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LETTER TO THE EDITOR

# A 3-year Study on Quality, Nutritional and Organoleptic Evaluation of Organic and Conventional Extra-Virgin Olive Oils

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**Abstract** The quality of extra-virgin olive oils (EVOO) from organic and conventional farming was investigated in this 3-year (2001–2003) study. The oils were extracted from Leccino and Frantoio olive (*Olea europaea*) cultivars, grown in the same geographical area under either organic or conventional methods. Extra-virgin olive oils (EVOO) were produced with the same technology and samples were analyzed for nutritional and quality parameters. Volatile compounds were measured with solid-phase microextraction combined with gas chromatography and mass spectrometry (SPME–GC–MS). Sensory evaluation was also completed by a trained panel. Significant differences were found in these parameters between organic and conventional oils in some years, but no consistent trends across the 3 years were found. The acidity of organic Leccino oils was higher than conventional oils in 2001 and 2002 but not in 2003; Frantoio oils were never different. Organic Leccino oils had higher peroxide index than conventional oils in 2001 and 2002 but it was the reverse in 2003. Organic Frantoio oils had lower peroxide index in 2001, but values were not statistically different in the other years. The concentrations of phenols, *o*-diphenols, tocopherols, the antioxidant capacity and the volatile compounds showed differences in some years and no difference, or opposite differences, in others. Sensory analysis showed only slight differences in few aromatic notes. Our results showed that organic versus conventional cultivation did not affect consistently the quality of the high quality EVOO considered in this study, at least in the measured parameters. Genotype and year-to-year changes in climate, instead, had more marked effects.

**Keywords** Extra-virgin olive oil quality · Organic agriculture · Conventional agriculture · Phenols · Volatile compounds · Sensory analysis

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## Introduction

Extra virgin olive oil (EVOO) is one of the essential elements of the Mediterranean diet [1] and consumption of high quality EVOO is increasing worldwide. The oil quality can be defined on the base of the nutritional value, the organoleptic properties, the origin of the product, as in the case of protected designation of origin (PDO) oils, the absence of toxic contaminants and the agronomic practices, which may be organic, integrated or conventional. The role of the organic or conventional agronomic practices in oil quality is controversial in the scarce number of studies reported. Thus, the effects of agronomic practices in oil quality must be clarified.

In fruit species, other than olives, the higher quality of organic fruits compared to the conventional ones is often supported by chemical and sensory analyses. For instance, organic produce is often found to have a higher content of vitamin C and dry matter, while nitrate levels are usually lower [2–5]. Minerals are often more concentrated in organic produce [6], while protein content is often lower but of greater quality [7]. Better flavor is sometime found in organic than in conventional foods, but in other studies conventional products are preferred by sensory panelists [8]. This is due to the fact that the flavor and the related content of minor compounds depend on many genetic and environmental factors [9, 11].

In the case of olive oil, the molecular composition is the result of complex interactions between cultivars, fruit ripening, pedo-climatic conditions and orchard management [12–14]. Moreover, the storage conditions and the extractive technology cause further differences [15]. All of these parameters might potentially affect EVOO quality or can simply induce aromatic differences. Data from Gutierrez et al. [16] support the hypothesis that organic olive oils have better intrinsic qualities than conventional oils, as documented by lower acidity and peroxide index, higher rancimat induction time, concentrations of tocopherols, polyphenols, *o*-diphenols and oleic acid. However, this work was carried out during 1 year, with one olive cultivar only, and the results cannot be generalized. Thus the objective of this study was to evaluate the quality, organoleptic and nutritional properties of olive oils from two cultivars, grown under organic or conventional methods.

## Materials and Methods

### Plant Material

The study was carried out in two olive orchards, one cultivated with the organic method and one under conventional agriculture practices. Both orchards were located in the village of Cartoceto, in the Province of Pesaro–Urbino, The Marches Region, Italy. Orchard size was 5.6 ha for the organic and 8 ha for the conventional. The two orchards were 1,500 m apart, had similar sun exposure (i.e. South) and similar altitude (about 200 m asl). Both orchards were subdivided in two plots of similar extension, one planted with Leccino and the other with Frantoio olive cultivars. The climate of the area is sub-Mediterranean with average annual temperatures between 14 and 26 °C in July–August and a minimum of 3 °C in January–February. Annual rainfall varies from 750 to 950 mm, with most falling in spring. Agronomic practices and pest control as well as other characteristics of the plant material are reported in Table 1.

### *Oil Production*

Within each treatment, cultivar and year, olives were hand picked within 2 days. The cv. *Leccino* was harvested in the last week of October and the cv. *Frantoio* in the first week of November in all years. The fruit maturation index at harvest, for each treatment, cultivar and year, determined accounting to Gutierrez et al. [16] is reported in Table 1.

Between harvest and processing, the olives were kept for 24–48 h in 20 kg plastic bags. The olives were hammer-crushed, 20% of water was then added and the olives malaxated for 40 min at 27 °C. The oil was then separated with a three-way decanter (Rapanelli NOVOIL SI mod.250). Oil samples were collected directly from the production line which processed 300 kg olives at one time. To avoid contamination, the oils were sampled from the second stock of olives for each treatment. Three different samples were taken for each treatment and cultivar. Oils were filtered using a paper filter. Oil yields from the olive paste are reported in Table 1. Oil samples were kept in the dark at −20 °C until the analyses were performed.

### *Olive Oil Analysis*

Quality parameters including acidity, peroxide index and spectrophotometric data were assessed according to the European official methods [17]. The nutritional value of the oils was evaluated by measuring the following series of compounds and parameters. Phenols were extracted following the procedure of Montedoro et al. [18] and assayed with the Folin–Ciocalteu method according to Singleton et al. [19]. Total phenolic content was expressed as gallic acid equivalence. *o*-Diphenols were determined by the method of Arnow [20] using 3,4-dihydroxyphenylethanol as the standard. Secoiridoids, a category of phenolic compounds which are specific to *Olea europaea* [20], were analysed using an HPLC as reported [18, 21]. Tocopherols were analysed with HPLC as reported [21]. Volatile compounds were analysed using solid-phase microextraction (SPME) and a GC system connected to a mass spectrometer, as reported by Servili et al. [15].

Antioxidant capacity, which is a parameter of quality for EVOO linearly correlated to both phenolic concentration and Rancimat induction time [22], was assessed with the oxygen radical absorbance capacity (ORAC) method using a Fluostar Optima plate reader (PBI International, Milan) equipped with a temperature-controlled incubation chamber and an injection pump, as previously reported [23]. ORAC values were expressed as μmol Trolox Equivalents (TE) per gram of oil.

The sensory analysis was carried out in 2001 by the Official Panel Test of virgin olive oil of Perugia (Italy), consisting of eight trained panelists. Oil samples were presented to the panelists in amber-colored glasses at room

**Table 1** Agronomic practices and plant performance in the organic and conventional olive orchards

| Parameters | Organic | Conventional |
|---|---|---|
| Soil composition[a] | | |
| Sand (%) | 29.5 ± 3.2 | 29.4 ± 3.2 |
| Lime (%) | 43.5 ± 4.7 | 23.3 ± 2.4 |
| Clay (%) | 25.9 ± 2.8 | 47.3 ± 5.0 |
| Limestone (%) | 26.2 ± 2.9 | 29.2 ± 3.2 |
| Organic matter (%) | 1.47 ± 0.2 | 1.41 ± 0.2 |
| pH | 7.85 ± 0.25 | 8.7 ± 0.20 |
| P (ppm) absorbable | 9.5 ± 1.0 | 31.6 ± 3.4 |
| $K_2O$ (ppm) | 214.5 ± 21.4 | 391.6 ± 40.2 |
| Planting and management dates | Both cultivars were planted 1940. Organic fertilization began in 1999 | Both cultivars were planted in 1940. Conventional fertilization began in 1990 |
| Plant productivity (kg/ha)[a] | Leccino, 4,125 ± 510 | Leccino, 5,514 ± 316 |
| | Frantoio, 3494 ± 412 | Frantoio 4721 ± 406 |
| Olives showing pest attack (%)[a] | 10 ± 2 | 4 ± 1 |
| Distance among plants | 6 × 8 m | 6 × 8 m |
| Fertilization in the period 1999–2003 | Foliar Sprays Before bloom: | Chemical fertilizers |
| | 1 kg Joker Bio Borlanda[b] per 100 l of water (2.6 kg $ha^{-1}$ of N) | Every year in December: |
| | After fruit set: 1.5 kg Challenger Bio per 100 l of water (2.6 kg $ha^{-1}$ of N) | 400 kg $ha^{-1}$ ammonium sulphate (25% N) 100 kg $ha^{-1}$ triple super phosphate 200 kg $ha^{-1}$ potassium sulphate |
| | | Every other year in December (i.e. during the experiment only in 2002) 500 kg $ha^{-1}$ calcium cyanamide (20% N). |
| Irrigation | Not irrigated | Not irrigated |
| Pest control treatments: one in July and one in September | Sulfur (5.5 kg $ha^{-1}$) against black scale (*Saissetia oleae*) | White oil (300 g in 100 l of water) against black scale (*Saissetia oleae*) |
| | Copper oxychloride (9.2 kg $ha^{-1}$) against olive fruit fly (*Bactrocera Oleae*) | Dimethoate (150 g in 100 l of water) against olive fruit fly (*Bactrocera oleae*) |
| Ripening index | 2001: Leccino 2.2; Frantoio 2.5 | 2001:Leccino 2.7; Frantoio 2.5 |
| | 2002: Leccino 3.8; Frantoio 2.3 | 2002 Leccino 3.6; Frantoio 2.6 |
| | 2003: Leccino 4.5; Frantoio 3.3 | 2003: Leccino 4.0; Frantoio 3.6 |
| Oil yield (%) | 2001: Leccino 13.9; Frantoio 15.8 | 2001: Leccino 11.0; Frantoio 14.5 |
| | 2002: Leccino 14.2; Frantoio 16.8 | 2002: Leccino 14.0; Frantoio 15.3 |
| | 2003: Leccino 15.1; Frantoio 16.2 | 2003: Leccino 14.9; Frantoio 16.5 |

[a] Means ± SD in years: 2001–2003

[b] Ergofito Bio (Joker and Challenger Bio) is produced by I.S.L.A as a liquid solution-suspension of umic, crenic and fulvic acids with umic carbon, enzymes, peptides, amino acids, phytostimulators, microelements and growth factors. Once prepared, the solution was left to ferment for 3 days and then applied with an atomizer as a foliar fertilizer

temperature and in duplicate. The following descriptors were adopted: fruity, cut-grass, artichoke, hay, green apple, floral, tomato, almond and fatty. For each descriptor, the intensity level was graded, using a 10 cm line scale where the Panelist marked the intensity [24]. The results were then converted to a numerical score by measuring the position of the mark along the line. Averages among the panelists judgements were then calculated, as suggested by the International Olive Oil Council (http://www.intwrnationalolivoil.org/).

*Statistics*

Three organic and three conventional EVOO from each cultivar and year, for a total of 12 samples a year, were analyzed. Each parameter determination was repeated three times per sample and the three values averaged. Differences among means were evaluated by a priori one-way analysis of variance (ANOVA) using the Tukey's honest significant differences test (Statgraphics, version 6; Manugistics, Inc.: Rockville, MA, USA 1992).

**Table 2** Quality parameters of organic and conventional virgin olive oils from two cultivars during a 3-year period

| Parameters | | *Leccino* cv. | | | | *Frantoio* cv. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Organic | | Conventional | | Organic | | Conventional | |
| Acidity (% oleic acid) | 2001 | 0.39 | (0.09)a,e | 0.23 | (0.02)b | 0.33 | (0.1)a,d | 0.22 | (0.09)a,e |
| | 2002 | 0.31 | (0.02)a,e | 0.23 | (0.02)b | 0.23 | (0.07)a,c | 0.23 | (0.06)a,e |
| | 2003 | 0.26 | (0.02)a,f | 0.24 | (0.02)a | 0.32 | (0.03)a,d | 0.31 | (0.02)a,f |
| | Mean | 0.32 | (0.06)a | 0.23 | (0.005)b | 0.29 | (0.05)a | 0.25 | (0.05)a |
| K 232(1%, 1 cm) | 2001 | 1.787 | (0.106)a | 1.699 | (0.132)a | 1.973 | (0.122)a | 1.672 | (0.125)b |
| | 2002 | 1.366 | (0.141)a,c | 1.264 | (0.111)a | 1.736 | (0.121)a | 1.738 | (0.132)a |
| | 2003 | 1.578 | (0.133)a | 1.446 | (0.126)a | 1.538 | (0.112)a,c | 1.556 | (0.089)a |
| | Mean | 1.577 | (0.210)a | 1.469 | (0.218)a | 1.749 | (0.218)a | 1.655 | (0.092)a |
| K 270 (1%, 1 cm) | 2001 | 0.104 | (0.011)a | 0.132 | (0.021)a | 0.156 | (0.066)a | 0.111 | (0.031)a |
| | 2002 | 0.029 | (0.013)a,f | 0.035 | (0.006)a | 0.122 | (0.098)a | 0.119 | (0.067)a |
| | 2003 | 0.105 | (0.061)a | 0.070 | (0.035)a | 0.107 | (0.061)a | 0.125 | (0.044)a |
| | Mean | 0.079 | (0.043)a | 0.079 | (0.049)a | 0.128 | (0.025)a | 0.118 | (0.007)a |
| Peroxide index (meq $O_2$/kg) | 2001 | 8.8 | (0.6)a,f | 6.8 | (0.9)b,f | 9.8 | (0.3)a,f | 11.1 | (0.5)b,f |
| | 2002 | 6.0 | (0.4)a,f | 4.0 | (0.3)b,c | 5.4 | (0.4)a,c | 4.8 | (0.4)a,c |
| | 2003 | 2.8 | (0.3)a,f | 4.0 | (0.3)b,c | 4.8 | (0.3)a,c | 4.8 | (0.3)a,c |
| | Mean | 5.8 | (3.0)a | 4.9 | (1.6)a | 6.6 | (2.7)a | 6.9 | (3.6)a,c |

Note: Values are the means of three independent determinations; the standard deviation is reported in brackets. Within each cultivar, values in each row having different letters, i.e. a vs. b, are significantly different ($p < 0.01$). In each column, the statistically significant differences of a parameter, measured throughout the 3 years, are indicated as follows: c, significantly different versus the 2001; d, significantly different versus the 2002; e, significantly different versus the 2003; f, significantly different versus the other two years ($p < 0.01$)

## Results and Discussion

The values of the quality parameters of organic and conventional oils in the 3-year study are presented in Table 2. The results are well within the EU standards, implying that all the oils sampled were of extra virgin quality. The acidity of the organic Leccino was higher than that of the conventional oil in 2001 and 2002, but values were not significantly different in 2003. The 3-year average was significantly higher for organic than for conventional Leccino. Oil acidity was not significantly different for the organic versus the conventional Frantoio in each of the 3 years.

The extinction coefficients K232, K270 varied more among the years than with fertilization systems and were not significantly different except for K232 in the Frantoio 2001. The peroxide index of the organic Leccino was higher than that of the conventional oil in 2001 and 2002 but, in 2003, the value was lower than that of the conventional oil. The organic Frantoio showed a peroxide index lower than the conventional Frantoio in the 2001, but the values were not significantly different in 2002 and 2003. The mean peroxide values of the 3 years did not show any significant difference. The pattern of the above parameters supports the importance of evaluating crops over several years versus 1 year.

The concentration of phenols, *o*-diphenols, tocopherols and the antioxidant capacity are presented in Table 3. Organic Leccino had significantly higher concentrations of phenols than conventional Leccino in 2002, but significantly lower in 2003 and the 3-year average was not significantly different. Oils from organic Frantoio had a higher concentration of phenols in 2001 but lower in 2002, while there was no difference in 2003. The concentration of *o*-diphenols was similarly inconsistent and the year-to-year variations were greater than between cultivation treatments. Tocopherol concentrations also fluctuated during the years in the two cultivars and no clear trend for distinguishing organic from conventional oils was evident.

The antioxidant capacity, as determined by the ORAC method, did not vary significantly between the two fertilization systems as a 3-year mean, although a significant difference appeared in the Frantoio 2002, with the conventional oil having higher ORAC values than that of the organic oil.

Some of the most important hydrophilic phenols were assayed in the two cultivars and in the two agronomic conditions. The most interesting aspect was the greater mean concentration of the secoiridoid derivative 3,4-DHPEA-EDA, i.e the dialdehydic form of the elenolic acid linked to the 3,4 dihydroxyphenylethanol, in the oils from Leccino with respect to Frantoio oils. The average 3,4-DHPEA-EDA concentration for the 3 years were as follows: Leccino, conventional (663 ± 70 mg/kg), organic (561 ± 50 mg/kg); Frantoio, conventional (309 ± 28 mg/kg),

**Table 3** Phytochemical parameters of organic and conventional virgin olive oils from two cultivars during a 3-year period

| Parameters | Years | *Leccino* cv. | | | | *Frantoio* cv. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Organic | | Conventional | | Organic | | Conventional | |
| Phenols (mg/kg) | 2001 | 190 | (15)a,f | 203 | (16)a,e | 313 | (16)a,d | 231 | (12)b,e |
| | 2002 | 278 | (18)a,c | 228 | (14)b,e | 150 | (11)a,f | 212 | (10)b,e |
| | 2003 | 247 | (12)a,c | 276 | (9)b,f | 308 | (15)a,d | 300 | (18)a,f |
| | Mean | 238 | (45)a | 235 | (37)a | 257 | (93)a | 247 | (46)a |
| *o*-Diphenols (mg/kg) | 2001 | 142 | (11)a,f | 121 | (13)b,e | 193 | (10)a,f | 154 | (9)b,f |
| | 2002 | 183 | (10)a,c | 145 | (8)b,e | 61 | (9)a,f | 105 | (4)b,f |
| | 2003 | 172 | (9)a,c | 209 | (11)b | 242 | (14)a,f | 212 | (11)b,f |
| | Mean | 165 | (21)a | 158 | (45)a | 165 | (94)a | 123 | (76)a |
| Tocopherols (mg/kg) | 2001 | 181 | (8)a,f | 221 | (12)b | 142 | (7)a,e | 104 | (9)b,f |
| | 2002 | 214 | (11)a,f | 130 | (11)b,f | 133 | (8)a | 148 | (10)a,c |
| | 2003 | 142 | (11)a,f | 210 | (7)b | 119 | (9)a,c | 127 | (10)a,c |
| | Mean | 179 | (36)a | 187 | (50)a | 131 | (12)a | 126 | (15)a |
| ORAC (μmol TE/g) | 2001 | 15.2 | (1.2)a | 14.8 | (1.3)a | 16.8 | (1.0)a,d | 17.7 | (2.0)a,d |
| | 2002 | 14.2 | (1.1)a | 12.7 | (1.0)a | 8.5 | (0.6)a,f | 10.9 | (0.6)b,f |
| | 2003 | 12.7 | (0.9)a | 13.9 | (1.0)a | 14.1 | (1.0)a,d | 14.2 | (1.0)a,d |
| | Mean | 14.0 | (1.2)a | 13.7 | (1.0)a | 13.1 | (2.4)a | 14.2 | (2.0)a |

Note: Values are the means of three independent determinations. Standard deviation is reported in brackets. Within each cultivar, values in each row having different letters, a vs. b, are significantly different from one another at $p < 0.01$. In each column, the statistically significant differences of a parameter, measured along the 3 years, are indicated as follows: c, significantly different versus the 2001; d, significantly different versus the 2002; e, significantly different versus the 2003; f, significantly different versus the other 2 years ($p < 0.01$)

organic (284 ± 32 mg/kg). Therefore, no significant difference in 3,4-DHPEA-EDA was observed between organic and conventional oils of the same cultivar.

Table 4 shows the oil concentration of the compounds responsible for positive aromatic notes: 2-*trans*-hexenal, 1-hexanol and 1-penten-3-ol [15, 24]. Many significant differences were found between organic and conventional oils but these always disappeared as a 3-year average.

Figure 1 shows the results of the panel test for the organic and conventional oils from the two cultivars. All oils scored >7 as overall grading thus classifying the oils as extra virgin. The oil from organic Leccino had more hay-like and artichoke aroma compared to the conventional Leccino oil; the latter had a more marked floral, cut-grass and fruity aroma. Moreover, the taste of the conventional Leccino oil was slightly more pungent and bitter than the organic oil. The oil from organic Frantoio, had a more marked floral character compared to the conventional Frantoio oil. These differences were found in 2001 but not in 2002 and 2003, where some other different aromatic notes appeared. For instance, in the year 2002 the organic Leccino was more pungent and bitter than the conventional oil, whereas the organic Frantoio was less pungent than the conventional oil.

Taken together, the results of this 3-year study suggest that organic and conventional oils exhibit occasional differences in the quality, nutritional and organoleptic parameters when analyzed within a single year. However, when results from more years were pooled, the differences disappear, resulting in no clear trend and the year-to-year variations were sometime greater than between cultivation treatments.

While the effects of phenolic compounds on human health have been increasingly studied [25, 26], the variation in the concentration of phenolic compounds with conventional or organic farming has not been studied extensively. The phenolic concentration depends on the type of agricultural practices [27, 28]. The results over the 3-year period did not show that organic cultivation increases the concentration of the main phenolic groups. It is worth noting, however, that the phenolic concentration in EVOO is merely a fraction of the total fruit phenolic concentration, so that treatment effects may reflect changes in the extractability of phenols or other compounds rather than on their synthesis in the fruit.

Similarly, the volatile compounds, which are correlated with positive or negative sensory attributes, differed occasionally but not consistently between organic and conventional oils, suggesting that the aroma depends on a wide number of variables, making it difficult to find a connection with the agricultural practices alone.

In an earlier paper, Gutierrez et al. [16] compared the quality of conventional and organic EVOO extracted from Picual olives harvested at increasing stages of ripeness. These authors found that the organic oil compared to the conventional oil was of superior quality in all parameters analyzed. In particular, a strikingly better score was

**Table 4** Head space volatile compounds of organic and conventional virgin olive oils

| Volatile compounds | | *Leccino* cv. | | | | *Frantoio* cv. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Organic | | Conventional | | Organic | | Conventional | |
| Hexanal | 2001 | 178.0 | (14.2)a | 236.0 | (23.6)b | 377.0 | (30.2)a | 555.0 | (56.6)b |
| | 2002 | 154.0 | (12.3)a | 86.0 | (6.9)b | 367.0 | (29.4)a | 356.0 | (36.3)a |
| | 2003 | 348.7 | (27.9)a | 463.0 | (37)b | 415.0 | (33.2)a | 517.0 | (46.7)b |
| | Mean | 226.9 | (106.1)a | 261.7 | (189.8)a | 386.3 | (25.3)a | 476.0 | (105.6)a |
| 2-Pentenal | 2001 | 30.1 | (2.4)a | 21.0 | (1.7)b | 36.0 | (2.9)a | 32.0 | (2.6)a |
| | 2002 | 6.0 | (0.5) | 0.0 | – | 21.0 | (1.7)a | 0.0 | – |
| | 2003 | 41.5 | (4.1)a | 9.0 | (0.7)b | 62.0 | (5)a | 68.0 | (5.4)a |
| | Mean | 25.9 | (18.1)a | 10.0 | (0.9)a | 39.7 | (20.7)a | 33.3 | (34)a |
| 2-Hexenal (*cis*) | 2001 | 269.0 | (26.9)a | 240.0 | (19.2)a | 174.0 | (13.9)a | 160.0 | (12.8)a |
| | 2002 | 312.0 | (31.2)a | 271.0 | (21.7)a | 301.0 | (24.1)a | 344.0 | (27.5)a |
| | 2003 | 516.6 | (41.3)a | 519.0 | (41.5)a | 515.0 | (41.2)a | 528.0 | (42.2)a |
| | Mean | 365.9 | (132.3)a | 343.3 | (152.9)a | 330.0 | (172.3)a | 344.0 | (184)a |
| 2-Hexenal (*trans*) | 2001 | 9330.0 | (897.6)a | 10955.0 | (976.4)a | 15482.0 | (1238.6)a | 12846.0 | (1027.7)b |
| | 2002 | 10955.0 | (950.3)a | 14180.0 | (1134.4)b | 20411.0 | (1632.9)a | 20171.0 | (1613.7)a |
| | 2003 | 13170.8 | (1117.1)a | 16611.0 | (1328.9)b | 17558.0 | (1404.6)a | 16911.0 | (1352.9)a |
| | Mean | 11151.9 | (1928)a | 13915.3 | (2837.3)a | 17817.0 | (2474.7)a | 16642.7 | (3669.9)a |
| 1-Pentanol | 2001 | 122.0 | (11)a | 92.0 | (7.4)b | 94.0 | (7.5)a | 135.0 | (10.8)b |
| | 2002 | 47.0 | (4.2)a | 71.0 | (5.7)b | 59.0 | (4.7)a | 81.0 | (6.5)b |
| | 2003 | 69.9 | (6.3)a | 61.0 | (4.9)a | 48.0 | (3.8)a | 63.0 | (5)b |
| | Mean | 79.6 | (38.4)a | 74.7 | (15.8)a | 67.0 | (24.1)a | 93.0 | (37.5)a |
| 1-Penten-3-ol | 2001 | 514.0 | (46.5)a | 461.0 | (36.9)a | 503.0 | (45.2)a | 500.0 | (43.0)a |
| | 2002 | 726.0 | (68.1)a | 482.0 | (48.6)b | 517.0 | (48.4)a | 465.0 | (37.2)a |
| | 2003 | 456.5 | (38.5)a | 462.0 | (40)a | 253.0 | (20.2)a | 464.0 | (37.1)b |
| | Mean | 565.5 | (141.9)a | 468.3 | (11.8)a | 424.3 | (148.5)a | 476.3 | (20.5)a |
| 1-Hexanol | 2001 | 1207.1 | (96.6)a | 948.0 | (75.8)b | 1821.0 | (147.7)a | 2249.0 | (209.9)a |
| | 2002 | 723.1 | (72.3)a | 893.0 | (81.4)a | 850.0 | (68)a | 730.0 | (58.4)a |
| | 2003 | 829.9 | (83)a | 586.0 | (46.9)b | 1095.0 | (87.6)a | 1123.0 | (99.8)a |
| | Mean | 920.0 | (254.3)a | 809.0 | (195.1)a | 1255.3 | (505.1)a | 1367.3 | (788.4)a |
| 1-Hexen-3-ol | 2001 | 13.0 | (1.3)a | 14.0 | (1.1)a | 12.0 | (1)a | 16.0 | (1.3)b |
| | 2002 | 13.0 | (1.2)a | 6.0 | (0.5)b | 13.0 | (1)a | 10.0 | (0.8)b |
| | 2003 | 166.7 | (15)a | 123.0 | (9.8)b | 176.0 | (14.1)a | 106.0 | (8.5)b |
| | Mean | 64.2 | (88.7)a | 47.7 | (65.4)a | 67.0 | (94.4)a | 44.0 | (53.8)a |
| 2-Hexen-1-ol (*cis*) | 2001 | 4989.0 | (399.1)a | 5610.0 | (448.8)a | 3792.0 | (363.4)a | 3310.0 | (294.8)a |
| | 2002 | 2444.0 | (220)a | 2366.0 | (189.3)a | 2052.0 | (174.2)a | 1064.0 | (95.1)b |
| | 2003 | 3195.2 | (255.6)a | 4236.0 | (338.9)b | 2099.0 | (167.9)a | 3049.0 | (293.9)b |
| | Mean | 3542.7 | (1307.6)a | 4070.7 | (1628.3)a | 2647.7 | (991.3)a | 2474.3 | (1228.3)a |
| 2-Hexen-1-ol (*trans*) | 2001 | 872.0 | (69.8)a | 937.0 | (75)a | 675.0 | (54)a | 508.0 | (40.6)b |
| | 2002 | 913.0 | (91.3)a | 497.0 | (39.8)b | 551.0 | (44.1)a | 450.0 | (36)b |
| | 2003 | 1472.8 | (132.5)a | 1524.0 | (121.9)a | 1929.0 | (174.3)a | 1611.0 | (148.9)a |
| | Mean | 1085.9 | (335.6)a | 986.0 | (515.3)a | 1051.7 | (762.3)a | 856.3 | (654.2)a |
| 3-Hexen-1-ol (*Cis*) | 2001 | 235.2 | (21.2)a | 252.0 | (20.2)a | 335.0 | (26.8)a | 512.0 | (41)b |
| | 2002 | 323.0 | (32.3)a | 395.0 | (31.6)a | 475.0 | (38)a | 536.0 | (42.9)a |
| | 2003 | 403.5 | (40.4)a | 416.0 | (33.3)a | 337.0 | (27)a | 426.0 | (34.1)b |
| | Mean | 320.6 | (84.2)a | 354.3 | (89.2)a | 382.3 | (80.3)a | 491.3 | (57.8)a |

Values are expressed as $\mu g.kg^{-1}$ oil and are the means of three independent determinations; standard deviation is reported in brackets. Values in each row having different letters are significantly different

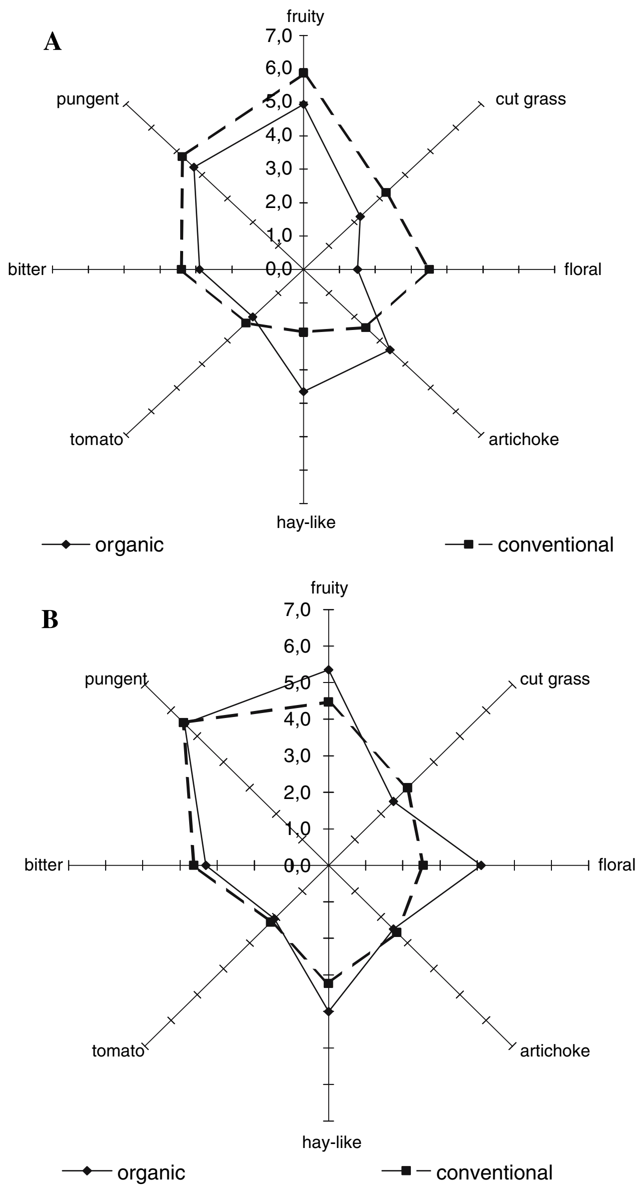


**Fig. 1** Sensory profile of virgin olive oil from cv. *Leccino* (**a**) and cv *Frantoio* (**b**)

obtained in organic oils in acidity, peroxide index, rancimat induction time, concentration of tocopherols, polyphenols, *o*-diphenols and percentage of oleic acid. However, our 3-year data do not recognize the superior quality of organic oils compared to conventional ones.

In order to explain contradictory conclusion, it is worth comparing our agronomic practices with those performed in the other study [16]. Our conventional fertilization included triple super phosphate, ammonium sulfate, potassium sulfate and, in 2002, calcium cyanamide, supplied once a year (Table 1). In the study of Gutierrez et al. [16], the conventional fertilization was carried out with urea and potassium nitrate in an unknown quantity. It is possible that large amounts of nitrate nitrogen have induced changes in the levels of the secondary metabolites of the plant. Urbanczyk-Wochniak and Fernie [29], for instance, found that nitrate assimilation strongly modified the amino acid metabolism of the plant with consequent changes in the level of the most representative secondary metabolites. The fertilizers used in our experiment did not contain nitrate nitrogen, but less readily available nitrogen forms.

In the study of Gutierrez et al. [16], the pest control was obtained with several pesticides, including malathion, formothion, glyphosate, oxyfluorfen, Bordeaux mixture and simazine as herbicide, while in our study pests were controlled using dimethoate only. It is possible that the use of many chemicals might have affected the quality parameters, but it is difficult to ascertain this hypothesis.

Finally, Gutierrez et al. [16] focused their study on the differences between conventional and organic oils following the ripening index of the fruits from 3.5 to 5. Although some significant differences between organic and conventional oils were present in the oils extracted at the ripening index of 3.5, the difference increased with the maturation index. We harvested most of our olives at a lower ripening index (i.e. between 2.5 and 3.5), because this is considered the best value for maximum oil quality [22, 24]. It may be possible that with less ripe fruits or with higher quality oils we were unable to find clear and consistent differences among treatments, which can emerge with more ripe olives and lower quality oils.

With two cultivars and 3 years of experimentation, our study provided a broad experimental base where the differences found in one year were not confirmed in other years.

Our findings agree with the majority of previous works [7, 8] where differences in nutrient content and sensory properties between organic and conventional foods were not found or were inconsistent over time. This is probably because the nutrient and sensory qualities of foods depends on a variety of factors, including cultivar, climate, soil type, nutrient and water availability, duration and conditions of storage [9, 10, 30, 31] and the differences related to the cultivation methods may be difficult to observe.

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