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Characterisation of virgin olive oil of Italian olive cultivars: 'Frantoio' and 'Leccino', grown in Andalusia

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Abstract

Work was carried out on the characterisation of virgin olive oils from the main Italian cultivars, 'Frantoio' and 'Leccino', grown in two different locations in Andalusia: Mengibar (Jaén) and Cabra (Córdoba), with important differences in altitude. The study was carried out during the crop years 1999/2000 and 2001/2002. There were significant differences between the oils from both cultivars when grown in the different environments, Cabra close to the hills and Mengibar in the open at 280 m height. At higher altitude, the oils showed a greater content of oleic acid and higher stability, while in the open the oils had higher tocopherol and linoleic acid contents. For the phenolic compounds, the environment influenced each cultivar in different ways. Sensorial characteristics, showed significant differences between the oils from each cultivar and location. In general, the oils from Andalusia had higher levels of natural antioxidants, greater oxidative stability and more marked sensorial characters.

Keywords: Virgin olive oil; Italian cultivar; Fatty acids; Tocopherols; Polyphenols; Oxidative stability; Sensorial characteristics

1. Introduction

The olive tree (*Olea europaea L.*) is one of the most important crops in Mediterranean countries, especially Spain, Italy and Greece. Virgin olive oil, due to its use without refining, shows very interesting nutritional and sensorial properties, being one of the pillars of the called Mediterranean diet. Its fatty acid composition, monounsaturated, and its natural antioxidants provide advantages for health (Martínez de Victoria & Mañas, 2001; Visioli & Galli, 1994, 1998).

In Andalusia, the first olive oil production zone in Spain, there are two main olive cultivars: 'Picual' and 'Hojiblanca'. These olive varieties have increased their growing areas while others, named secondary cultivars: 'Picudo', Carrasqueño de Alcaudete' 'Lechin de Granada', 'Nevadillo azul' and others, are losing their traditional locations. Because of this trend, in some parts of Andalusia, such as Jaén and Córdoba, olive growing has become monovarietal, secondary cultivars being removed. When only one cultivar is grown it shows some disadvantages, such as susceptibility to insects and diseases and due to the fact that the fruit ripens within a short time, it has to be harvested quickly. This produces some industrial problems: oversized oil mills and the need of a large workforce.

The use of different cultivars, Spanish or from other countries, could be interesting, based on their agronomical as well as their oil composition and sensorial profile. However, before using new cultivars, their behaviour in different environments must be evaluated. There are some experimental olive yields where interesting cultivars are evaluated beside the traditional and most important olive varieties of each zone. In

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Andalusia two different yields have been designed in the most representative olive growing areas: Mengibar in Jaén and Cabra in Córdoba. Among the foreign olive cultivars there are two of the most important Italian cultivars: 'Frantoio' and 'Leccino'. 'Frantoio' is located in Tuscany and represents around of 48% of the growing area while 'Leccino' represent 16% (Piscolla & Zoppi, 2001). 'Frantoio' shows a high and constant productivity and adaptation capacity to different agronomical conditions; although cold-sensitive; its organoleptic characteristics and oxidative stability are very appreciated. 'Leccino' is cold tolerant with an early start and high yield, since a low resistance to fruit drop has been described, as well as tolerance against different plant diseases (Barranco, Cimato, Fiorino, Rallo, Touzani, Castañeda, Serafini & Trujillo, 2000).

The aim of this work is to describe the composition and organoleptic characteristics of virgin olive oils from 'Frantoio' and 'Leccino' cultivars grown in two characteristic and representative olive growing areas in Andalusia: Jaén and Córdoba.

2. Material and methods

2.1. Plant material and growing areas selected

Twelve olive (*O. europaea L.*) trees of each cultivar, 'Frantoio' and 'Leccino', were disposed at random in the yield. The one-trunk trees, 16 years old, were grown at 7×7 m distance in the experimental farm of the Estación de Olivicultura y Elaiotecnia in Mengibar (Jaén, Spain), located at 280 m above sea level and CIFA de Cabra in Cabra (Córdoba, Spain) at 440 m, close to the Penibetico mountains. The trees were selected on the basis of volume and canopy criteria.

2.2. Fruit sampling

The study was carried out on the 1999/2000 and 2001/2002 crop years. For each crop year yielding samples, trees of each cultivar were divided into two blocks, each of 6 trees. From all olive trees of each block, a representative 5 kg sample was collected. The samples were harvested when the most abundant ripening stage in the tree was 3, according to the fruit classification based on skin and flesh colour described in the ripening index method (Uceda & Frias, 1975).

2.3. Oil extraction

Oil extraction was performed using an Abencor laboratory oil mill (Abengoa, Seville), kneading the olive paste at 28 °C for 30 min. The oil was filtered and stored at −24 °C prior to analysis.

2.4. Oil analysis

Fatty acid methyl ester (FAME's) composition was determined according the EU Regulation 2568/91 (European Union Commission, 1991). The chromatographic separation was performed a Perkin–Elmer Autosystem gas chromatograph with a split/splittless injector and a FID detector, equipped with a BPX 70 capillary column of 50 m of length, 0.22 mm i.d. and 0.25 μm film thickness (SGE, Australia). The oven temperature was held at 198 °C and helium was used as carrier gas. The results were expressed as peak area (relative) percent. Polyphenol content was analysed as described by Vazquez Roncero, Janer del Valle, & Janer del Valle (1973) using the Folin–Ciocalteau reagent and absorbance measurement at 726 nm, the results were expressed as mg/kg of caffeic acid. Tocopherol composition was analysed by HPLC, applying the IUPAC method 2432 (1992). Detection and quantification were carried out in a Perkin–Elmer HPLC equipped with a isocratic pump Lc 200 and a UV–Vis detector, Lc295, set at 295 nm, the tocopherol concentration was expressed as milligrammes per kilogramme of oil. Bitterness index (K_{225}) was determined by solid phase extraction and absorbance measurement at 225 nm (Gutiérrez Rosales, Perdiguero, Gutiérrez, & Olías, 1992). Oxidative stability was measured as the induction time in the Rancimat equipment (Metrohm, Basel, Switzerland) at 98 °C and an air flow of 10–12 l/h (Gutiérrez, 1989), the measurements were determined in duplicate for each sample and the results given as induction time (h).

2.5. Sensorial analysis

Sensorial evaluation of the oils was performed according to the Panel test method (European Union Commission, 1991) by the analytical Panel Test of the Estación de Olivicultura y Elaiotecnia of Mengibar (Jaén, Spain), using nine trained tasters. The 'triangle test' was applied during the second crop year, for each olive cultivar, in order to evaluate the differences between oils from different environments. Three samples were presented simultaneously to the panellists, two from the same oil sample and one from a different sample. Each panellist had to indicate which sample was the odd sample.

2.6. Statistical analysis

Analysis of variance (ANOVA) was applied to study the effect of the environments on the oil characteristics of both cultivars. Tukey's test was used to establish differences between means.

Table 1
Fatty acid composition of virgin olive oils from cultivars 'Frantoio' and 'Leccino' grown in Mengibar (Jaén) and Cabra (Córdoba)

	'Frantoio'		'Leccino'	
	Cabra	Mengíbar	Cabra	Mengíbar
C16:0[a]	10.9 ± 0.34[b]	14.5 ± 1.37	12,6 ± 1.22	15.0 ± 0.86
C16:1	0.89 ± 0.01	1.12 ± 0.17	1.08 ± 0.10	1.24 ± 0.09
C17:0	0.07 ± 0.04	0.03 ± 0.01	0.04 ± 0.03	0.04 ± 0.01
C17:1	0.13 ± 0.05	0.10 ± 0.05	0.11 ± 0.06	0.08 ± 0.04
C18:0	1.53 ± 0.14	1.66 ± 0.20	1.80 ± 0.06	1.61 ± 0.08
C18:1	78.3 ± 0.33	70.9 ± 0.66	77.8 ± 1.42	74.1 ± 0.72
C18:2	6.79 ± 0.45	10.43 ± 1.02	5.30 ± 0.36	6.73 ± 0.33
C18:3	0.49 ± 0.03	0.54 ± 0.02	0.52 ± 0.03	0.52 ± 0.07
C20.0	0.33 ± 0.04	0.32 ± 0.02	0.33 ± 0.02	0.28 ± 0.01
C20:1	0.27 ± 0.02	0.27 ± 0.02	0.26 ± 0.03	0.24 ± 0.02
C22:0	0.18 ± 0.09	0.10 ± 0.02	0.10 ± 0.01	0.08 ± 0.01
$\sum$ SFAs	13.1 ± 0.09	17.1 ± 1.42	15.0 ± 1.21	17.6 ± 0.44
$\sum$ PUFAs	7.28 ± 0.42	10.5 ± 1.05	5.81 ± 0.39	7.12 ± 0.35
$\sum$ MUFAs	79.6 ± 0.34	72.5 ± 0.94	79.3 ± 1.55	75.3 ± 0.19
Oleic/linoleic	11.6 ± 0.80	7.20 ± 0.72	14.8 ± 1.26	11.2 ± 0.43
MUFAs/PUFAs	11.0 ± 0.68	6.97 ± 0.67	13.7 ± 1.18	10.6 ± 0.51

[a] C16:0 palmitic, C16:1 palmitoleic, C17:0 margaric, C17:1 margaroleic, C18:0 stearic, C18:1 oleic, C18:2 linoleic, C18:3 linolenic, C20:0 arachidic, C20:1 gadoleic, C22:0 behenic, SFAs saturated fatty acids, PUFAs polyunsaturated fatty acids, MUFAs monounsaturated fatty acids.
[b] Mean ± SD ($n = 4$).

3. Results and discussion

The mean FAME composition of the oils of both cultivars, from each location,is shown in Table 1. Palmitic acid, the major saturated fatty acid in olive oil, has mean values 12.9% and 14.1% for 'Frantoio' and 'Leccino', respectively. These results are similar to those described for these cultivars (Cimato, Modi, Mattei, Niccolai, & Alessandri, 1991; Uceda & Hermoso, 2001). Respect the effect of the environment, could be observed a higher content in the oils obtained at low altitude (Mengibar) for both cultivars, with significant differences ($p < 0.01$). Another important saturated acid is stearic acid; its content is within the range 1.36–1.93% for 'Frantoio' and 1.50–1.86% for 'Leccino' oils. The behaviour of this fatty acid does not present a general trend and differences have not been found between the mean values observed for each growing location. In general, saturated fatty acids were found at greater concentrations in Mengibar, as described previously for oils from lower altitudes (Osman, Metzidakis, Gerasopoulos, & Kiritsakis, 1994; Cimato et al., 1991; Uceda & Hermoso, 2001).

The monounsaturated fatty acids have great importance because of their nutritional implication and effect on oxidative stability of oils (Aguilera, Ramirez-Tortosa, Mesa, & Gil, 2000; Aparicio, Roda, Albi, & Gutiérrez, 1999; Beltrán, 2000; Gutiérrez, Jiménez, Ruiz, & Albi, 1999; Martínez de Victoria & Mañas, 2001). The olive cultivars studied showed similar mean values for oleic acid, 'Leccino' the highest value 75.6% and 'Frantoio' 75.1%. When the oils from the different locations are compared there is a trend showing greater oleic content for Cabra oils, and significant differences for both cultivars. The linoleic acid is at higher in 'Frantoio' oils, as described previously (Cimato et al., 1991; Uceda & Hermoso, 2001), there being greater levels for both cultivars in the Mengibar oils. Linolenic acid, which presents the highest level of unsaturation of olive oil, shows similar contents for the cultivars analysed, although there is a slight difference for 'Frantoio', that presents higher content when the oils are from Mengibar. The ratio MUFAs/PUFAs, for both cultivars, was higher in the oils from Cabra. The differences observed between locations for the fatty acid composition may be explained by the different altitudes of the locations. This agrees with the results described by other authors for oils from olives growing at different altitudes (Cimato et al., 1991; Mousa, Gerasopoulos, Metzidakis, & Kiritsakis, 1996; Uceda & Hermoso, 2001).

Among the natural antioxidants present in virgin olive oil, tocopherols stand out because of their antioxidant activity and important nutritional activity. The oils from 'Leccino' cultivar have higher total tocopherol content (314 mg/kg) than 'Frantoio' (181 mg/kg), reaching a higher content, for both cultivars, in the oils from olive trees grown in Mengibar (Table 2); these results agree with those described for the oil from regions of low altitude (Mousa et al., 1996). In virgin olive oil three different tocopherols have been described: α-tocopherol, β-tocopherol and γ-tocopherol; the contents of these antioxidants are shown in Table 2. α-Tocopherol represents around the 95% of the total; the level of γ-tocopherol is higher for the 'Leccino' oils, reaching significant differences ($p < 0.01$) when they are from different locations. β-Tocopherol showed to differences between cultivars on locations.

Table 2
Mean values of antioxidant content (phenols and tocopherols), bitterness index and oxidative stability of virgin oils of 'Frantoio' and 'Leccino' cultivars from two locations in Andalusia, Mengibar (Jaén) and Cabra (Córdoba)

	'Frantoio'		'Leccino'	
	Cabra	Mengibar	Cabra	Mengibar
Total phenols (mg/kg)	726 ± 180[a]	635 ± 258	472 ± 104	718 ± 268
Bitterness K_{225}	0.41 ± 0.11	0.37 ± 0.10	0.38 ± 0.07	0.43 ± 0.10
Oxidative stability (h)	96.5 ± 12.8	87.7 ± 14.8	55.2 ± 11.4	82.3 ± 14.3
Total tocopherols (mg/kg)	151 ± 22.3	286 ± 20.1	205.5 ± 51	334 ± 46.7
α-Tocopherol (mg/kg)	148 ± 21.7	162 ± 15.6	275 ± 19.9	306 ± 47.9
β-Tocopherol (mg/kg)	2 ± 0.0	1.67 ± 0.58	2.75 ± 0.43	2 ± 0.70
γ-Tocopherol (mg/kg)	0.75 ± 0.83	1.67 ± 0.58	8 ± 0.71	12.3 ± 2.90

[a] Mean ± SD ($n = 4$).

Other natural antioxidants that can be found in the virgin olive oils are the polyphenols, they are important antioxidants that protect the oil against autoxidation, at cellular level, against oxygen radicals. For these compounds, 'Frantoio' cultivar shows the higher level (Table 2); the effect of the agronomical conditions on these compounds was clear observed because of the different behaviour for each cultivar, while 'Frantoio' has a higher polyphenol content in Cabra, 'Leccino' has in Mengibar, although in this case differences between means are not significant. Therefore, different response, to the environment conditions, were observed for each cultivar.

The bitterness index is related with the polyphenol content (Beltrán, Jiménez, Aguilera, & Uceda, 2000), showing a similar variation (Table 2). 'Leccino' oils present the highest bitterness although differences between locations were not found: 'Frantoio' achieves greater oil bitterness in Cabra without differences between locations.

The oxidative stability of the virgin olive oil was measured with the Rancimat equipment; of the two olive cultivars analysed, the most stable was 'Leccino' (Table 2) with a mean value of 84.47 h. The influence of the environmental conditions was greater for 'Frantoio' which shows significant differences between them, more stable oils being obtained in Cabra. The values of oil oxidative stability for both cultivars are similar to those described in the literature (Cimato et al., 1991; Uceda & Hermoso, 2001). The differences observed in the oils from different locations can be explained better than their antioxidant contents, because the oils from Cabra present higher levels of oleic acid and lower of linoleic. The relationship between these fatty acids, or the ratio between monounsaturated and polyunsaturated, have been described as the main responsible factors for of the oxidative stability of virgin olive oils (Aparicio et al., 1999; Beltrán, 2000; Gutiérrez et al., 1999).

Both 'Frantoio' and 'Leccino', grown in the two different locations, gave extra virgin olive oils but their

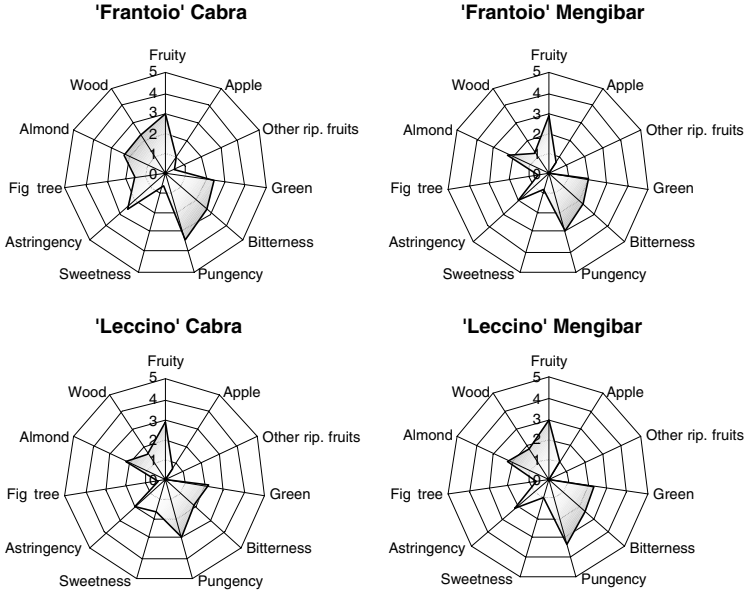

Fig. 1. Sensorial wheels of virgin olive oils for the Italian olive cultivars, 'Frantoio' and 'Leccino', for both locations in Andalusia, Cabra (Córdoba) and Mengibar (Jaén).

sensorial profiles showed some slight differences, (Fig. 1). 'Leccino' oils from Cabra and Mengibar are similar: Fruity, with a soft touch of apple, without other ripening fruits, with attributes such as green, bitterness, pungency, astringency and almond (marked) and slightly sweet. This profile is common for both locations although the Mengibar oils show higher intensities. However, in Cabra, 'Frantoio' oils showed two different attributes: 'Wood' and 'fig tree', typical of oils with higher phenolic content. The description may be considered similar for the remaining sensorial attributes of 'Frantoio' oils. The 'triangle test' was applied to evaluate differences between oils from different locations; for the second crop year there were significant differences between the oils for both cultivars from Mengibar and Cabra ($p < 0.05$).

4. Conclusion

The Italian cultivars analysed, when grown in Andalusia, produced oils with some differences from those obtained in their traditional Italian growing areas. The fatty acid composition differed, at least for the main fatty acids, depending of the growing location. There was an increase of saturated and polyunsaturated fatty acids, and natural antioxidants at lower altitudes but, in general, the levels of natural antioxidants were higher in the oils from Andalusia. The sensorial characteristics were influenced by the environmental conditions and the oils showed higher intensities of bitterness, pungency and astringency than those described for the oils from Italy, although differences were found between the oils obtained from both Andalusian locations assayed.

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References

Aguilera, M. C., Ramirez-Tortosa, M. C., Mesa, M. D., & Gil, A. (2000). Do MUFA and PUFA have benefitial effects on development of cardiovascular disease?. In S. G. Pandai (Ed.), *Recent research developments in lipids (Advances in Lipid Research*) (pp. 369–390). Trivandrum (India): Transworld Research Network.

Aparicio, R., Roda, L., Albi, M. A., & Gutiérrez, F. (1999). Effect of various compounds on virgin olive oil stability measured by Rancimat. *Journal of the Agricultural and Food Chemistry, 47*, 4150–4155.

Barranco, D., Cimato, A., Fiorino, P., Rallo, L., Touzani, A., Castañeda, C., Serafini, F., & Trujillo, I. (2000). *Catalogo mundial de variedades del olivo*. Madrid: Consejo Oleicola Internacional.

Beltrán, G. (2000). Influencia del proceso de maduración del fruto de *Olea europaea L* sobre las características fisico-químicas de los aceites. PhD thesis, Facultad de CC, Experimentales, Universidad de Jaén.

Beltrán, G., Jiménez, A., Aguilera, M. P., & Uceda, M. (2000). Análisis mediante HPLC de la fracción fenólica del aceite de oliva virgen de la variedad Arbequina. Relación con la medida del amargor K225 y la estabilidad. *Grasas y Aceites, 51*, 320–324.

Cimato, A., Modi, G., Mattei, A., Niccolai, M., & Alessandri, S. (1991). La caratterizzazione de'll olio 'tipico toscano'. II Anno di ricerca. Florencia, CROEVOTT.

European Union Commission. (1991). Regulation EEC 2568/91 on the characteristics of olive oil and olive pomace and their analytical methods. *Official Journal of European Communities* L248.

Gutiérrez Rosales, F., Perdiguero, S., Gutiérrez, R., & Olías, J. M. (1992). Evaluation of bitter taste in virgin olive oil. *Journal of American Oil Chemists' Society, 69*, 394–395.

Gutiérrez, F. (1989). Determinación de la estabilidad oxidativa de aceites de oliva vírgenes: Comparación entre el Método del Oxigeno Activo (AOM) y el método Rancimat. *Grasas y Aceites, 40*, 1–5.

Gutiérrez, F., Jiménez, B., Ruiz, A., & Albi, M. A. (1999). Effect of olive ripeness on the oxidative stability of virgin olive oil extracted from the varieties Picual and Hojiblanca and on the different components involved. *Journal of the Agricultural and Food Chemistry, 47*, 121–127.

IUPAC. (1992). Determination of tocopherols and tocotrienols in vegetable fats by HPLC. Method No. 2432. *Standard methods of analyses of oils, fats and derivatives* Oxford: Blackwell.

Martínez de Victoria, E., & Mañas, M. (2001). El aceite de oliva en la dieta y salud humanas. In D. Barranco, R. Fernández-Escobar, & L. Rallo (Eds.), *El cultivo del olivo* (pp. 663–684). Madrid: MundiPrensa.

Mousa, Y. M., Gerasopoulos, D., Metzidakis, I., & Kiritsakis, A. (1996). Effect of altitude on fruit and oil quality characteristics of mastoids olives. *Journal of the Science of Food and Agriculture, 71*, 345–349.

Osman, M., Metzidakis, I., Gerasopoulos, D., & Kiritsakis, A. (1994). Qualitative changes in olive oil collected from trees grown at two altitudes. *Rivista italiana de'lla Sostanze Grasse, 71*, 187–194.

Piscolla, G., & Zoppi, L. (2001). *The olive tree in Tuscany*. Florencia: Agenzia di Promozione Economique de'lla Toscana.

Uceda, M., & Frías, L. (1975). Harvest dates. Evolution of the fruit oil content, oil composition and oil quality. In: *Proceedings del Segundo Seminario Oleicola Internacional* (pp. 125–128). Córdobe: COI.

Uceda, M., & Hermoso, M. (2001). La calidad del aceite de oliva. In D. Barranco, R. Fernández-Escobar, & L. Rallo (Eds.), *El cultivo del olivo* (pp. 589–614). Madrid: MundiPrensa.

Vazquez Roncero, A., Janer del Valle, C., & Janer del Valle, M. L. (1973). Determinación de polifenoles totales del aceite de oliva. *Grasas y Aceites, 24*, 350–357.

Visioli, F., & Galli, C. (1994). Oleuropein protects low density lipoproteins from oxidation. *Life Science, 55*, 1965–1971.

Visioli, F., & Galli, C. (1998). The effect of minor constituents of olive oil on cardiovascular disease: New findings. *Nutrition reviews, 56*, 142–147.