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Characterization of monovarietal olive oils obtained from mills of Calabria region (Southern Italy)

Amalia Piscopo [a,*], Alessandra De Bruno [a], Angela Zappia [a], Carmine Ventre [b], Marco Poiana [a]

[a] Department of AGRARIA, University Mediterranea of Reggio Calabria, 89124 Vito (Reggio Calabria), Italy
[b] Centro Analisi Biochimiche Sas, Via Pitagora 4, 89016 Rizziconi (Reggio Calabria), Italy

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ABSTRACT

The qualitative characteristics of four monovarietal olive oils produced in Calabria region (Southern Italy) were evaluated. The aim of this work was to evidence the differences on chemical parameters due to variety and to growing environment. Results demonstrated a large variability in qualitative indexes according to the variety. Most of the Grossa di Gerace oils sampled in Ionian Southern coast revealed a high total acidity (percentage upper 0.8% of oleic acid). Fatty acid composition showed some varietal characters: in Grossa di Gerace oils possessed a low content of oleic acid and many Carolea oils showed a heptadecenoic acid level higher than 0.3% as European Rules requires for the extra virgin olive oil category. Carolea cultivar is widely grown in different sites of Calabria and so it is influenced by the different climatic conditions: the obtained oils strongly differed according to the production area.

1. Introduction

Olive oil is the principal fat of the Mediterranean diet, universally recognized for its healthy properties. It has demonstrated that olive oil consumption involves the reduction of LDL-cholesterol levels and the increase of HDL-cholesterol content on plasma. This is due to the olive oil composition, characterized by a high content of monounsaturated fatty acids, in particular oleic acid and phytosterols as β-sitosterol. Moreover, olive oil is a valid source of essential fatty acids: α-linolenic acid (ω-3) and linoleic acid (ω-6) that human body requires and cannot synthetize.

Among minor components of olive oil, tocopherols and phenolic compounds represent antioxidants. Tocopherols are known as lipophilic constituents, while phenols are hydrophilic compounds. In particular, phenolics make important contribution to the nutritional properties, the sensory characteristics, and the shelf life of olive oil. Indeed, it is known that the healthy properties of the phenolic compounds are correlated to their antioxidant activity (Papadopoulos & Boskou, 1991). The Fatty Acid Methyl Esters (FAME) and Fatty Acid Ethyl Esters (FAEE) content in olive oil are indicative of incorrect handling, strong processing of drupes or deodorization step. In addition, the climate can influence these qualitative parameters if it promotes optimal conditions for parasitic attacks on the trees and on the drupes. It is in fact widely known that the quality of virgin olive oil is influenced by various agronomic factors such as olive cultivar, climatic conditions and agronomic practices (Abu-Reidah, Yasin, Urbani, Servili, & Montedoro, 2013). Calabria region is placed at the end of the so-called "Italian boot", washed by the Ionian Sea in the east and by Tyrrhenian Sea in the west. Its territorial geography varies from hill (Pollino, Aspromonte) to plateau (Sila's and Sibari's Plateau) and to flat areas (Valley of Sant'Eufemia and Valley of Gioia Tauro). The olive growing has a long tradition in Calabria with the presence of autochthonous and allochthonous varieties largely cultivated along the region. For several years the Calabrian olive oils were characterized by a low quality, due to incorrect practices on olive grove management and olive oil processing. Considering that Calabria region possesses a natural vocationality to the olive growing and it is one of the main Italian olive oil producers, in the last times it has been aimed to obtain olive oils with higher quality. Three Calabrian olive oils have obtained the quality identification of

* Corresponding author.
E-mail addresses: amalia.piscopo@unirc.it (A. Piscopo), alessandra.debruno@unirc.it (A. De Bruno), angela.zappia@unirc.it (A. Zappia), ventre.carmine@gmail.com (C. Ventre), mpoiana@unirc.it (M. Poiana).

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PDO (Protected Designation Origin): "Bruzio", "Lametia", and "Alto Crotonese". Among the most representative olive varieties in the region this work considered the monovarietal olive oils of Carolea, Ottobratica, Sinopolese and Grossa di Gerace cultivars. Carolea is polyclonal (Muzzalupo, Chiappetta, Stabile, Bucci, & Perri, 2011) and cultivated in all the areas of the region; Ottobratica and Sinopolese are mainly present in the Tyrrhenian southern area, while Grossa di Gerace is cultivated in the Ionian southern coast. The climate in Calabria is variable depending on site and the average annual precipitation varies from 770.6 mm in Ionic southern site to 1102.7 mm in Valley of Sant'Eufemia. The effect of growing environment on olive oil quality has been focused by several authors (Salvador, Aranda, Gòmez-Alonso, & Fregapane, 2003; Tura et al., 2008). Moreover, many studies reported that the content of antioxidants in olive oils was affected by different climate and soil environments (Cimato et al., 2003; Ranalli, De Mattia, Patumi, & Proietti, 1999; Vihna et al., 2005). The composition of Calabrian olive oils has been evaluated with respect to harvest time and varietal effect (Giuffrè, Piscopo, Sicari, & Poiana, 2010; Runcio, Sorgonà, Mincione, Santacaterina, & Poiana, 2008; Sicari, Giuffrè, Piscopo, & Poiana, 2009). In this work, the quality of four monovarietal olive oils was studied and the effect of the different growing areas of Calabria region on chemical parameters of Carolea olive oils was also evaluated as a secondary goal.

2. Materials and methods

2.1. Sampling

Monovarietal olive oils (Carolea, Ottobratica, Sinopolese and Grossa di Gerace) were supplied by different mills of Calabria region at October and November 2014. Five sampling areas were considered: the Sibari's plateau (SP), the Valley of S. Eufemia (VSE), the Tyrrhenian Southern area (TSA), the Ionian Southern coast (ISC) and the Ionian area of Catanzaro (IAC) (Fig. 1). Olive farms were chosen following qualitative criteria based on geographical position and processing techniques to obtain qualitative products. The drupes were harvested at an optimal stage of ripeness, and farm operators followed the correct practices of olive grove management and olive oil processing. The olive oil was extracted by continuous technological plant provided by centrifugal system with two or three phases. Samples were stored in dark bottles without headspace at room temperature. In this study, 151 samples of Carolea olive oils, 55 samples of Ottobratica olive oils, 31 samples of Grossa di Gerace olive oils and 12 samples of Sinopolese olive oils were evaluated. The different number of sampling is due to the different level of diffusion of the cited olive cultivars in the Calabria region. Concerning the Carolea olive oils, 24, 44, 15, 30 and 34 samples were supplied from SP, VSE, TSA,

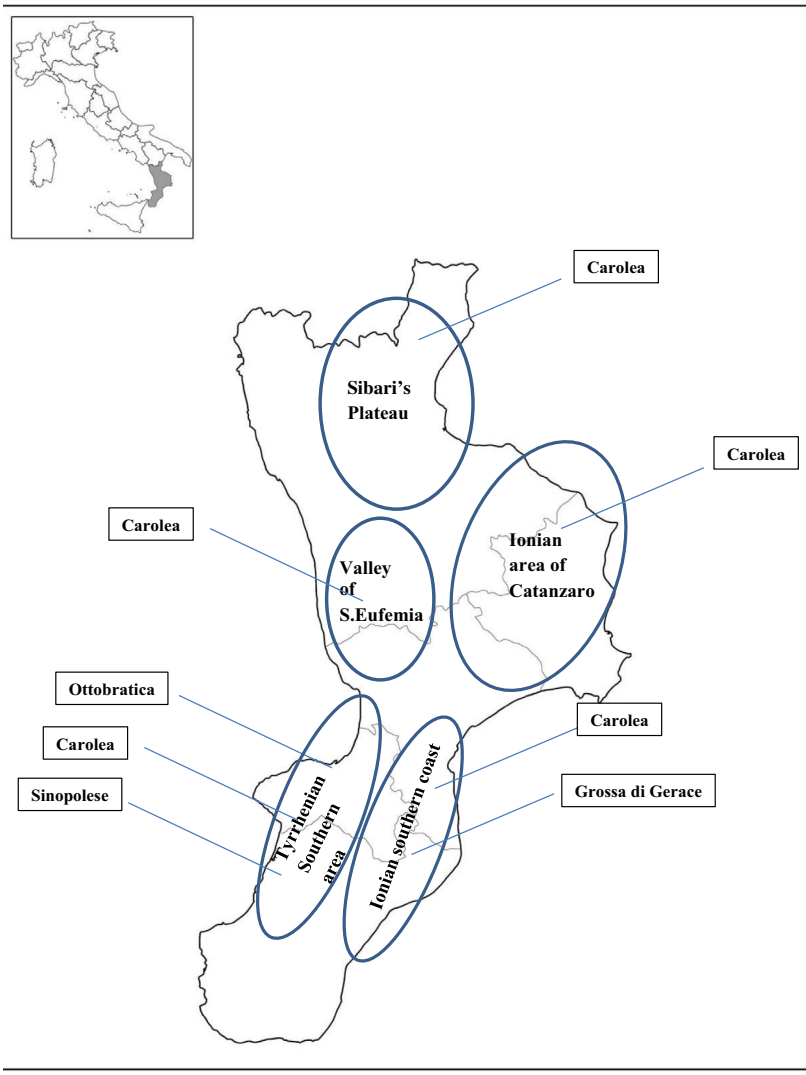

Fig. 1. Sampling areas and distribution of principal olive cultivars.

ISC and ICC, respectively. All chemical analyses were carried out contemporarily.

2.2. Qualitative determinations

Acidity value, peroxide index, UV light absorption (K_{232} and K_{270}), waxes, fatty acids, alkyl esters content and sterols were determined following the analytical methods described EC Regulation (EUC, 2013). The total phenols were analysed spectrophotometrically at 725 nm using Folin-Ciocalteau reagent as reported by Baiano et al. (2009), and expressed as mg/kg of gallic acid by the calibration plot of pure gallic acid as standard at different concentrations. Oxidative stability was expressed as the induction time (h) in the Rancimat equipment (Metrohm, Basel, Switzerland) at 98 °C and an air flow of 10–12 l/h, as defined in AOCS Official Method Cd 12b-92 (AOCS, 1993).

Tocopherol composition analysis was performed by HPLC, applying the IUPAC method 2432 (1987). All the analyses were determined in duplicate for each sample.

2.3. Statistical analysis

One-way analysis of variance (ANOVA) was applied to the data to determine the presence of significant differences among monovarietal olive oils (Tukey's test, significant level for $P < 0.05$).

Moreover, eventual differences in the waxes and fatty acids composition of extracted oils were tested with Hierarchical cluster analysis (HCA). For classification, the single linkage method was utilized. The squared Euclidean distance was employed as similarity measure in the analyses. SPSS Software (Version 15.0, SPSS Inc., Chicago, IL, USA) was used for data processing.

3. Results and discussion

3.1. Characterization of olive oils

As illustrated in Table 1, the free acidity was within the limit for extra virgin olive oil category in all cultivars considering the mean value from the samples of each variety. In particular, Ottobratica and Sinopolese oils denoted lower values, linked to the climatic and soil parameters of the growing area, the Tyrrhenian Southern coast. Hilly and flat areas are in this production area, with different thermal regimes, typically the first colder than the second. The oils were obtained by farms located in the hilly area, and not in the plateau one. As already demonstrated by García-Inza, Castro, Hall, and Rousseaux (2014), high temperatures during the oil accumulation phase may negatively affect olive oil yield and quality in warm regions, particularly if the high-temperature event occurs early in the phase. Therefore, the low acidity observed in Ottobratica and Sinopolese oils produced in hilly areas can be also dependent on the environmental parameters, apart from other variables, such as olive processing. The highest mean acidity was observed in Grossa di Gerace oils, and some of these were not classified as extra virgin oils because of the percentage upper than 0.8%, as defined by European Regulation (EUC, 2011). High statistical variability of the free acidity values was observed in Carolea oils, with a maximum of 2.18% and a minimum of 0.09% (data not shown). Agronomic variables, but also environmental conditions, influenced these results. In fact, among the Carolea olive oils that were not extra virgin, the 52% was produced in the Ionian Southern Coast, characterized by a very hot humid climate in some periods of the year. The peroxide value for all analysed samples was within the limits for extra virgin olive oils (20 mEq O_2/kg), with the only exception of several Sinopolese oils which denoted higher numbers. These results could be due to varietal characters, as dimensions of drupes, and agronomical practices, as pruning and olive grove management. The results of K_{232} and K_{270} determinations complied with the Regulation limits for the extra virgin olive oil (EUC, 2013). The wax ester content varied significantly from 60 mg/kg in Carolea to 122 mg/kg in Grossa di Gerace oils. Grossa di Gerace olive oils are differentiated in a cluster with respect to Ottobratica, Sinopolese and Carolea cultivars that were included in a same cluster at a dissimilarity level of 10 in the hierarchical scheme, as reported in Fig. 2. The affinity of these cultivars confirms the results of a previous study on the varietal influence on wax composition of several olive cultivars (Giuffrè, 2013). In dry hot weather, plants produce

Table 1
Chemical and qualitative parameters of monovarietal olive oils produced in Calabria (Southern Italy).

	Carolea	Ottobratica	Grossa di Gerace	Sinopolese	Sign.
Free acidity (%)	0.47 ± 0.37^{ab}	0.26 ± 0.11^{b}	0.65 ± 0.26^{a}	0.35 ± 0.14^{b}	**
Peroxide value (mEqO_2/kg)	6.91 ± 3.44^{b}	7.48 ± 2.84^{b}	7.41 ± 3.75^{b}	19.82 ± 7.61^{a}	**
K_{232}	1.82 ± 0.16^{b}	1.84 ± 0.17^{b}	1.81 ± 0.10^{b}	1.97 ± 0.25^{a}	*
K_{270}	0.11 ± 0.02^{b}	0.11 ± 0.02^{b}	0.12 ± 0.02^{b}	0.15 ± 0.02^{a}	**
Wax esters (mg/kg)	59.05 ± 21.26^{b}	90.08 ± 36.51^{b}	121.56 ± 31.10^{a}	81.19 ± 30.46^{b}	**
Σ FAME (mg/kg)	15.91 ± 19.98^{bc}	7.83 ± 7.09^{c}	33.04 ± 19.92^{a}	19.97 ± 8.82^{b}	**
Σ FAEE (mg/kg)	9.82 ± 12.93^{b}	6.30 ± 7.63^{b}	25.72 ± 32.75^{a}	16.78 ± 19.63^{ab}	**
Σ FAME + FAEE (mg/kg)	25.03 ± 31.08^{bc}	14.13 ± 13.88^{c}	58.76 ± 51.14^{a}	36.75 ± 25.29^{b}	**
Total Polyphenols (mg/kg)	317.44 ± 89.94	286.73 ± 91.76	291.55 ± 83.17	305.65 ± 109.81	n.s.
Total Tocopherols (mg/kg)	214.62 ± 38.32^{b}	334.80 ± 55.08^{a}	340.95 ± 48.11^{a}	330.90 ± 68.92^{a}	**
Induction Time (h)	12.19 ± 3.69^{a}	10.55 ± 2.69^{a}	7.10 ± 2.55^{b}	10.45 ± 2.24^{a}	**
C16:0 (%)	14.56 ± 1.19	14.90 ± 1.06	14.75 ± 0.66	14.76 ± 0.81	n.s.
C16:1 (%)	1.49 ± 0.32^{a}	1.06 ± 0.21^{c}	1.26 ± 0.22^{b}	1.03 ± 0.18^{c}	**
C17:0 (%)	0.16 ± 0.04^{a}	0.15 ± 0.05^{ab}	0.04 ± 0.03^{c}	0.12 ± 0.04^{b}	**
C17:1 (%)	0.31 ± 0.07^{a}	0.22 ± 0.06^{b}	0.07 ± 0.06^{c}	0.17 ± 0.05^{b}	**
C18:0 (%)	2.33 ± 0.32^{a}	2.05 ± 0.34^{b}	1.90 ± 0.19^{c}	2.10 ± 0.22^{b}	**
C18:1 (%)	73.04 ± 2.87^{ab}	71.82 ± 2.74^{b}	66.09 ± 2.37^{c}	74.44 ± 2.20^{a}	**
C18:2 (%)	6.87 ± 1.63^{c}	8.58 ± 1.51^{b}	14.59 ± 2.00^{a}	6.11 ± 1.96^{c}	**
C20:0 (%)	0.38 ± 0.07	0.36 ± 0.06	0.34 ± 0.02	0.36 ± 0.04	n.s.
C18:3 (%)	0.42 ± 0.09^{c}	0.47 ± 0.09^{bc}	0.63 ± 0.07^{a}	0.53 ± 0.10^{b}	**
C20:1 (%)	0.25 ± 0.05^{a}	0.23 ± 0.03^{ab}	0.20 ± 0.01^{b}	0.23 ± 0.04^{ab}	**
C22:0 (%)	0.11 ± 0.03^{a}	0.11 ± 0.02^{a}	0.08 ± 0.00^{b}	0.11 ± 0.01^{a}	**
C24:0 (%)	0.06 ± 0.02^{a}	0.05 ± 0.01^{ab}	0.04 ± 0.01^{b}	0.05 ± 0.01^{b}	**
C18:1/C18:2	11.20 ± 2.59^{b}	8.68 ± 2.01^{c}	4.78 ± 1.98^{d}	12.18 ± 3.57^{a}	**
MUFA/PUFA	10.30 ± 2.38^{a}	8.11 ± 1.84^{b}	4.44 ± 1.87^{c}	11.44 ± 3.17^{a}	n.s.

Results are expressed as mean ± SD.
** Significance at $P < 0.01$.
* Significance at $P < 0.05$; n.s. not significant. Results followed by different letters are significantly different by Tukey's multiple range test.

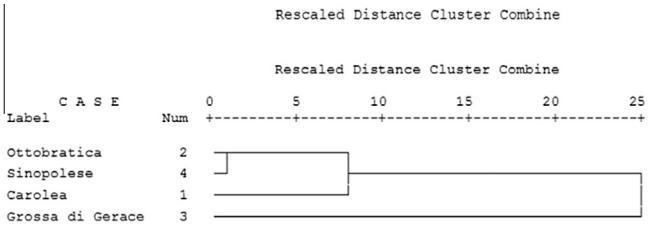

Fig. 2. Dendrogram for the classification of the monovarietal oils according to the wax content.

more waxes to control the rate of transpiration in order to reduce water loss (Bianchi, 1995). Considering that all olive oil samples were obtained by mean of physical process, the results obtained in wax ester content could be explained by a stronger response of Grossa di Gerace drupes to several environmental factors, typical of the Ionian Southern coast, that are heat, humidity and irradiance levels. The obtained results were similar to the waxes content of olive oils extracted in other hotter climates, demonstrating the effect of growing region (Mailer, Ayton, & Graham, 2010).

In recent years, an indicator for the assessment of extra virgin olive oil has been established for the alkyl esters content. The recent Regulation EC/1348/2013 attested for extra virgin olive oil a maximum content FAEE of 35 mg/kg for the 2014/2015 olive harvest. The results of alkyl esters quantification in monovarietal oils denoted a great significance among cultivars. Some Grossa di Gerace oils manifested amounts over the legal limit for extra virgin olive oil category: it is certainly due to the hot-humid climate in Ionic Southern Coast that has promoted parasitic attacks on olives with successive qualitative alteration in the extracted oil. Some oils exceeded the limit of 35 mg/kg also for the FAEE content (average of 25.72 ± 32.75). Moreover, an effect of different olive growing practices and processing is also notable, manifested by the high standard deviations for each variety. Concerning the antioxidant compounds, no significant differences resulted in total polyphenol content among cultivars ($P > 0.05$), with a range of the mean value for each cultivar comprised between 287 and 318 mg/kg. The total polyphenol contents of the studied olive oils were more abundant than the mean amounts of two monovarietal oils produced in Campania (Ortice and Ravece cv.) reported by Barbarisi et al. (2014), similar to Ogliarola oils (Servili, De Stefano, Poiacquadio, Di Giovacchino, & Sciancalepore, 1999), lower than Roggianella and Tonda Iblea oils (Galvano et al., 2007; Giuffrè et al., 2010).

The mean of tocopherol content in Ottobratica, Grossa di Gerace and Sinopolese olive oils ranged from 331 and 341 mg/kg without significant differences as denoted by post hoc test. Carolea oils possessed instead the lowest average of total tocopherols (215 mg/kg). The amounts of tocopherols in the studied oils produced in Calabria was higher than some Turkish and Spanish oils (Dag et al., 2015; García, Brenes, García, Romero, & Garrido, 2003) and some previously studied monovarietal and mixtures of oils produced in Calabria (Di Serio et al., 2016).

The main saturated fatty acid, the palmitic acid (C16:0), was present as mean from 14.6% to 14.9% without significant differences among cultivars ($P > 0.05$). The stearic acid (C18:0) ranged instead from 1.9% to 2.3% in Grossa di Gerace and in Carolea oils respectively. The major fatty acid in olive oil is the oleic acid, and in this research the lowest content was observed in Grossa di Gerace oils (mean of 66.1%) while the highest amount was in Sinopolese oils (mean of 74.4%). Among polyunsaturated fatty acids, the linoleic acid showed the highest content in Grossa di Gerace oils, because of a probable enzyme oleate desaturase activity (Katsoyannos, Chatzilazarou, Bratakos, Stamatopoulos, & Sinanoglou, 2015), and the lowest amounts were quantified in Carolea and Sinopolese oils. The olive oils of this last cultivar denoted also the biggest MUFA/PUFA and oleic/linoleic ratio, as observed in a previous paper (Poiana & Mincione, 2004), mainly confirming the fatty acid composition as a genotypic parameter. All the results of fatty acids analysis are in conformity to those defined by the more recent European Regulation (EUC, 2015) with the exception of numerous olive oil samples of Carolea (46%) which showed a level of heptadecenoic acid higher than 0.3%. The mean value of this fatty acid in the Carolea oils was 0.31% and probably it is related to a varietal characteristic. The low standard deviations in results of FAME composition denoted a prevailing genotypic effect.

The Carolea oils manifested a longer induction time (12.19 h), denoting a more prolonged opposition to oxidative reactions. The relationship between antioxidant contents and oxidative stability of oils was investigated by Pearson's correlation coefficient. Probably the lowest amount of tocopherols in Carolea oils, but the highest induction time could be due to a combine effect of o-diphenols and monounsaturated/polyunsaturated fatty acids ratio. Concerning the correlation between total phenols and induction time, the oils of Carolea expressed the lowest Pearson's coefficient ($r = 0.68$), whereas higher correlations were observed in the other cultivars: $r = 0.74$ in Ottobratica, $r = 0.82$ in Grossa di Gerace and $r = 0.87$ in Sinopolese. Considering the contribution of fatty acid composition to the oxidative stability of olive oils, the negative and low correlation between MUFA/PUFA and induction time observed in Sinopolese olive oils ($r = 0.39$) confirmed a stronger contribution of polyphenols to the oxidative stability. Grossa di Gerace oils manifested instead the highest positive correlation ($r = 0.71$). Their lowest mean induction time was so influenced by the polyunsaturated fatty acid percentage, as even denoted by the Pearson's coefficient between linoleic acid and induction time ($r = -0.61$).

The percentage of several single sterols varied among varieties with significance ($p < 0.05$), as denoted by post hoc test (Table 2). The sterolic composition of oils varies as function of the variability of gene expression in relation to climatic variables (Abu-Reidah et al., 2013).

The Grossa di Gerace oils had the highest amount (1906 mg/kg): it seems to be due to the hottest growing region, as also confirmed by Mailer et al. (2010). Carolea oils possessed the total lowest content (1746 mg/kg). The major sterol present in olive oil, the β-Sitosterol, was detected in high amount in Sinopolese and Ottobratica (95.97% and 95.85% respectively).

3.2. Effect of production area on quality of Carolea olive oils

Respect to other cultivars, Carolea is widely diffused in Calabria. To study the effect of the different growing sites on chemical parameters of Carolea olive oils, the results of qualitative indexes were reported separately for the different areas of Calabria. High significance was observed in the several reported chemical parameters, showing large differences among samples (Table 3). The free acidity seemed to be influenced by the environmental and the olive grow management or processing. The lowest free acidity value was observed in oils produced in TSA while most of the oils produced in the opposite area (ISC) were classified in the virgin olive oil category. The effect of the environment on total acidity content was confirmed by a cluster analysis (results not illustrated). Both Carolea and Grossa di Gerace oils produced in ISC are grouped and differentiated from the other olive oil samples. Also different agronomic and processing practices influenced the quality of Carolea oils produced in the same area, as denoted by high standard deviations of all free acidity mean values. Concerning the wax content, a significant variability was observed among Carolea oils sampled in the areas of Calabria and the different resistance of Carolea

Table 2
Sterol composition of the monovarietal olive oils produced in Calabria (Southern Italy).

	Carolea	Ottobratica	Grossa di Gerace	Sinopolese	Sign.
Cholesterol	0.09 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	n.s.
Campesterol	2.34 ± 0.49^{b}	2.35 ± 0.50^{b}	2.72 ± 0.30^{a}	2.27 ± 0.68^{b}	**
Campestanol	0.15 ± 0.01^{ab}	0.15 ± 0.01^{ab}	0.14 ± 0.02^{b}	0.16 ± 0.01^{a}	*
Stigmasterol	0.89 ± 0.27	0.85 ± 0.20	0.95 ± 0.30	0.82 ± 0.23	n.s.
Clerosterol	0.88 ± 0.08	0.86 ± 0.08	0.84 ± 0.03	0.86 ± 0.07	n.s.
Δ-5-Avenasterol	5.99 ± 1.78^{a}	5.43 ± 0.54^{ab}	4.79 ± 0.77^{b}	5.38 ± 0.42^{ab}	**
Δ-5.24-Stigmastadienol	0.85 ± 0.08^{ab}	0.86 ± 0.08^{a}	0.80 ± 0.06^{b}	0.86 ± 0.07^{a}	**
Δ-5-Stigmastenol	0.17 ± 0.05	0.18 ± 0.08	0.17 ± 0.05	0.16 ± 0.05	n.s.
Δ-7-Avenasterol	0.45 ± 0.07^{a}	0.43 ± 0.04^{ab}	0.39 ± 0.04^{b}	0.43 ± 0.03^{ab}	**
β-sitosterol	95.80 ± 0.62^{ab}	95.85 ± 0.66^{a}	95.43 ± 0.24^{b}	95.97 ± 0.87^{a}	**
Total (mg/kg)	1746 ± 220^{b}	1808 ± 180^{ab}	1906 ± 157^{a}	1779 ± 114^{ab}	**

Results are expressed as mean ± SD;∗;∗∗; n.s; a.b.c see Table 1.

Table 3
Chemical and qualitative parameters of Carolea olive oils produced different areas of Calabria: SP (Sibari's Plateau). VSE (Valley of Sant'Eufemia). TSA (Tyrrhenian Southern area). ISC (Ionian Southern coast). IAC (Ionian Area of Catanzaro).

	SP	VSE	TSA	ISC	IAC	Sign.
Free acidity (%)	0.42 ± 0.21^{b}	0.43 ± 0.40^{b}	0.17 ± 0.10^{c}	0.72 ± 0.38^{a}	0.39 ± 0.28^{b}	**
Peroxide value (mEqO_2/kg)	7.91 ± 3.85^{a}	8.24 ± 1.74^{a}	5.47 ± 1.93^{b}	6.47 ± 2.95^{ab}	4.77 ± 3.71^{b}	**
K_{232}	1.88 ± 0.12^{a}	1.85 ± 0.10^{abc}	1.75 ± 0.12^{bc}	1.85 ± 0.11^{ab}	1.73 ± 0.24^{c}	**
K_{270}	0.11 ± 0.02^{a}	0.12 ± 0.01^{a}	0.09 ± 0.02^{b}	0.12 ± 0.01^{a}	0.11 ± 0.01^{a}	**
Wax esters(mg/kg)	51.00 ± 23.00^{b}	66.00 ± 16.00^{a}	60.00 ± 26.00^{ab}	68.00 ± 20.00^{a}	50.00 ± 19.00^{b}	**
Σ FAME (mg/kg)	8.52 ± 5.80^{b}	11.89 ± 22.08^{b}	12.81 ± 14.31^{b}	32.05 ± 24.52^{a}	11.69 ± 11.14^{b}	**
Σ FAEE (mg/kg)	8.92 ± 7.50	9.10 ± 13.69	2.49 ± 2.46	14.06 ± 14.77	9.61 ± 14.66	n.s.
Σ FAME + FAEE(mg/kg)	17 ± 12.00^{b}	21 ± 36.00^{b}	15.00 ± 15.00^{b}	46.00 ± 38.00^{a}	21.00 ± 25.00^{b}	**
Total Polyphenols (mg/kg)	322.35 ± 48.18^{bc}	275.89 ± 42.02^{c}	201.56 ± 35.43^{d}	412.03 ± 106.80^{a}	344.87 ± 61.68^{b}	**
Total Tocopherols (mg/kg)	231.51 ± 44.99^{a}	201.93 ± 33.11^{b}	199.26 ± 18.66^{b}	227.54 ± 39.03^{ab}	212.12 ± 39.62^{ab}	**
Induction Time (h)	13.44 ± 3.97^{a}	10.69 ± 2.02^{bc}	9.18 ± 1.10^{c}	12.61 ± 3.31^{ab}	14.53 ± 4.14^{a}	**
β-sitosterol (%)	95.79 ± 0.44^{c}	95.95 ± 0.45^{ab}	96.24 ± 0.71^{a}	95.24 ± 0.65^{c}	95.95 ± 0.52^{ab}	**
Total sterols (mg/kg)	1774.82 ± 233.98^{a}	1745.66 ± 207.27^{a}	1585.35 ± 315.89^{b}	1795.73 ± 224.38^{a}	1738.05 ± 147.06^{a}	*

Results are expressed as mean ± SD;∗;∗∗; n.s; a.b.c see Table 1.

clones to the biotic and abiotic stresses can explain it. As also observed in Grossa di Gerace olive oils, some Carolea oils obtained in the same area possessed a high alkyl esters content, upper the European limits for the extra virgin olive oils (EUC, 2013). This unfavourable event appeared correlated to the olive grove management. The fatty acids composition of Carolea oils was significantly different ($p < 0.05$) among growing areas (Table 4). It is interesting to observe the lower content of oleic acid in ISC area as it was observed for another cultivar (Grossa di Gerace), so a strong environmental effect could be supposed. These results are also linked to the variability observed in total antioxidant content (total polyphenols and total tocopherols values), that is correlated to the oxidative stability. The influence of growing condition and environmental was manifested by the significance in results of most of sterols. The β-sitosterol was in particular more abundant in Carolea oils produced at the Tyrrhenian southern area, whereas oils of the other varieties produced in the same area had the lowest total content of sterols (1585 mg/kg). The olive oils sampled in the other areas of Calabria region ranged from 1738 to 1796 mg/kg for this qualitative parameter.

4. Conclusions

The qualitative investigation on olive oils produced in Calabria region denoted some peculiar characteristics. The expanded growing of Carolea olive cultivar in the Calabria region involved the production of oils with different characteristics, due to the microclimate influences. Most of Carolea oils denoted a content of heptadecenoic acid upper the limit of 0.3% and this seems to

Table 4
Fatty acid composition of Carolea olive oils produced in different areas of Calabria: SP (Sibari's Plateau). VSE (Valley of Sant'Eufemia). TSA (Tyrrhenian Southern area). ISC (Ionian Southern coast). IAC (Ionian Area of Catanzaro).

	SP	VSE	TSA	ISC	IAC	Sign.
C16:0 (%)	14.16 ± 0.78^{bc}	14.63 ± 0.52^{b}	14.06 ± 0.57^{bc}	16.03 ± 1.36^{a}	13.72 ± 0.96^{c}	**
C16:1 (%)	1.46 ± 0.20^{bc}	1.50 ± 0.23^{b}	1.28 ± 0.29^{c}	1.82 ± 0.34^{a}	1.34 ± 0.27^{bc}	**
C17:0 (%)	0.14 ± 0.03^{c}	0.17 ± 0.04^{ab}	0.17 ± 0.03^{a}	0.15 ± 0.03^{bc}	0.16 ± 0.03^{abc}	**
C17:1 (%)	0.29 ± 0.06^{ab}	0.33 ± 0.08^{a}	0.33 ± 0.06^{a}	0.27 ± 0.05^{b}	0.32 ± 0.07^{ab}	**
C18:0 (%)	2.16 ± 0.37^{b}	2.40 ± 0.34^{a}	2.34 ± 0.36^{ab}	2.38 ± 0.25^{a}	2.37 ± 0.21^{a}	*
C18:1 (%)	74.24 ± 1.85^{ab}	72.97 ± 1.49^{b}	73.99 ± 1.80^{ab}	69.57 ± 3.08^{c}	74.88 ± 2.51^{a}	**
C18:2 (%)	6.35 ± 1.15^{b}	6.67 ± 1.13^{b}	6.46 ± 0.49^{b}	8.70 ± 1.59^{a}	6.00 ± 1.68^{b}	**
C20:0 (%)	0.36 ± 0.06^{b}	0.41 ± 0.10^{a}	0.43 ± 0.06^{a}	0.35 ± 0.04^{b}	0.38 ± 0.06^{ab}	**
C18:3 (%)	0.42 ± 0.08^{ab}	0.44 ± 0.12^{ab}	0.46 ± 0.09^{a}	0.39 ± 0.07^{b}	0.40 ± 0.08^{ab}	*
C20:1 (%)	0.24 ± 0.04^{b}	0.27 ± 0.05^{ab}	0.27 ± 0.04^{a}	0.21 ± 0.03^{c}	0.25 ± 0.04^{ab}	**
C22:0 (%)	0.10 ± 0.02^{bc}	0.12 ± 0.03^{a}	0.12 ± 0.02^{a}	0.08 ± 0.01^{c}	0.11 ± 0.02^{ab}	**
C24:0 (%)	0.06 ± 0.02^{bc}	0.07 ± 0.02^{a}	0.07 ± 0.01^{a}	0.05 ± 0.01^{c}	0.06 ± 0.02^{ab}	**

Results are expressed as mean ± SD;∗;∗∗; n.s; a.b.c see Table 1.

be a genotypic characteristic. The hot-humid climate of Ionian southern coast could often reduce the quality of olives and produced oil, as demonstrated by analytical results on Grossa di Gerace and Carolea. So, suitable agronomical and plant protect practices need to be applied particularly in that area. Finally, Sinopolese oils denoted good qualitative parameters, as FAME composition, oleic/linoleic ratio, and sterol content but sometimes they showed high peroxide value, which could seem a varietal and gestional-dependent parameter. In general, olive oils in Calabria region possessed an amount of antioxidant compounds in the average of 300 mg/kg for polyphenols and 260 mg/kg for tocopherols

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