

Article

Olive Oil Quality Produced Under Conventional and Organic Farming Systems in a Multisite Two-Year Evaluation in Greece [†]

Petros Anargyrou Roussos ^{*}, Asimina-Georgia Karyda, Vassilios Kaibalis and Konstantinos Zontanos

Laboratory of Pomology, Department of Crop Science, Agricultural University of Athens, Iera Odos 75, 118 55 Athens, Greece; romina_karyda@hotmail.com (A.-G.K.); billakosltg@gmail.com (V.K.); stud118025@aua.gr (K.Z.)

^{*} Correspondence: roussosp@aua.gr; Tel.: +30-210-5294596

[†] This paper is an extended version of our paper published in Roussos, P.A.; Karida, A.-G.; Kaibalis, V. Olive oil quality characteristics under organic and integrated management in messinia county Greece. In Proceedings of the XIV International Scientific Agriculture Symposium “AGROSYM 2023”, Jahorina, Bosnia and Herzegovina, 5–8 October 2023.

Abstract: Six olive groves (three conventional and three organic) of “Koroneiki” olive cultivar were selected in two different provinces in southern Greece during a two-year trial (one province per year). At harvest, the oil was extracted from olive fruits using an Abenchor-type olive mill. Olive oil quality characteristics, including free acidity, ultraviolet absorbance indexes, peroxide value, free fatty acids, total and individual phenolic compounds, antioxidant capacity, and α -tocopherol content, were assessed. During the second year, olive oil samples were stored for 12 months, and their quality was re-evaluated. Few significant differences were observed between organically and conventionally produced olive oils, while the quality of both deteriorated significantly after storage (decrease in antioxidant capacity and major phenolic compounds, except for hydroxytyrosol and tyrosol, and increase in peroxide index value). Principal component analysis revealed that, during the first year, oils produced following organic and conventional practices could be distinguished; however, this distinction was not evident during the second year. Nevertheless, significant differentiation was found between oils produced under the same cultivation practice. In conclusion, the discrepancies found in the literature regarding organic versus conventional olive oil properties probably originate from the differences detected even among similar products (organic or conventional), including high-standard deviations.



Academic Editors: Simona Fabroni, Francesco Montemurro and Luana Bontempo

Received: 19 December 2024

Revised: 16 January 2025

Accepted: 21 January 2025

Published: 26 January 2025

Citation: Roussos, P.A.; Karyda, A.-G.; Kaibalis, V.; Zontanos, K. Olive Oil Quality Produced Under Conventional and Organic Farming Systems in a Multisite Two-Year Evaluation in Greece. *Horticulturae* **2025**, *11*, 130. <https://doi.org/10.3390/horticulturae11020130>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: free fatty acids; functional properties; Koroneiki; phenolic compounds; tocopherol

1. Introduction

The olive tree is an emblematic species of the Mediterranean basin, holding significant social, economic, and environmental value for the countries in the region [1]. It is highly appreciated for several characteristics, including its drought resistance, adaptability to diverse pedoclimatic conditions, and, most notably, its uniquely valuable products: table olives and olive oil. The olive tree is considered one of the oldest plants cultivated for its oil [2]. Although in the modern world olive oil accounts for only a small portion of the total consumption of plant-derived oils, it holds immense economic importance for producing countries and consumers worldwide due to its nutritional value and exceptional sensory attributes [2,3]. Extra-virgin olive oil (EVOO) is a cornerstone of the Mediterranean diet, with its consumption steadily increasing worldwide thanks to its health-promoting properties. Studies have shown that it can reduce the risk of coronary heart disease, cancer, inflammation, diabetes, Alzheimer’s disease, and metabolic disorders [4,5].

These beneficial properties are attributed to the unique composition of olive oil. It is rich in monounsaturated fatty acids (MUFAs), primarily oleic acid (C18:1), which accounts for 56% to 85% of its total fatty acid content. Additionally, it contains low levels of polyunsaturated fatty acids (PUFAs), such as linoleic and linolenic acids, and saturated fatty acids (SFAs), mainly palmitic and stearic acids [4,6]. Olive oil is also abundant in natural antioxidants, including phenolic compounds, tocopherols, squalene, and carotenoids, all of which contribute to its antioxidant properties and stability over time [5,7,8].

Phenolic compounds represent a diverse group of bioactive metabolites found in olive oil [4]. Secoiridoids, such as the aldehydic forms of oleuropein and ligstroside aglycone, oleocanthal, and oleacein, as well as free tyrosol and hydroxytyrosol and their respective bound forms, are among the most important phenolic compounds present in EVOO. These compounds significantly enhance its health-promoting properties, oxidative stability, and sensory attributes [6,7,9,10]. Flavonoids such as luteolin and apigenin have been also found in EVOO, both contributing to its antioxidant, as well as health-promoting properties [9,11–13]. Additionally, tocopherols, particularly α -tocopherol, the most abundant in olive oil, serve as potent antioxidant molecules [4,7].

The overall quality of olive oil is evaluated through various attributes, including free acidity, peroxide value, spectrophotometric indices, phenolic content, oxidative stability, nutritional value (fatty acid and tocopherol composition), and sensory characteristics [6,7,10,14]. These quality parameters result from a complex interplay of numerous factors, with cultivar being one of the most significant [9,15,16]. However, other factors, such as pedoclimatic conditions, altitude, cultivation practices (irrigation, fertilization, pest, and disease control), harvest timing, oil extraction techniques, and storage conditions, also play crucial roles in determining the quality of the final product [9,17,18].

In recent decades, there has been growing interest in the benefits of organic farming for both the environment and human health. This trend has been driven largely by increased consumer awareness of pesticide residues in food and concerns about environmental contamination and sustainability [3,4,19]. An improper use of phytosanitary products in conventional farming can lead to pesticide residues in food. Even with proper use, detectable levels of pesticides may remain within legally defined limits. Organic agriculture, on the other hand, is generally considered environmentally friendly due to reduced chemical pollution. While evidence suggests that organic farming may produce food with a higher nutritional quality, some studies have found no clear advantages over conventional methods [1,20–22]. Moreover, research on the impact of organic practices on the quality and nutritional attributes of olive oil remains limited compared to other food products [23,24].

Given that olive oil quality is influenced by numerous factors, the present study aimed to investigate the effects of organic versus conventional farming practices. The trial was conducted as a multisite two-year experiment using the same cultivar to minimize variability arising from factors such as cultivar differences, pedoclimatic conditions, farming practices, and seasonal variations.

2. Materials and Methods

2.1. Test Site Location—Plant Material

The trial was conducted in southern Greece, in the Messenia Prefecture, a region where olive cultivation is extensively practiced. The trial lasted for two growing seasons, during the year 2019–2020 in Pylia (Pila) province (36°57'0" N, 21°44'0" E, altitude 110 m) and during the year 2020–2021 in Raches province (37°27'86" N, 21°71'61" E, altitude 130 m) (Figure 1). Pylia province is characterized by typical Mediterranean climate, with an average annual rainfall of about 800 mm and mild winters. The average annual tem-

perature is around 20 °C, with January averaging approximately 10.8 °C and July around 25.5 °C. The soils are primarily calcareous and clayey–loamy. Raches province has also a Mediterranean climate, with mild winters and warm summers, and an average annual rainfall of about 800 mm. The average annual temperature is around 21 °C, with January having an average temperature of approximately 14.9 °C and July around 26.7 °C. The soils are primarily clayey–loamy, with good drainage. At each location, three conventionally managed orchards were selected, each belonging to a different grower, along with three organically managed olive groves, each owned by a separate farmer (Figure 2). Cultivation practices were individually recorded for each olive grove. The cultivar used in all groves was “Koroneiki”, the most renowned olive oil cultivar in Greece and one of the most important olive oil cultivars worldwide, owing to its adaptability to various pedoclimatic conditions and its high productivity and supreme oil quality. The trees, ranging in age from 30 to 50 years, were fully productive. In each orchard, eight trees (organized as four replications of two trees each) were selected at the end of September based on uniform growth and production.

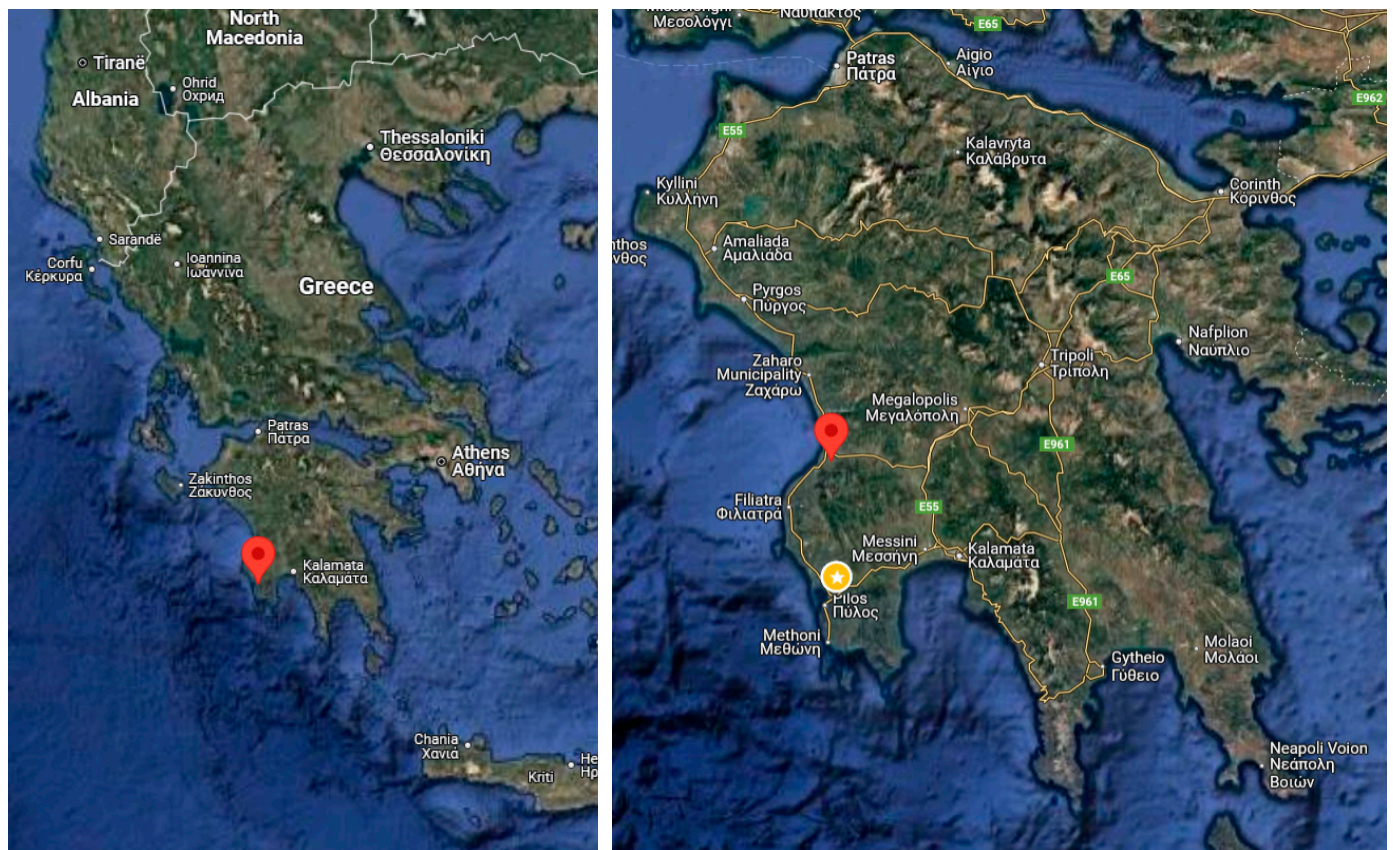


Figure 1. The location of the two provinces in Greece, in Messinia county (on the left). On the right a closer aspect of the area is depicted, where Pylia (yellow tag) and Raches (red tag) provinces are shown (produced by Google Maps).

At harvest, each tree was harvested separately, and the fruit weight was recorded. Approximately 1.5 kg of olives was randomly sampled from each plot and immediately transferred to the laboratory for processing.

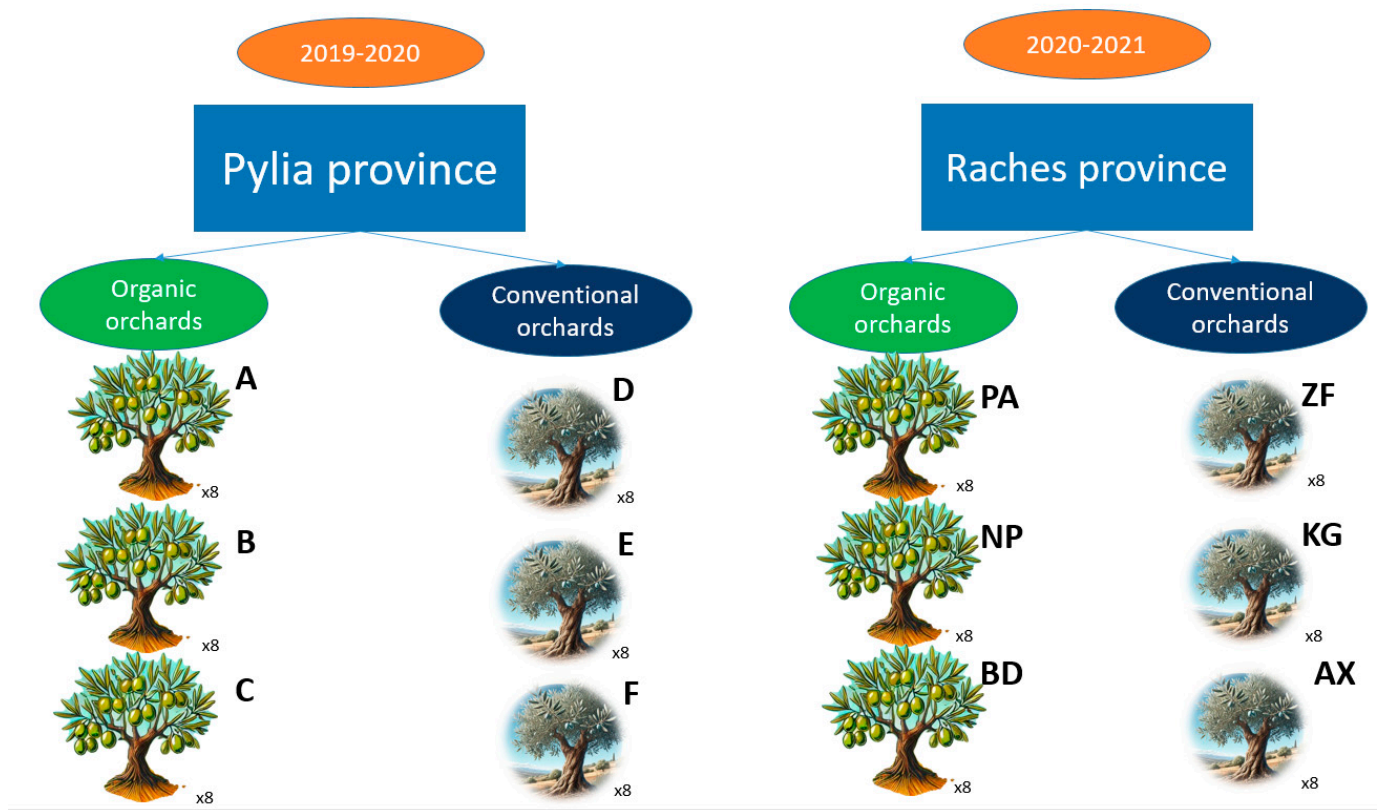


Figure 2. Schematic visualization of the trial. The letters indicate the farmers responsible for each olive grove ($\times 8$, indicates the number of trees used per orchard).

2.2. Olive Oil Extraction Procedure

In the laboratory, the maturity index of the fruits was determined using a sample of 100 randomly selected olive fruits, based on fruit skin and pulp color. After removing the leaves, the olives were crushed using a semi-industrial Abencor-type olive mill (Callis S.A., Athens, Greece). The crusher operated at 2800 rpm, and the resulting paste was transferred to a malaxer, where it was malaxed for 30 min at 50 rpm and 25–27 °C. Following malaxation, 50 g of the paste was transferred to a Falcon-type tube and centrifuged at $2500 \times g$ for 15 min to accurately determine the oil percentage in the paste. The remaining paste was centrifuged at $1400 \times g$ for 3–4 min using the semi-industrial centrifuge of the Abencor-type olive mill, and the oil produced was stored in filled bottles at 4 °C until analysis, which was performed within one week of extraction. During the second year, part of the olive oil produced from the Raches province trial was stored at room temperature in the dark to evaluate oil stability under different management practices over 12 months.

2.3. Olive Oil Analyses

The determination of olive oil free acidity, peroxide index, and ultraviolet absorption at 232 and 270 (K232, K270 respectively), as well as DK (Delta Kappa) was conducted according to the European Official Methods of Analysis 2016/1784.

2.4. Determination of Total Phenols

Phenolic compounds were extracted by adding 5 mL of hexane into 2.5 g of olive oil. After vortexing, 5 mL of methanol–water solution (60:40) was added and the mixture was vortexed for 2 min. The sample was then centrifuged at $2500 \times g$ for 10 min and the upper phase was discarded. The lower phase containing the phenolic fraction was transferred to another tube and used for the determination of the different phenol fractions. The total

phenols were determined by the spectrophotometric Folin–Ciocalteu method, as described by Roussos et al. [25], and expressed in mg gallic acid equivalents (GAEs) kg^{-1} olive oil. The o-diphenols were determined according to Roussos et al. [25] and expressed as mg caffeic acid equivalents (CAEs) kg^{-1} olive oil, while the total flavonoids were determined according to Roussos et al. [25] and expressed as mg catechin equivalents (CtAEs) kg^{-1} olive oil.

Individual phenolic compounds were detected in the same phenolic extract by a high-performance liquid chromatography (HPLC), Shimadzu Nexera X2 (Shimadzu Europa GmbH, Albert-Hahn-Str. 6-10, 47269 Duisburg, Germany), equipped with a quaternary pump, a diode array detector operating at 260 nm, 280 nm, 325 nm, and 360 nm. A sample of 40 μL was injected in a column Luna LC Column 250 $\times$ 4.6 mm 5 μm C18 (2) 100 Å (Phenomenex, 411 Madrid Avenue, Torrance, CA 90501-1430, USA) thermostated at 20 °C. The different phenols were eluted by a gradient program using two mobile phases, i.e., (A) methanol:acetonitrile (1:1) and (B) 1% *v/v* acetic acid in water. The flow rate was adjusted at 1 mL min^{-1} and the gradient profile was as follows: at time 0 min solvent A at 10% till time 5 min, at 10 min and till 35 min A at 20%, at 45 and till 55 min A at 25%, at 70 min A at 30%, at 100 min A at 40% and at 106 min till 123 min A at 70%. A total of eleven (11) phenolic compounds were detected based on their retention time and spectra similarity with the corresponding standards. The phenolic compounds detected were as follows: hydroxytyrosol, tyrosol, vannilic acid, caffeic acid, vannilin, p-coumaric acid, ferulic acid, oleacein, oleocanthal, luteolin, and apigenin. The corresponding standards were purchased from Sigma-Aldrich (Sigma-Aldrich, Inc., P.O. Box 14508, St. Louis, MO 63178, USA) and their concentration was expressed in mg kg^{-1} olive oil.

2.5. Antioxidant Capacity

The antioxidant capacity of the oils was determined in the same extract of phenolic compounds, based on two different assays, i.e., the diphenyl picryl hydrazyl (DPPH) and the ferric reducing antioxidant power (FRAP) assays, according to Roussos et al. [25]. The antioxidant capacity was expressed as $\mu\text{mol Trolox equivalent kg}^{-1}$ olive oil.

2.6. *a*-Tocopherol Determination

The concentration of *a*-tocopherol was determined in the samples of the second year only. In 1 g of olive oil, 2 mL of hexane was added and the mixture was vortexed. The *a*-tocopherol was detected by the HPLC described above using a normal phase column (Lichrosorb 250 $\times$ 4.6 mm Si 60 5 μm) (Sigma-Aldrich, Inc., P.O. Box 14508, St. Louis, MO 63178, USA) thermostated at 20 °C using as eluent a mixture of 99% hexane and 1% 2-propanol. The flow rate was 0.8 mL min^{-1} and *a*-tocopherol was detected by a fluorescence detector at 290 nm excitation wavelength and 325 nm emission wavelength. Identification and quantification were performed using authentic standards.

2.7. Fatty Acids and Squalene Determination

Fatty acid composition, expressed as a percentage of corresponding methyl esters (FAMES), was determined by diluting 0.5 g of olive oil in 2 mL of GC-grade hexane and vigorously shaken, followed by the addition of 1 mL 0.2 N solution of KOH. The methyl-esters were analyzed by gas chromatography (Shimadzu GC-2030) (Shimadzu Europa GmbH, Albert-Hahn-Str. 6-10, 47269 Duisburg, Germany) equipped with an autosampler (AOC-20i+s), and a flame ionization detector (FID). The analysis was performed using a fused silica capillary column (Supelco SP®-2340 60 $\times$ 0.32 mm $\times$ 0.2 μm film thickness) (Sigma-Aldrich, Inc., P.O. Box 14508, St. Louis, MO 63178, USA). A split ratio of 80.0 was used and the injector temperature was set at 249 °C, while the detector temperature was set at 249 °C. Then, 10 μL of the sample was injected at an initial column temperature

of 150 °C, which was held for 18 min. The temperature was then increased at a rate of 2 °C min^{−1} to 175 °C and held for 5 min, and was then raised at a rate of 5 °C min^{−1} to a final temperature of 200 °C, which was held for 22 min. The identified fatty acids were as follows: palmitic (C16:0), palmitoleic (C16:1), heptadecenoic (C17:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), arachidic (C20:0), and gadoleic (C20:1) acids. Squalene (Sigma-Aldrich, Inc., P.O. Box 14508, St. Louis, MO 63178, USA) concentration was determined by a five-point standard curve of the corresponding analytical standard and expressed as mg 100 g^{−1} of olive oil.

2.8. Statistical Analysis

The trial was designed as a pseudo-replicated trial (treatments, i.e., organic versus conventional cultivation practices were not in the same orchard) with four replicates of two trees in each orchard (i.e., four plots of two trees per orchard, three orchards per management system). The four plots within each orchard were randomly selected in each orchard's area (completely randomized in the orchard). Significant differences among cultivation practices for the same year (province) were determined based on the *t*-test at $\alpha = 0.05$ after checking the normal distribution of the raw data using standard skewness, standard kurtosis, and the homogeneity of variances. The comparison of the cultivation practices used the data derived from all three orchards under the same practice. Principal component analysis of raw data (olive oil quality indexes, FAMES content, phenolic compounds concentration, squalene and α -tocopherol concentration, and antioxidant capacity as well as yield, oil percentage per fruit and oil quantity per tree at harvest only) was used to describe the characteristics and differences of each management practice as well as to assess possible differences among orchards under the same cultivation practice, using a small number of variables. A comparison of olive oil quality in time under the same management practice took also place, using *t*-test at $\alpha = 0.05$ to assess the possible differences. The statistical software JMP 13.0 (SAS Institute) and Statgraphics Centurion XV (Statgraphics Technologies, Inc., The Plains, VA, USA) were used for the aforementioned analyses.

3. Results

3.1. Results at Harvest

Organic orchards in Pylia province presented significantly higher fruit production per tree compared to the conventional ones (Table 1). While the oil percentage per fruit and maturity index was similar under both organic and conventional management, the oil produced per tree was significantly higher under organic management.

Table 1. Effects of the cultivation management on olive fruit yield, olive oil percentage, and oil produced per tree at harvest.

Parameter	Organic	Conventional	Significance
In Pylia province			
Yield (kg tree ^{−1})	35.64	25.65	*
Oil percentage per fruit	19.65	20.86	ns
Oil per tree (kg)	6.79	5.31	*
Maturity Index	2.8	3.1	ns
In Raches province			
Yield (kg tree ^{−1})	29.10	40.94	**
Oil percentage per fruit	23.81	26.0	ns
Oil per tree (kg)	6.90	10.24	*
Maturity Index	3.2	3.5	ns

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$. **, $p < 0.01$.

Yield as well as oil produced per tree was significantly higher under conventional practice in Raches province, while no significant difference was determined regarding oil percentage per fruit and maturity index.

There were not any significant differences regarding the oil's free acidity, peroxide index, K232, and K270 in any of the two provinces, as can be seen in Table 2.

Table 2. Effects of the cultivation management on the oil's free acidity, peroxide index, K232, K270, at harvest.

Parameter	Organic	Conventional	Significance
In Pylia province			
Free acidity (g oleic acid 100 g ⁻¹)	0.47	0.48	ns
Peroxides (meq O ₂ kg ⁻¹)	13.75	10.83	ns
K232	1.41	1.43	ns
K270	0.111	0.121	ns
In Raches province			
Free acidity (g oleic acid 100 g ⁻¹)	0.42	0.34	ns
Peroxides (meq O ₂ kg ⁻¹)	12.91	9.58	ns
K232	1.64	1.92	ns
K270	0.17	0.18	ns

ns, not significant.

Total phenols and total o-diphenols were detected in higher concentrations in the oil produced under the conventional practice in Pylia province (Table 3). There were not any significant differences though regarding the total flavonoids' concentration and antioxidant capacity of the oils with either DPPH or FRAP assays. On the other hand, in Raches province, olive oils produced under conventional practice exhibited higher FRAP values than the corresponding organic ones, while no other significant difference was detected concerning total phenol concentration.

Table 3. Effects of cultivation management on olive total phenol, o-diphenol, and flavonoid concentration and antioxidant capacity at harvest.

Parameter	Organic	Conventional	Significance
In Pylia province			
Total phenols (mg GAE kg ⁻¹)	374.1	418.9	ns
o-diphenols (mg CAE kg ⁻¹)	123.4	166.4	*
Total flavonoids (mg CtE kg ⁻¹)	124.1	187.8	*
FRAP (μmol Trolox equiv. kg ⁻¹)	1127.7	1442.4	ns
DPPH (μmol Trolox equiv. kg ⁻¹)	960.1	1210.6	ns
In Raches province			
Total phenols (mg GAE kg ⁻¹)	283.8	330.5	ns
o-diphenols (mg CAE kg ⁻¹)	40.81	53.70	ns
Total flavonoids (mg CtE kg ⁻¹)	378.3	475.4	ns
FRAP (μmol Trolox equiv. kg ⁻¹)	1142.77	1431.1	*
DPPH (μmol Trolox equiv. kg ⁻¹)	1180.0	1400.2	ns

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$.

The concentration of the individual phenolic compounds detected was slightly affected by the management practice in Pylia province, as only vanillic acid was determined in higher concentration in organic olive oils, while p-coumaric acid and apigenin were found in higher concentrations in conventionally produced olive oils (Table 4). Only one significant difference was detected in oils produced in Raches province, as organically produced

oils presented higher concentrations of hydroxytyrosol compared to the conventionally produced ones.

Table 4. Effects of cultivation management on the concentration of individual phenolic compounds detected in olive oils in mg kg^{−1} at harvest.

Parameter	Organic	Conventional	Significance
In Pylia province			
Hydroxytyrosol	31.03	40.23	ns
Tyrosol	112.32	130.85	ns
Vanillic acid	21.49	17.67	**
Caffeic acid	0.52	0.57	ns
Vanillin	0.58	0.69	ns
p-coumaric acid	4.44	5.38	**
Ferulic acid	0.61	0.60	ns
Oleacein	12.23	12.11	ns
Oleocanthal	101.40	107.28	ns
Luteolin	42.40	52.39	ns
Apigenin	16.03	23.41	*
In Raches province			
Hydroxytyrosol	5.69	4.14	*
Tyrosol	9.39	8.33	ns
Vanillic acid	0.48	0.42	ns
Caffeic acid	0.19	0.11	ns
Vanillin	0.15	0.15	ns
p-coumaric acid	0.64	0.45	ns
Ferulic acid	0.05	0.03	ns
Oleacein	37.46	39.19	ns
Oleocanthal	143.74	152.38	ns
Luteolin	15.20	14.02	ns
Apigenin	2.75	2.62	ns
α-tocopherol	81.38	85.60	ns

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$, **, $p < 0.01$.

The concentration of fatty acids (determined as FAMES) differed among the olive oils produced under conventional and organic management (Table 5). Olive oils produced under conventional practice in Pylia province exhibited a higher content of palmitoleic (C16:1) and oleic (C18:1) acids, as well as a higher content of monounsaturated fatty acids (MUFAs), a higher ratio of MUFAs against polyunsaturated fatty acids (PUFAs), and oleic against linoleic (C18:2) acid. In contrast, organically produced olive oils exhibited higher content of C18:2, arachidic (C20), and gadoleic (C20:1) acids, as well as a higher content of PUFAs. There were not any significant differences concerning the content of the other fatty acids detected or squalene concentration. No significant difference was detected between organic and conventional olive oils regarding the content of free fatty acids and the concentration of squalene in oils produced in Raches province.

In Figure 3, it is obvious that there is a slight separation between organic and conventional management practices, taking into account all the raw data derived from sample analysis at harvest in Pylia province. Conventionally managed orchards can be found mainly on the positive side of principal component (PC) 1, while the organic ones are on the negative side of PC1.

Table 5. Effects of cultivation management on the content of free fatty acids (determined as FAMES—%) and squalene concentration at harvest.

Parameter	Organic	Conventional	Significance
In Pylia province			
C16	11.73	11.99	ns
C16:1	0.74	0.79	*
C17	0.025	0.024	ns
C18	2.53	2.53	ns
C18:1	77.94	78.35	*
C18:2	5.32	4.71	**
C20	0.46	0.44	**
C18:3	0.69	0.63	**
C20:1	0.33	0.31	**
C22	0.14	0.13	ns
C24	0.03	0.03	ns
SFA	14.9	15.2	ns
MUFA	79.06	79.49	**
PUFA	6.01	5.34	**
MUFA/PUFA	13.14	14.9	***
UFA/SFA	5.70	5.59	ns
C18:1/C18:2	14.66	16.65	***
Squalene (mg 100 g ^{−1})	448.9	492.5	ns
In Raches province			
C16	12.98	13.23	ns
C16:1	0.82	0.82	ns
C18	2.61	2.60	ns
C18:1	76.85	76.64	ns
C18:2	5.42	5.54	ns
C20	0.32	0.31	ns
C18:3	0.71	0.69	ns
C20:1	0.19	0.18	ns
SFA	15.91	16.14	ns
MUFA	77.85	77.68	ns
PUFA	6.13	6.23	ns
MUFA/PUFA	12.95	12.52	ns
UFA/SFA	5.28	5.20	ns
C18:1/C18:2	14.53	13.8	ns
Squalene (mg 100 g ^{−1})	605.4	676.9	ns

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$, **, $p < 0.01$, ***, $p < 0.001$.

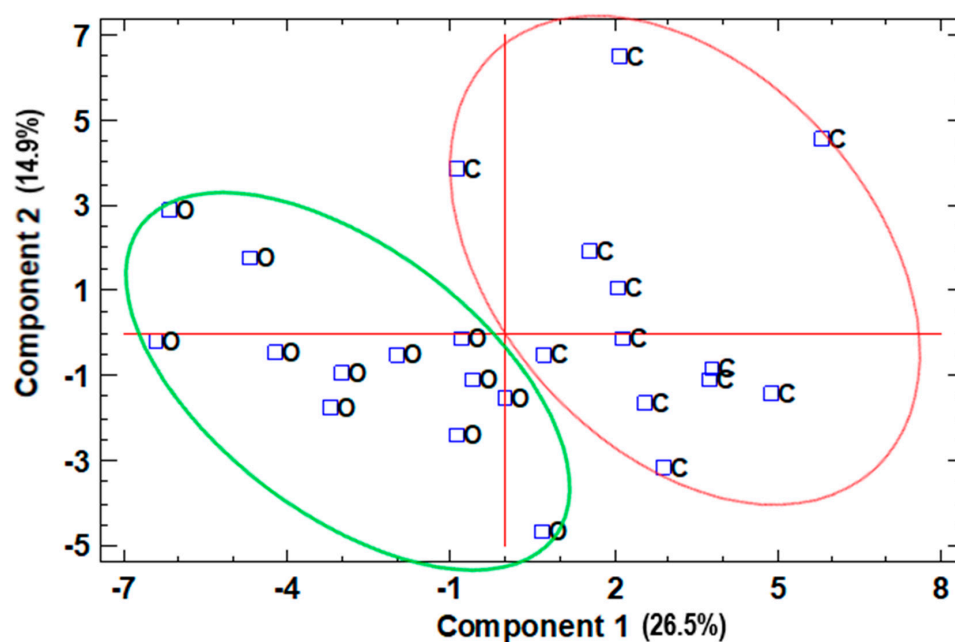
**Figure 3.** Scatterplot of the principal component analysis of the raw data at harvest in Pylia province. Abbreviations: O, organic management (denoted with the green eclipse), C, conventional management (denoted with the red eclipse).

Figure 4 presents the analysis of the PCA applied to the raw data per farmer in Pylia province, regarding only the conventionally managed orchards at harvest. There are significant differences among the three farmers, as they do not share common areas in the scatterplot.

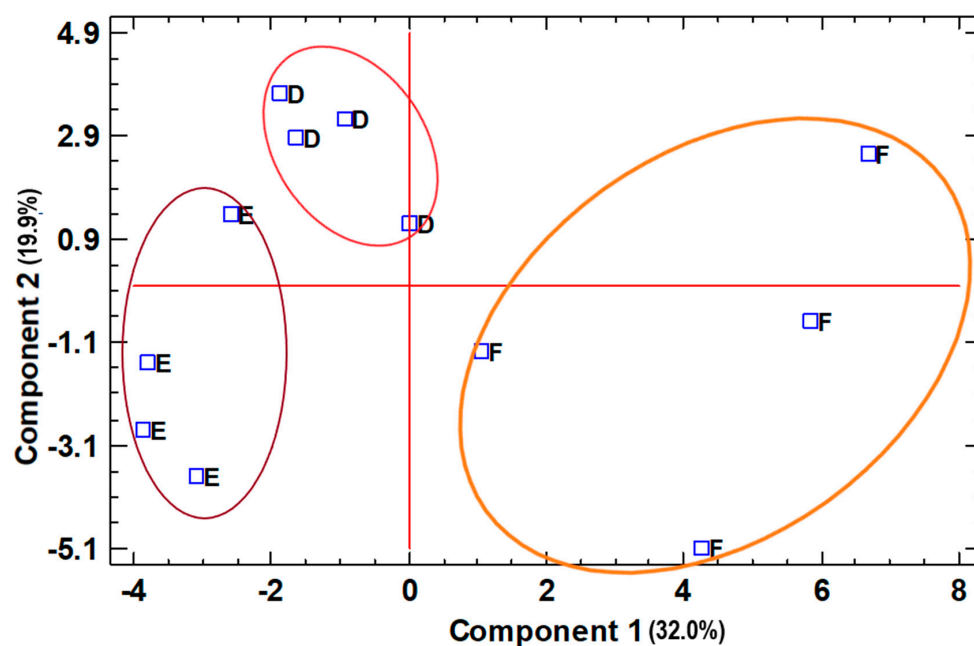


Figure 4. Scatterplot of the principal component analysis of the raw data of conventional orchards at harvest in Pylia province. The abbreviations (D, E, and F) represent the different olive groves (each grove is separately enclosed within one ellipse).

Figure 5 illustrates the raw data obtained from the analysis of the organic olive oil samples collected during harvest in the Pylia province. The data reveal a distinct separation among farmers: Farmer A is positioned on the negative side of PC1, whereas the other two farmers are located on the positive side of PC1.

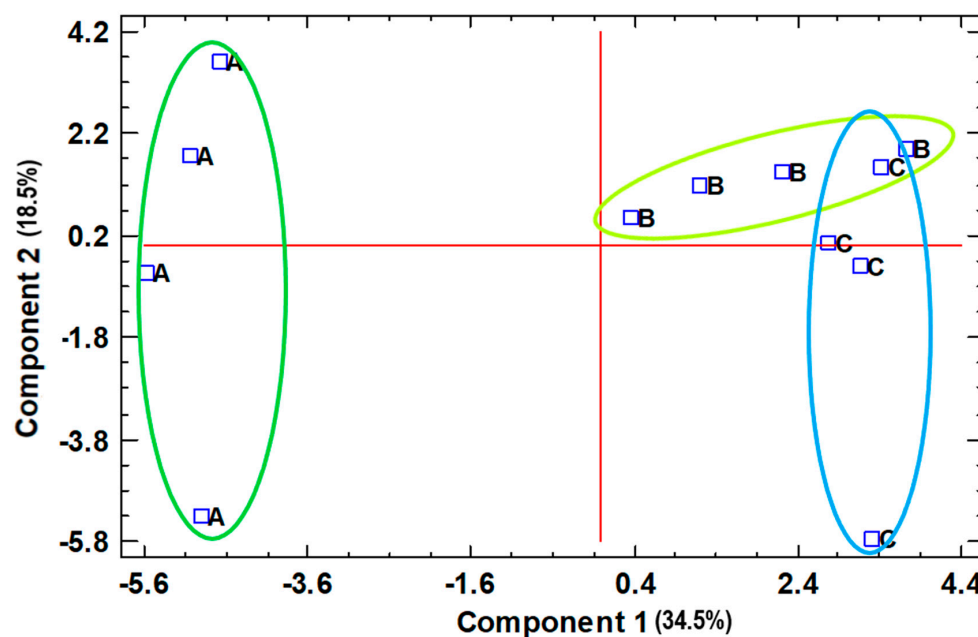


Figure 5. Scatterplot of the principal component analysis of the raw data of organic orchards at harvest in Pylia province. The abbreviations (A, B, and C) represent the different olive groves (each grove is separately enclosed within one ellipse).

Figure 6 shows that there is no distinct separation between organic and conventional management practices when considering the raw data from the sample analysis conducted at harvest in the Raches province.

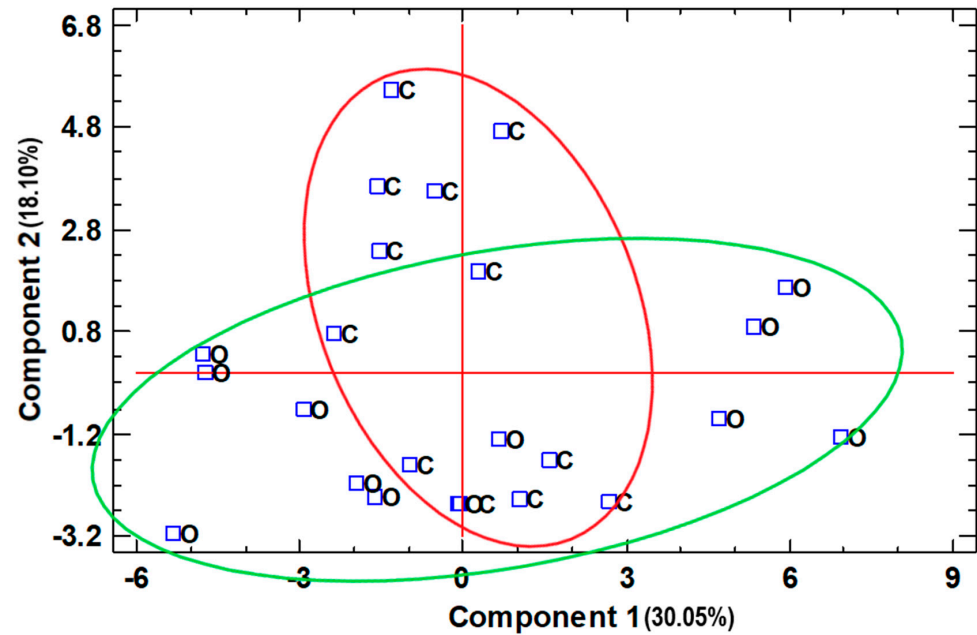


Figure 6. Scatterplot of the principal component analysis of the raw data at harvest in Raches province. Abbreviations: O, organic management (green eclipse), C, conventional management (red eclipse).

Figure 7 illustrates the PCA analysis applied to the raw data per farmer, focusing exclusively on conventionally managed orchards at harvest in Raches province. The results indicate that farmer AX is distinct from the other two, positioned on the positive side of PC1 and the negative side of PC2, while farmers KG and ZF occupy overlapping areas.

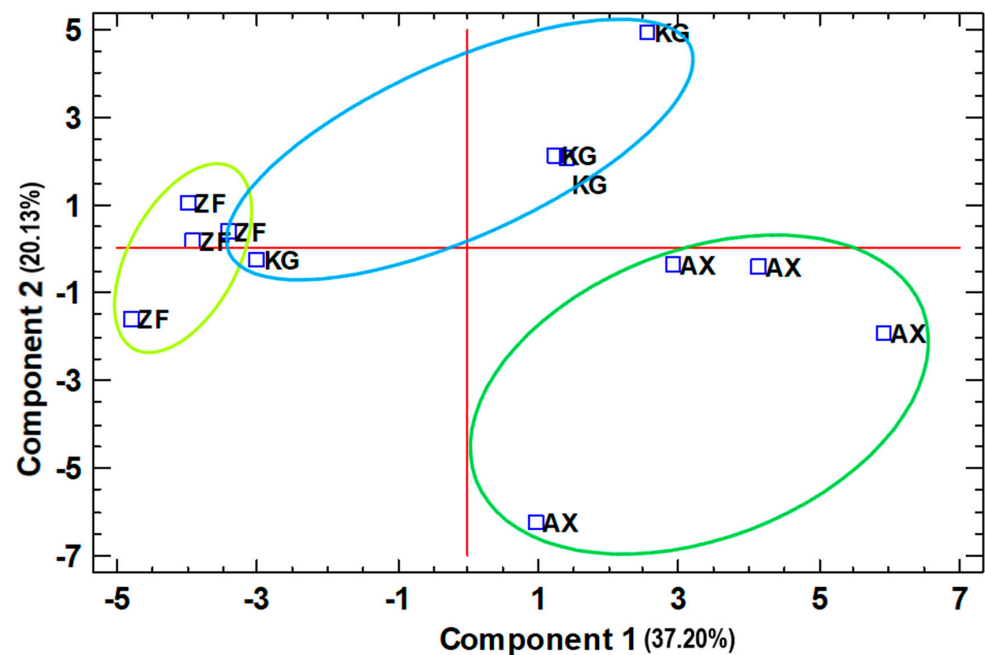


Figure 7. Scatterplot of the principal component analysis of the raw data of conventional orchards at harvest in Raches province. The abbreviations (ZF, KG, and AX) represent the initials of the farmers responsible for each olive grove (each grove is separately enclosed within one eclipse).

Figure 8 presents the raw data from the analysis of organic olive oil samples collected at harvest in Raches province. The results reveal a clear separation among farmers practicing organic management. Farmer PA is positioned on the positive side of PC2 and the negative side of PC1, farmer BD is located on the negative side of both PC2 and PC1, and farmer NP is situated on the positive side of PC1.

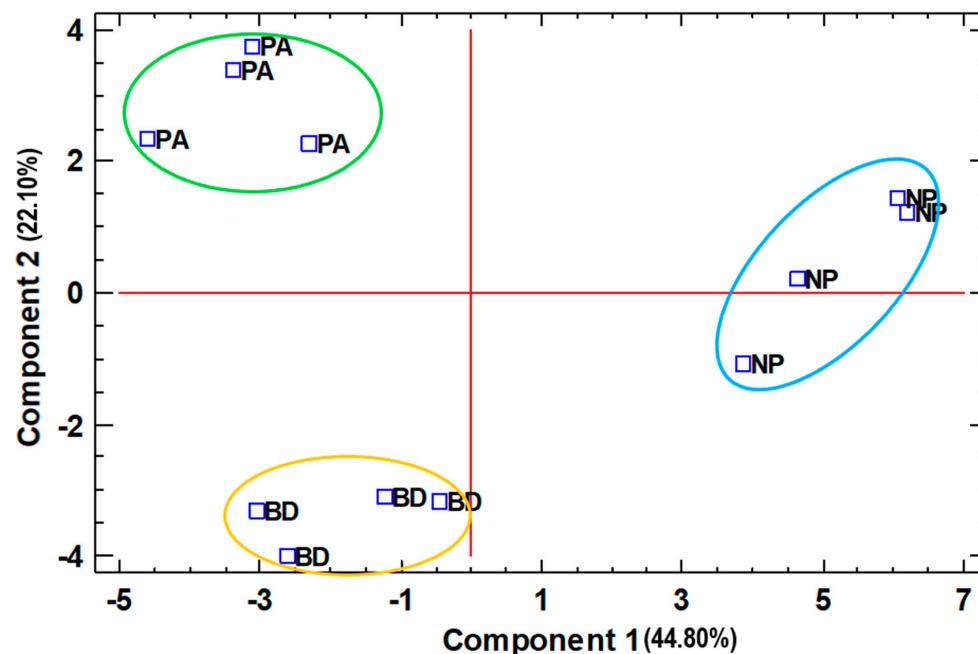


Figure 8. Scatterplot of the principal component analysis of the raw data of organic orchards at harvest in Raches province. The abbreviations (PA, NP, and BD) represent the initials of the farmers responsible for each olive grove (each grove is separately enclosed within one ellipse).

3.2. Olive Oil Quality 12 Months After Storage at Room Temperature (Derived from Raches Province Trial)

Twelve months after the oil was stored in the dark at room temperature, significant differences were detected regarding K232 and K270 indexes, with the conventionally produced oil presenting higher values (Table 6).

Table 6. Effects of the cultivation management on the oil's free acidity, peroxide index, K232, K270, twelve months after storage deriving from Raches province.

Parameter	Organic	Conventional	Significance
Free acidity (g oleic acid 100 g ⁻¹)	0.50	0.43	ns
Peroxides (meq O ₂ kg ⁻¹)	16.67	17.91	ns
K232	1.09	1.96	**
K270	0.08	0.16	*

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$, **, $p < 0.01$.

On the other hand, conventionally produced oils presented higher antioxidant capacity based on the FRAP assay, as can be seen in Table 7.

Table 7. Effects of cultivation management on olive total phenol, o-diphenol, and flavonoid concentration and antioxidant capacity twelve months after storage derived from Raches province.

Parameter	Organic	Conventional	Significance
Total phenols (mg GAE kg ⁻¹)	249.8	283.7	ns
o-diphenols (mg CAE kg ⁻¹)	19.38	14.63	ns
Total flavonoids (mg CtE kg ⁻¹)	145.8	160.8	ns
FRAP (μmol Trolox equiv. kg ⁻¹)	1120.38	1297.3	*
DPPH (μmol Trolox equiv. kg ⁻¹)	750.8	831.0	ns

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$.

No significant differences were determined among organic and conventional oils twelve months after storage regarding the individual phenolic compound concentration (Table 8).

Table 8. Effects of cultivation management on the concentration of individual phenolic compounds detected in olive oils in mg kg⁻¹ twelve months after storage derived from Raches province.

Parameter	Organic	Conventional	Significance
Hydroxytyrosol	14.05	12.94	ns
Tyrosol	51.24	53.97	ns
Vanillic acid	0.22	0.22	ns
Caffeic acid	0.14	0.07	ns
Vanillin	0.05	0.06	ns
p-coumaric acid	0.14	0.11	ns
Ferulic acid	0.03	0.03	ns
Oleacein	42.56	46.98	ns
Oleocanthal	129.85	127.23	ns
Luteolin	17.06	15.96	ns
Apigenin	2.61	2.53	ns
α-tocopherol	17.33	13.84	ns

ns, not significant.

Similarly, no significant differences were determined among organic and conventional oils twelve months after storage regarding the fatty acids content and squalene concentration (Table 9).

Table 9. Effects of cultivation management on the content of free fatty acids (determined as FAMES—%) and squalene concentration twelve months after storage derived from Raches province.

Parameter	Organic	Conventional	Significance
C16	13.06	13.38	ns
C16:1	0.63	0.67	ns
C18	2.51	2.58	ns
C18:1	77.47	76.92	ns
C18:2	5.30	5.43	ns
C20	0.27	0.26	ns
C18:3	0.58	0.59	ns
C20:1	0.18	0.17	ns
SFA	15.82	16.19	ns
MUFA	78.29	77.77	ns
PUFA	5.88	6.03	ns
MUFA/PUFA	13.65	12.93	ns
UFA/SFA	5.32	5.17	ns
C18:1/C18:2	15.07	14.18	ns
Squalene (mg 100 g ⁻¹)	689.2	660.6	ns

ns, not significant.

The following table (Table 10) presents the significant changes observed during storage, as well as the percentage of change (positive—increase or negative—decrease) in the oils produced in Raches province under the two cultivation practices. Changes that were not significant under both cultivation practices are not presented. The concentration of o-diphenols was significantly reduced under storage, but the reduction was greater in the conventional oils. Total flavonoid concentration was also significantly reduced, similar to the antioxidant capacity measured by the DPPH assay. Free acidity increased under storage in both conventional and organic oils, as did the peroxide concentration. The UV absorbance indexes (K232 and K270) were significantly reduced only in organic oils during the storage period. Both C16:1 and C18:3 fatty acids were significantly reduced in both conventional and organic oils, presenting almost similar reduction percentages. On the other hand, the concentration of both hydroxytyrosol and tyrosol increased in storage, exhibiting almost similar percentages in both oils. Nonetheless, all four other phenolic compounds (vanillin acid, vanillin, p-coumaric acid, and oleocanthal) presented significant differences, with the most significant reduction being that of p-coumaric acid, reaching almost 80%. A-tocopherol presented a similar reduction too, losing almost 80% of its original concentration during storage.

Table 10. The percentage change and its significance during the twelve-month storage of the oils produced under the two cultivation practices in Raches province.

Parameter	Organic		Conventional	
	%	Significance	%	Significance
o-diphenols (mg CAE kg ^{−1})	−52.5	ns	−72.7	***
Total flavonoids (mg CtE kg ^{−1})	−61.4	***	−66.2	***
DPPH (μmol Trolox equiv. kg ^{−1})	−36.4	***	−40.6	***
Free acidity (g oleic acid 100 g ^{−1})	18.3	ns	26.10	*
Peroxides (meq O ₂ kg ^{−1})	29.0	ns	87.0	***
K232	−33.4	*	2.54	ns
K270	−52.2	***	−9.3	ns
C16:1	−22.2	***	−18.8	***
C18:3	−17.7	***	−13.3	*
Hydroxytyrosol	146.7	***	211.9	***
Tyrosol	445.6	***	547.9	***
Vanillic acid	−53.4	***	−48.5	***
Vanillin	−64.8	***	−59.7	***
p-coumaric acid	−78.6	***	−74.8	***
Oleocanthal	−9.70	*	−16.5	*
a-tocopherol	−78.7	***	−83.8	***

Asterisk indicates a significant difference between the means within the same row. ns, not significant, *, $p < 0.05$, ***, $p < 0.001$.

4. Discussion

The PCA analyses at harvest showed minimal significant differences between organically and conventionally produced olive oil. Similar findings have been reported by various researchers, suggesting that the observed differences are not substantial enough to clearly distinguish the two cultivation systems. Most researchers agree that the greatest difference lies in the zero-pesticide residues found in organic olive oil.

In the present experiment, the two practices resulted in similar but slightly differing olive oil quality in the trial conducted in Pylia. On the other hand, in the second year, the trial in Raches revealed no significant differences between the two systems concerning olive oil quality attributes. Based on our results, it can be inferred that the major reason for these non-significant differences is the variability in olive oil quality within each production

system. This was demonstrated by the differences found between farmers managing their olive groves under the same principles of either organic or conventional practices.

In Pylia province, organic olive groves produced significantly higher yield and oil quantity per tree, as also reported by Volakakis et al. [26]. However, the opposite was observed in Raches province, underscoring the difficulty of determining which production system is superior based solely on yield. Similar discrepancies have been reported by other researchers too [1,21,23,26] driving the meta-analyses to conclude that there are generally no significant differences between the two systems [26]. This is especially true when organic olive groves are managed intensively with balanced nutrient inputs and under both irrigated as well as rain-fed conditions [1].

The oil content per fruit mass was not statistically different between the two systems in either region, suggesting that the biosynthetic pathway of olive oil is not affected by management practices, even when differences in fruit yield occur. Contrarily, Volakakis et al. [23] found a higher oil content per fruit in organically managed groves. This discrepancy could be attributed to several factors, such as cultivar, irrigation practices, fruit maturity at harvest, and pedoclimatic conditions.

None of the most commonly assessed quality attributes of the olive oil (i.e., free acidity, Kappa values, and peroxide index) differed between the two systems in either province. This aligns with findings from other studies [12,19,24,27], although conflicting reports exist, with some studies reporting higher or lower acidity in organic oils [3,17,19,28]. It appears that the oil acidity produced under either system largely depends on the cultivar assayed [19]. It must be noted here though that all oils produced were within the range of EVOO solely based on these parameters. Their values are significantly influenced by both pre-harvest (pest infestation, ripening stage etc) and post-harvest management (time passed between harvest and milling, malaxation conditions etc) [2,12,23,28,29]. As all these factors were carefully controlled and managed, and the milling conditions were consistent, it can be assumed that healthy fruits processed under favorable conditions preserved olive oil quality.

Phenolic compounds are a group of bioactive molecules of significant importance for human health [4,10,16]. Olive oil is considered a valuable source of such molecules and its role in the Mediterranean diet highlights its importance [27,30]. In this study, no significant differences in phenolic compounds were observed between conventionally and organically produced olive oil. However, in Pylia, o-diphenols and total flavonoids were higher in conventionally produced olive oil. Similarly, in Raches village the antioxidant capacity of the conventional olive oil (based on FRAP assay) was higher than the one of organic oil. While some studies report higher phenolic content in organic olive oil [12,13,15,18,19,31], others find no consistent or significant differences [3,6,27]. Lozano-Castellón et al. [16] reported higher tyrosol and hydroxytyrosol concentrations in conventional oils, while Jiménez et al. [24,32] observed higher phenol concentrations in conventionally produced oils from the Picual cultivar.

It is often expected that organic olive oil would contain higher phenolic compound concentrations, but this was not observed in our study. In Pylia, this discrepancy may be partly due to the higher fruit load in organically managed trees. Rosati et al. [3] and Inglese et al. [33] noted that low fruit load leads to earlier fruit coloration and higher polyphenol content, which may explain our findings. Furthermore, the variability among farms managed under the same practice, may also contribute to the lack of significant differences, as already mentioned by Rosati et al. [3]. The different microclimatic conditions of each orchard may have played a significant role in phenolic compound biosynthesis, justifying the differences found among orchards managed under the same practice. It is important to note that the oil (the fatty portion of the fruit) is only a small fraction of the

constituents of the olive fruit. Therefore, any agronomic practice-induced changes in the fruit are often not detectable in the extracted oil [3]. This was further evidenced by the minimal differences observed in individual phenolic compound concentrations over both years, consistent with previous literature [9,27].

The phenolic profile of the oil samples included various classes of compounds, such as phenolic acids (vanillic acid, caffeic acid, p-coumaric acid, ferulic acid), phenolic alcohols (hydroxytyrosol, tyrosol), flavonoids (luteolin, apigenin), and secoiridoids (oleacein and oleocanthal), in line with previous studies [34–37]. Overall, the olive cultivar, the growing practices, the pedoclimatic conditions, and the technological factors during oil extraction collectively influence the phenolic composition of the olive products, making it difficult to identify a single dominant factor [13,15,17,32]. Similarly, α -tocopherol concentration did not differ between oils produced under the two practices in Raches, although previous studies have reported higher concentrations in organic oils [17,31].

Even though in Raches province the oils produced did not exhibit any significant difference regarding their fatty acid composition, this was not the same in oils from Pyllia. Conventionally produced oil presented a higher oleic acid and MUFA percentage, while organic oils exhibited higher PUFA percentages. No significant difference was observed regarding the squalene concentration. Rosati et al. [3] also reported increased PUFA concentrations in organic oils, attributing this to reduced nitrogen fertilization compared to conventional systems. Contrarily, Malheiro et al. [4] observed the opposite, while other studies found no differences [6,26,28], highlighting the complexity of agronomic practices' effects on fatty acid composition.

After twelve months of storage at room temperature, oils from Raches showed significant changes in major quality and functional attributes. Both systems exhibited similar degradation patterns, except for o-diphenol and peroxide concentrations, where conventional oils showed a larger change. It was clear that the quality of oils deteriorated significantly, based on most of the quality characteristics assayed. Similar quality degradation after storage has been reported by numerous researchers, attributed to various factors, with the most important ones being exposure to oxygen, high temperature, and light, inducing hydrolytic and oxidative phenomena [9,38,39]. These oxidation procedures result in phenol and tocopherol losses, followed by a decrease in the concentration of unsaturated fatty acids, similar to those recorded in the present study. Interestingly, only hydroxytyrosol and tyrosol concentrations increased during storage, likely due to their release from more complex compounds (bound phenols), as has been already described [7,9]. The decreases in antioxidant compounds such as phenolic compounds and α -tocopherol were expected, as these contribute to the antioxidant capacity and stability of the oil [7], protecting the fatty acids from oxidation and olive oil from degradation through oxidation and hydrolysis processes [6,7,39]. An average loss of 46% of the initial phenol concentration in the olive oil after 12 months of storage in the dark at 25 °C, as in the present experiment, has been also reported by others [40,41]. However, when their concentration falls below the limit for efficient protection of valuable olive biomolecules, the increase in free acidity and peroxides is expected [7].

The most significant result was the fact that the production system (organic or conventional) did not appear to influence olive oil stability or functional properties during storage. The fatty acid composition and the balance of antioxidants and pro-oxidants are the key factors affecting oxidation patterns [7]. Since in this study few differences were observed at harvest between the two systems, a similar stability behavior during storage is justifiable.

5. Conclusions

Olive oils produced under the two cultivation systems exhibited similar quality characteristics. All farmers managed their trees based on judicious use of inputs and protected the olive fruit from biotic damages, thus resulting in extra-virgin olive oil production. The individual farmer appears to play a significant role in the implementation of cultivation practices, which, in turn, affects the quality traits of the oil. This leads to variations even among oils produced within the same cultivation system (organic or conventional). In conclusion, when management practices lead to healthy fruit production and oil extraction occurs under optimal conditions, the oil quality is expected to be high, regardless of the management system used. However, farmers may influence the quality attributes of the oil produced by applying different fertilization and plant protection programs. In the future, attention should be focused on how such practices may affect desirable oil characteristics.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/horticulturae11020130/s1>, Table S1: Pesticide and fertilizer applications in organic and conventional olive groves in Pyllia province; Table S2: Pesticide and fertilizer applications in organic and conventional olive groves in Raches province.

Author Contributions: Conceptualization, P.A.R.; methodology, P.A.R.; software, P.A.R. and A.-G.K.; validation, P.A.R.; formal analysis, A.-G.K., V.K. and K.Z.; investigation, P.A.R., A.-G.K., V.K. and K.Z.; resources, P.A.R.; data curation, P.A.R., A.-G.K., V.K. and K.Z.; writing—original draft preparation, P.A.R. and A.-G.K.; writing—review and editing, P.A.R.; visualization, P.A.R.; supervision, P.A.R. and A.-G.K.; project administration, P.A.R. and A.-G.K.; funding acquisition, P.A.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data is contained within the article and Supplementary Materials.

Acknowledgments: We would like to thank all the farmers who gave us access to their farms and contributed with the olive fruits produced. This article is a revised and expanded version of a paper entitled “Olive oil quality characteristics under organic and integrated management in Messinia county Greece”, which was presented at the XIV International Scientific Agriculture Symposium “AGROSYM 2023”, Jahorina, Bosnia and Herzegovina, 5–8 October 2023.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pleguezuelo, C.R.R.; Zuazo, V.H.D.; Martínez, J.R.F.; Peinado, F.J.M.; Martín, F.M.; Tejero, I.F.G. Organic olive farming in Andalusia, Spain. A review. *Agron. Sustain. Dev.* **2018**, *38*, 20. [\[CrossRef\]](#)
2. Caporaso, N.; Boskou, D. Olive (*Olea europaea*). In *Oilseeds: Health Attributes and Food Applications*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 211–252.
3. Rosati, A.; Cafiero, C.; Paoletti, A.; Alfei, B.; Caporali, S.; Casciani, L.; Valentini, M. Effect of agronomical practices on carpology, fruit and oil composition, and oil sensory properties, in olive (*Olea europaea* L.). *Food Chem.* **2014**, *159*, 236–243. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Malheiro, R.; Casal, S.; Baptista, P.; Pereira, J.A. *How Agronomic Factors Affects Olive Oil Composition and Quality*; Nova Science Publishers: Hauppauge, NY, USA, 2014.
5. Beltrán, G.; Bucheli, M.E.; Aguilera, M.P.; Belaj, A.; Jimenez, A. Squalene in virgin olive oil: Screening of variability in olive cultivars. *Eur. J. Lipid Sci. Technol.* **2016**, *118*, 1250–1253. [\[CrossRef\]](#)
6. Lanza, B.; Ninfali, P. Antioxidants in extra virgin olive oil and table olives: Connections between agriculture and processing for health choices. *Antioxidants* **2020**, *9*, 41. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Tsimidou, M.Z. Olive oil quality. In *Olive Oil*; Elsevier: Amsterdam, The Netherlands, 2006; pp. 93–111.
8. Mastralexi, A.; Tsimidou, M.Z. On the squalene content of CV Chondrolia Chalkidikis and Chalkidiki (Greece) virgin olive oil. *Molecules* **2021**, *26*, 6007. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Kalogeropoulos, N.; Tsimidou, M.Z. Antioxidants in Greek virgin olive oils. *Antioxidants* **2014**, *3*, 387–413. [\[CrossRef\]](#)

10. Olmo-Cunillera, A.; Lozano-Castellón, J.; Pérez, M.; Miliarakis, E.; Tresserra-Rimbau, A.; Ninot, A.; Romero-Aroca, A.; Lamuela-Raventós, R.M.; Vallverdú-Queralt, A. Optimizing the Malaxation Conditions to Produce an Arbequina EVOO with High Content of Bioactive Compounds. *Antioxidants* **2021**, *10*, 1819. [\[CrossRef\]](#)
11. Jurado-Campos, N.; García-Nicolás, M.; Pastor-Belda, M.; Bußmann, T.; Arroyo-Manzanares, N.; Jiménez, B.; Viñas, P.; Arce, L. Exploration of the potential of different analytical techniques to authenticate organic vs. conventional olives and olive oils from two varieties using untargeted fingerprinting approaches. *Food Control* **2021**, *124*, 107828. [\[CrossRef\]](#)
12. Carrapiso, A.I.; Rubio, A.; Sánchez-Casas, J.; Martín, L.; Martínez-Cañas, M.; de Miguel, C. Effect of the organic production and the harvesting method on the chemical quality and the volatile compounds of virgin olive oil over the harvesting season. *Foods* **2020**, *9*, 1766. [\[CrossRef\]](#) [\[PubMed\]](#)
13. López-Yerena, A.; Lozano-Castellón, J.; Olmo-Cunillera, A.; Tresserra-Rimbau, A.; Quifer-Rada, P.; Jiménez, B.; Pérez, M.; Vallverdú-Queralt, A. Effects of organic and conventional growing systems on the phenolic profile of extra-virgin olive oil. *Molecules* **2019**, *24*, 1986. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Inglese, P.; Famiani, F.; Galvano, F.; Servili, M.; Esposto, S.; Urbani, S. 3 factors affecting extra-virgin olive oil composition. *Hortic. Rev.* **2011**, *38*, 83.
15. Boskou, D. Olive fruit, table olives, and olive oil bioactive constituents. In *Olive and Olive Oil Bioactive Constituents*; Elsevier: Amsterdam, The Netherlands, 2015; pp. 1–30.
16. Lozano-Castellón, J.; López-Yerena, A.; Domínguez-López, I.; Siscart-Serra, A.; Fraga, N.; Sámano, S.; López-Sabater, C.; Lamuela-Raventós, R.M.; Vallverdú-Queralt, A.; Pérez, M. Extra virgin olive oil: A comprehensive review of efforts to ensure its authenticity, traceability, and safety. *Compr. Rev. Food Sci. Food Saf.* **2022**, *21*, 2639–2664. [\[CrossRef\]](#)
17. Ríos-Reina, R.; Camacho, F.; Morales, M.L.; Jiménez-Herrera, B.; Callejón, R.M. Influence of irrigation modalities (irrigation management and dryland), fruit ripening, and cultivation modality (organic and conventional) on quality and chemosensory profile of Hojiblanca and Picual extra virgin olive oils. *Eur. J. Lipid Sci. Technol.* **2021**, *123*, 2000375. [\[CrossRef\]](#)
18. Anastasopoulos, E.; Kalogeropoulos, N.; Kaliora, A.C.; Kountouri, A.; Andrikopoulos, N.K. The influence of ripening and crop year on quality indices, polyphenols, terpenic acids, squalene, fatty acid profile, and sterols in virgin olive oil (Koroneiki cv.) produced by organic versus non-organic cultivation method. *Int. J. Food Sci. Technol.* **2011**, *46*, 170–178. [\[CrossRef\]](#)
19. Jimenez, B.; Sánchez-Ortiz, A.; Lorenzo, M.L.; Rivas, A. Effect of organic cultivation of Picual and Hojiblanca olive varieties on the quality of virgin olive oil at four ripening stages. *Eur. J. Lipid Sci. Technol.* **2014**, *116*, 1634–1646. [\[CrossRef\]](#)
20. Panagodimou, E.; Roussis, I.; Papadas, C.T.; Bilalis, D.J. A Comparison of Cost in Organic and Conventional Olive Oil Production in Greece. *Bull. Univ. Agric. Sci. Vet. Med. Cluj-Napoca. Hortic.* **2019**, *76*, 127–130. [\[CrossRef\]](#)
21. Berg, H.; Maneas, G.; Salguero Engström, A. A Comparison between Organic and Conventional Olive Farming in Messenia, Greece. *Horticulturae* **2018**, *4*, 15. [\[CrossRef\]](#)
22. Kalogiouri, N.P.; Aalizadeh, R.; Thomaidis, N.S. Investigating the organic and conventional production type of olive oil with target and suspect screening by LC-QTOF-MS, a novel semi-quantification method using chemical similarity and advanced chemometrics. *Anal. Bioanal. Chem.* **2017**, *409*, 5413–5426. [\[CrossRef\]](#)
23. Volakakis, N.; Kabourakis, E.; Kiritsakis, A.; Rempelos, L.; Leifert, C. Effect of Production System (Organic versus Conventional) on Olive Fruit and Oil Yields and Oil Quality Parameters in the Messara Valley, Crete, Greece; Results from a 3-Year Farm Survey. *Agronomy* **2022**, *12*, 1484. [\[CrossRef\]](#)
24. Jimenez, B.; Sánchez-Ortiz, A.; Lorenzo, M.L.; Rivas, A. Effect of Agronomical Practices on the Nutritional Quality of Virgin Olive Oil at Different Ripening Stages. *J. Am. Oil Chem. Soc.* **2015**, *92*, 1491–1501. [\[CrossRef\]](#)
25. Roussos, P.A.; Karabi, A.; Anastasiou, L.; Assimakopoulou, A.; Gasparatos, D. Apricot tree nutrient uptake, fruit quality and phytochemical attributes, and soil fertility under organic and integrated management. *Appl. Sci.* **2023**, *13*, 2596. [\[CrossRef\]](#)
26. Volakakis, N.; Kabourakis, E.; Leifert, C. Conventional and organic cultivation and their effect on the functional composition of olive oil. In *Olives and Olive Oil as Functional Foods: Bioactivity, Chemistry and Processing*; Wiley: Oxford, UK, 2017; pp. 35–43.
27. Ninfali, P.; Bacchiocca, M.; Biagiotti, E.; Esposto, S.; Servili, M.; Rosati, A.; Montedoro, G. A 3-year study on quality, nutritional and organoleptic evaluation of organic and conventional extra-virgin olive oils. *J. Am. Oil Chem. Soc.* **2008**, *85*, 151–158. [\[CrossRef\]](#)
28. Luis, G.-G.D.; Ramón, A.-R.; Teresa, M.M. Chemical characterization of organic and non-organic virgin olive oils. *OCL* **2014**, *21*, D506.
29. Ghreishi Rad, S.A.; Jalili, M.; Ansari, F.; Rashidi Nodeh, H.; Rashidi, L. Maturity impact on physicochemical composition and polyphenol properties of extra virgin olive oils obtained from Manzanilla, Arbequina, and Koroneiki varieties in Iran. *Food Sci. Nutr.* **2023**, *11*, 5396–5408. [\[CrossRef\]](#)
30. López-Yerena, A.; Ninot, A.; Jiménez-Ruiz, N.; Lozano-Castellón, J.; Pérez, M.; Escribano-Ferrer, E.; Romero-Aroca, A.; Lamuela-Raventós, R.M.; Vallverdú-Queralt, A. Influence of the Ripening Stage and Extraction Conditions on the Phenolic Fingerprint of ‘Corbella’ Extra-Virgin Olive Oil. *Antioxidants* **2021**, *10*, 877. [\[CrossRef\]](#)
31. Gutiérrez, F.; Arnaud, T.; Albi, M.A. Influence of ecological cultivation on virgin olive oil quality. *J. Am. Oil Chem. Soc.* **1999**, *76*, 617–621. [\[CrossRef\]](#)

32. Jiménez, B.; Rivas, A.; Lorenzo, M.L.; Sánchez-Ortiz, A. Chemosensory characterization of virgin olive oils obtained from organic and conventional practices during fruit ripening. *Flavour Fragr. J.* **2017**, *32*, 294–304. [[CrossRef](#)]
33. Inglese, P.; Famiani, F.; Servili, M. I fattori di variabilità genetici, ambientali e culturali della composizione dell'olio di oliva. *Italus Hortus* **2009**, *16*, 67–81.
34. Pino, C.; Sepúlveda, B.; Tapia, F.; Saavedra, J.; García-González, D.L.; Romero, N. The Impact of Mild Frost Occurring at Different Harvesting Times on the Volatile and Phenolic Composition of Virgin Olive Oil. *Antioxidants* **2022**, *11*, 852. [[CrossRef](#)] [[PubMed](#)]
35. Faghim, J.; Mohamed, M.B.; Bagues, M.; Guasmi, F.; Triki, T.; Nagaz, K. Irrigation effects on phenolic profile and extra virgin olive oil quality of “Chemlali” variety grown in South Tunisia. *S. Afr. J. Bot.* **2021**, *141*, 322–329. [[CrossRef](#)]
36. Flammini, F.; Gaggiotti, S.; Chiaudani, A.; Compagnone, D.; Cichelli, A. The Introduction of Allochthonous Olive Variety and Super High-Density System in the Abruzzo Region: A Study on Olive Oil Quality. *Foods* **2023**, *12*, 1292. [[CrossRef](#)]
37. Crizel, R.L.; Hoffmann, J.F.; Zandoná, G.P.; Lobo, P.M.S.; Jorge, R.O.; Chaves, F.C. Characterization of Extra Virgin Olive Oil from Southern Brazil. *Eur. J. Lipid Sci. Technol.* **2020**, *122*, 1900347. [[CrossRef](#)]
38. Velasco, J.; Dobarganes, C. Oxidative stability of virgin olive oil. *Eur. J. Lipid Sci. Technol.* **2002**, *104*, 661–676. [[CrossRef](#)]
39. Cinquanta, L.; Esti, M.; Notte, E.L. Evolution of phenolic compounds in virgin olive oil during storage. *J. Am. Oil Chem. Soc.* **1997**, *74*, 1259–1264. [[CrossRef](#)]
40. Diamantakos, P.; Ioannidis, K.; Papanikolaou, C.; Tsolakou, A.; Rigakou, A.; Melliou, E.; Magiatis, P. A New Definition of the Term “High-Phenolic Olive Oil” Based on Large Scale Statistical Data of Greek Olive Oils Analyzed by qNMR. *Molecules* **2021**, *26*, 1115. [[CrossRef](#)] [[PubMed](#)]
41. Roussos, P.A.; Karida, A.-G.; Kaibalis, V. Olive oil quality characteristics under organic and integrated management in messinia county Greece. In Proceedings of the XIV International Scientific Agriculture Symposium “AGROSYM 2023”, Jahorina, Bosnia and Herzegovina, 5–8 October 2023; pp. 165–171.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.