented in Table 110.

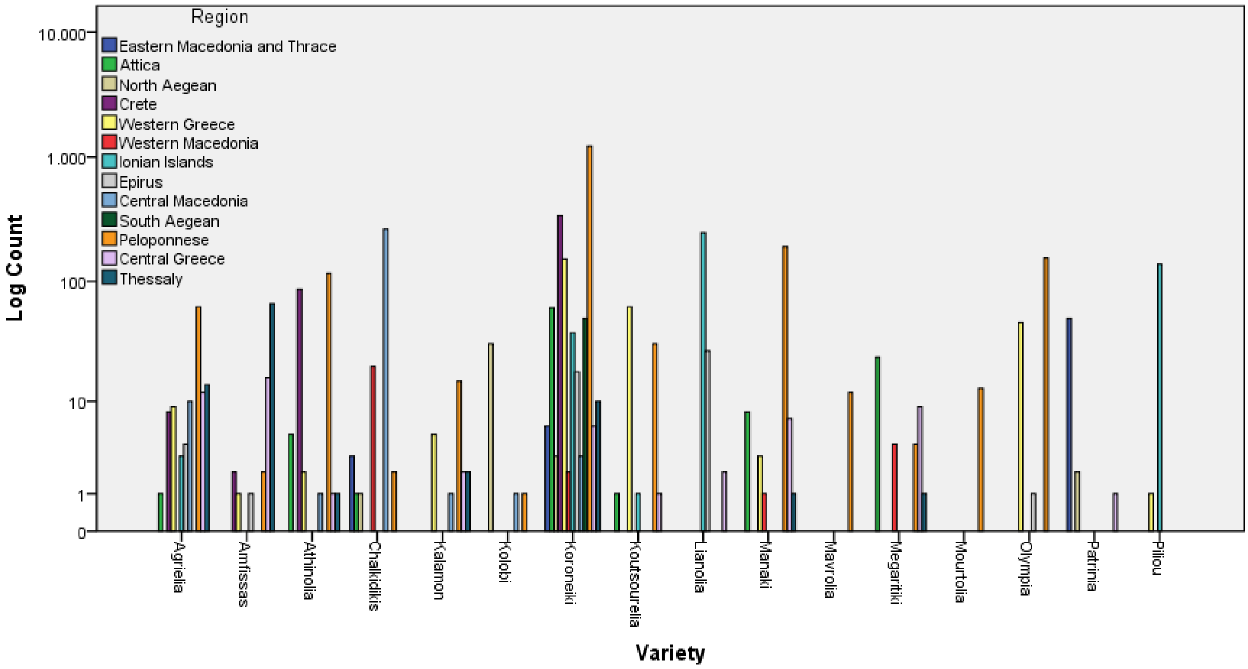

Diagram 48. Difference in the concentration of total phenols (mg/g) among the studied regions.

The results of χ^2 test are presented in Table 120. The relationship between variety and region was found to be strong (*V=0.603*) and statistically significant (*p<0.001*).

Table 110. ***Chi-Square test of independence between variety and region.***

Pearson Chi-Square	***
Likelihood Ratio	***
Cramer's V	0,603
N of Valid Cases	3,718

****** =p<0.001, **=p<0.01, *=p<0.05, ns=not significant***

Conclusions

1. The main cultivated variety in Greece is Koroneiki variety.
2. November is the main olive harvest month although there is a geographical diversification due to climatic conditions.
3. The Peloponnese is the region with the most analyzed samples, followed by Ionian Islands.
4. The most used olive oil mill type is the two-phase mill.
5. Variety plays an important role in phenolic concentration.
6. Olympia is the variety that is ranked first for all studied phenol concentration except for oleocanthal, oleacein and their sum for which is ranked fourth, second and third respectively.
7. Lianolia is the variety with the highest oleacein and sum of oleocanthal and oleacein concentration.
8. Kalamon variety is ranked first in oleocanthal concentration.
9. Although Koroneiki variety is the most widespread and cultivated is at the average for the most studied phenols concentration.
10. Olive oil mill type plays an important role in phenolic concentration. Two phase oil mill type lead to higher phenolic concentrations.
11. Harvest month plays an important role in phenolic concentration. The earlier the olives are harvested, the more phenolic substances are present.

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