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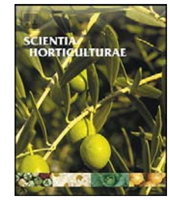

Environmental and seasonal influence on virgin olive (*Olea europaea* L.) oil volatiles in northern Italy

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ABSTRACT

The flavor profile of extra virgin olive oil is an important quality factor to differentiate the market opportunities and to increase the value of Protected Designation of Origin products. The volatile compounds and sensory notes of 'Casaliva' and 'Leccino' olive oils from 16 olive orchards near lake Garda, northern Italy, were analyzed for three years. Results showed that in this specific mesoclimate the aromatic olive oil quality depends firstly on the year and secondly on the cultivar. 'Casaliva' oils showed a higher content of volatiles (aldehydes and compounds from LOX) and phenols, higher 'green', 'fruity' and 'taste' notes than 'Leccino'. The most effective in separating cultivars were: *trans*-2-hexenal, *cis*-2-penten-1-ol, *trans*-2-hexen-1-ol, total phenols, 'lawn', 'olives' and 'bitter' sensory descriptors. The cultivar × year interaction also significantly differentiated and characterized quality and typicality of oils. Moreover, this study showed that oils volatile compounds were more significant than sensory evaluation in discriminating the cultivars and the years.

1. Introduction

Elite consumers appreciate extra virgin oil's aromatic quality as well as its nutritional properties (Giordano, 2003). Prenzler et al. (2002) carefully discussed many factors affecting oil volatile profile such as: cultivar, geographic origin, maturity stage of the fruit, processing details and storage conditions and therefore oil flavor. They pointed out there are very few reports on the influence of geographic origin and cultivar on volatile profiles.

Environmental conditions influenced the volatile synthesis and the oil composition (fatty acids, triacylglycerols and phenols) in cv 'Chétoui' oil from different farms in northern Tunisia (Temime et al., 2006a,b).

According to Cavaliere et al. (2007), the selection of five volatile compounds from the secondary metabolism of lipoxigenase (hexanal, *E*-2-hexenal, *E*-2-hexen-1-ol, 1-hexanol and *Z*-3-hexen-1-yl acetate) allowed to discriminate between oil quality in relation to their production sites and irrigation regimes applied.

Several works on the influence of the mesoclimate environment on olive oil aromatic composition were carried out in Italy, as follows. In oils from different areas of Lazio (central Italy), the content of oleic and saturated acids turned out to be strongly influenced by the irrigation practice, whereas the content of volatile compounds was affected by the altitude of the cultivation site (D'Imperio et al., 2007). Head-space analysis by electronic nose/mass spectrometry and pigment analysis by visible spectroscopy have been used to differentiate the geographical origin of olive oils from three different Protected Designation of Origin areas of Liguria (northern Italy) (Casale et al., 2007). The characterization of virgin olive oils from two distinct geographical areas of northern Italy (Gulf of Trieste and near lake Garda) was developed by Vichi et al. (2003). The authors analyzed the volatile fraction obtaining significant differences among the cultivars and the environments. Cosio et al. (2006) classified extra virgin olive oils by means of electronic nose distinguishing those coming from the lake Garda region from those coming from other areas such as: Abruzzo, Campania, Sardinia (southern Italy) and Spain. The authors demonstrated the use and the effectiveness of this methodology to classify and/or distinguish oils from a restricted area like 'Garda lake' region. This is a peculiar environment given to the large body of water influencing the climatic conditions and making this area suitable to olive cultivation despite its northern latitude. This region is characterized by abundant rainfall and mild temperatures. Spring and autumn are the rainiest periods, summer is rather cool due to mountains vicinity and winter is mild (Mediterranean climate) (Bassi et al., 2003). The cultivar influence on flavor of 'Garda lake' oils has been already discussed in a previous work (Tura et al., 2008a). In this article the influence of the peculiar

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mesoclimate on the volatile compounds and sensory notes of oils of two major cultivars during three years to assess the influence of cultivar, year and their interaction was carried on.

2. Materials and methods

2.1. Oil samplings

The research was conducted for three years (1998–2000) analyzing 59 oil samples from 'Casaliva' and 'Leccino' cultivars in 16 orchards of 'Garda bresciano' area (Fig. 1), the south west coast of lake Garda. Trees were from 15 to 20 years old and trained as open vase, spaced 8 m between and 6 m within rows. All orchards were managed with similar cultural practices and not irrigated. All oil samples were obtained from about 10 kg of olives each, hand harvested at veraison stage (corresponding to stages 4 and 5 according to Uceda, 1983: almost full blackening of the epicarp and flesh still green). Each fruit sample was collected from the same crown sections of three uniform trees for each cultivar and orchard. The olives were crushed within one day from picking with a stainless steel hammer crusher mill and malaxed for 30 min at 28 °C. The oil was extracted by hydraulic press (max 20 MPa) and separated by centrifugation at 2000 rpm. All oils were classified as "virgin" because acidity value, peroxide number, K_{232}, K_{270} and ΔK were under the limits defined by the Commission Regulation (EC) no. 1989/2003.

Due to olive tree alternate bearing, oil samples were not always available every year and in a few cases the oil quantity was not enough to run all the analyses.

2.2. Volatiles analysis

The volatile composition was determined following the extraction procedure and GC analysis described in Angerosa et al. (1997).

2.3. Sensory analysis

The sensory evaluation was carried out by three distinct panel groups following the procedures described in Tura et al. (2008a).

2.4. Statistical analysis

Normal distribution of chemical and sensory variables was checked by the Kolmogorov–Smirnov test. When distribution was not normal, the standard deviation was not reported in summary tables. In order to test the significance of the differences among chemical and sensory variables in relation to cultivar and year, data were processed by a general linear model (GLM) which included both factors and their interaction as the sources of variability. Orchard location was not included in the model because significant effects on the studied factors were missing. Year and cultivar averages were separated according to Duncan's multiple comparison test. The magnitude of variability in chemical oil composition and sensory notes was quantified in terms of the expected components of the variance due to the different sources of variation: cultivar, year and 'cultivar per year' interaction.

In order to evaluate the importance and the ability of the chemical and sensory variables to discriminate oils from different cultivars and years, linear discriminant analyses (LDA) were performed by step-wise method separately for chemical and sensory data.

Data processed by the SPSS statistical package (version 14.0 for Window—SPSS Inc., Chicago, IL, 2006).

3. Results

The comparison of volatiles composition and sensorial data of oils obtained from different orchards did not show significant differences in both cultivars (data not shown).

3.1. Aromatic profiling

To define the influence of cultivar and year on oils, the aromatic profile based on the content of single compounds and the total content of compounds with chemical affinity and/or similar biosynthetic pathway was considered (Tables 1 and 2).

The total volatile compounds (see Fig. 1 for orchard identification) ranged from 77.0 mg/kg ('Casaliva' FA in 1998) to 2498.4 ('Casaliva' LF in 1999). Total alcohols ranged from 17.4 mg/kg ('Casaliva' BI in 1998) to 367.7 ('Casaliva' VI in 1999). Total

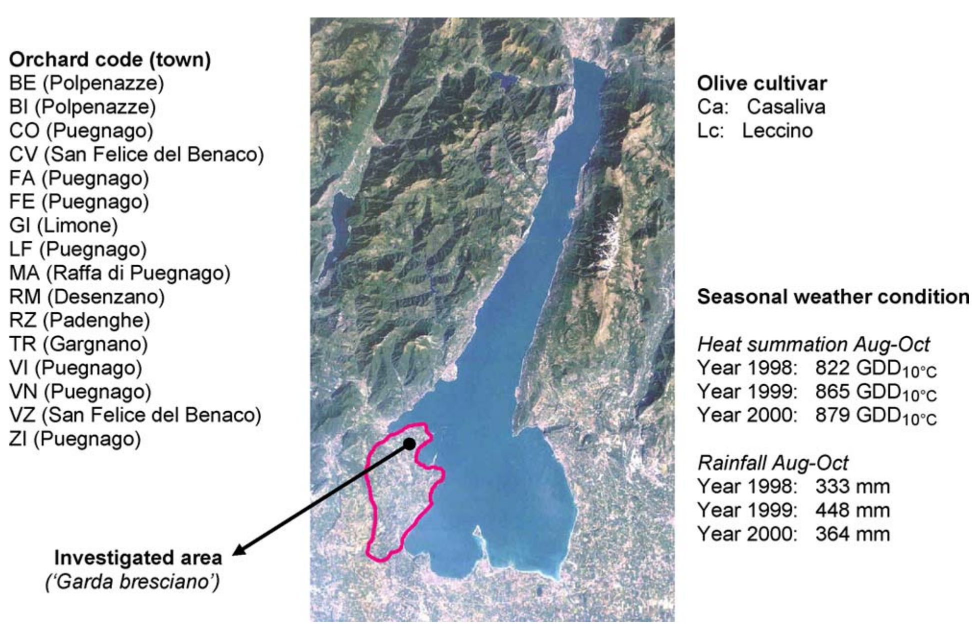

Fig. 1. 'Garda bresciano' area (Brescia, Lombardy), on the western cost of lake Garda (northern Italy), where the 16 olive orchards assessed are located. Olive oil cultivars tested and seasonal weather conditions during olives ripening in three years.

Table 1
Oil aromatic profiling from two cultivars (three-year average): number of samples, value range, mean, standard deviation and expected variance component due to cultivar, year and their interaction.

Compound	N	Range (mg/kg)	Mean (mg/kg)	S.D. (mg/kg)	Variance (%)		
					Cultivar	Year	Cv × Y
n-Octane	59	0.329–55.288	7.235	n.r.	0.0	24.3	0.0
Ethyl acetate	59	0.136–71.327	8.236	n.r.	0.9	43.3	0.0
2-methyl-Butanal	59	0.045–28.214	3.354	n.r.	2.3	8.4	24.9
3-methyl-Butanal	59	0.045–39.954	5.416	n.r.	13.7	11.8	23.5
Ethanol	59	1.122–56.824	21.269	16.274	2.3	80.4	0.9
Pentan-3-one	59	0.581–75.045	18.797	14.705	2.7	29.4	5.0
1-Penten-3-one	59	2.185–30.246	9.452	4.535	0.0	7.2	27.7
Hexanal	59	0.812–113.748	31.336	26.060	11.7	41.8	14.0
2-methyl-Propan-1-ol	59	0.059–2.200	0.706	n.r.	12.1	33.9	19.5
trans-2-Pentenal	59	0.039–20.329	5.414	n.r.	0.0	80.2	0.0
1-Penten-3-ol	59	2.033–61.672	20.633	13.394	14.7	55.3	1.9
3-methyl-Butan-1-ol	59	0.305–13.455	6.271	3.714	0.0	51.4	1.4
trans-2-Hexenal	59	44.528–1979.753	752.603	493.584	3.7	74.5	0.0
Pentan-1-ol	59	0.019–10.731	0.738	n.r.	2.3	7.6	18.6
cis-2-Penten-1-ol	59	2.411–41.739	13.377	7.735	15.3	51.6	0.7
Hexan-1-ol	59	0.551–58.665	14.639	n.r.	0.0	14.1	18.2
cis-3-Hexen-1-ol	59	0.540–35.564	9.524	7.417	0.0	25.6	23.2
trans-2-Hexen-1-ol	59	0.950–194.539	47.831	41.196	1.7	32.6	10.0
Acetic acid	59	0.019–7.594	0.669	n.r.	0.0	0.0	0.4
Octan-1-ol	59	0.118–11.016	0.965	n.r.	0.0	0.0	6.1
Total alcohols	59	17.424–367.656	135.953	77.570	0.0	56.7	1.7
Total aldehydes	59	45.601–2115.658	798.123	520.041	3.7	74.7	0.0
Total ketons	59	3.235–83.094	28.250	15.655	3.4	20.1	15.6
Total C_5 compounds	59	6.777–127.600	48.877	26.557	7.0	63.5	0.0
Total C_6 compounds	59	59.034–2257.961	855.933	532.444	3.3	73.1	0.0
Total C_6 from LA	59	3.910–140.178	45.974	31.104	10.6	37.7	0.0
Total C_6 from LnA	59	52.404–2130.325	809.958	512.953	2.8	74.4	0.0
Total volatiles	59	77.043–2498.369	978.465	571.971	2.6	74.3	0.0
Total phenols[a]	59	37.644–555.217	200.670	112.720	22.8	20.8	20.1

n.r.: not reported because frequency distributions were not normal according to Kolmogorov-Smirnov test (P = 0.05).
LA: linoleic acid.
LnA: linolenic acid.
[a] From Tura et al. (2007).

aldehydes ranged from 45.6 (‘Casaliva’ FA in 1998) to 2115.7 (‘Casaliva’ LF in 1999). Total ketons ranged from 3.2 (‘Casaliva’ FA in 1998) to 83.1 (‘Leccino’ FA in 1999). Considering the volatiles from lipoxygenase pathway (LOX), the total amount of C_5 and C_6 compounds ranged from 6.8 (‘Casaliva’ FA in 1998) to 127.6 (‘Casaliva’ LF in 1999) and from 59.0 (‘Casaliva’ FA in 1998) to 2258.0 (‘Casaliva’ LF in 1999), respectively.

The cultivar was the least important factor in influencing the aromatic compounds content and the effect on total observed variance was minimal, except on the following compounds: 1-penten-3-ol (14.7%***), *cis*-2-penten-1-ol (15.3%***) and total phenols (22.8%***): Table 1.

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‘Casaliva’ and ‘Leccino’ oils were differentiated by discriminant analysis mainly for *trans*-2-pentenal, *trans*-2-hexenal, *cis*-2-penten-1-ol, hexan-1-ol, *cis*-3-hexen-1-ol, *trans*-2-hexen-1-ol and total phenols (Table 3) (linear function: 2.88 eingvalue, 100% of variance, $r = 0.862^{***}$; figure not shown).

The years (Fig. 2 and Table 3) were separated by discriminant analysis mainly for the relationships among 2-methyl-butanal, ethanol, 2-methyl-propan-1-ol, and pentan-1-ol for the first function (20.42 eingvalue, 75.1% of variance, $r = 0.976^{***}$), and 2- and 3-methyl-butanal and 3-methyl-butan-1-ol for the second one (6.76 eingvalue, 100% of cumulative variance, $r = 0.933^{***}$).

The compounds highly and clearly affected by year on the basis of the total observed variance were: ethanol (80.4%***), *trans*-2-pentenal (80.2%***), 1-penten-3-ol (55.3%***), 3-methyl-butan-1-ol (51.5%***), *trans*-2-hexenal (74.5%***), *cis*-2-penten-1-ol (51.6%***), total alcohols and aldehydes (56.7%*** and 74.7%***), total C5 and C6 compounds from LOX, in particular from linolenic acid (63.5%***, 73.1%*** and 74.4%***), and total volatiles (74.3%***): Table 1.

‘Cultivar × year’ interaction, according to GLM, affected 2- and 3-methyl-butanal (25.0%** and 23.5%**), 1-penten-3-one (27.7%**), *cis*-3-hexen-1-ol (23.2%**), and total phenols (20.1%**): Table 1. All the oils in 1998 and ‘Casaliva’ in 1999, according to the LDA, were well separated from ‘Casaliva’ in 2000 and ‘Leccino’ in 1999 and 2000, given the effect of 2-methyl-butanal, ethanol, 2-methyl-propan-1-ol and pentan-1-ol for the first function (21.1 eingvalue, 53.7% of variance, $r = 0.977^{***}$), and *trans*-2-penenal, 1-pentan-3-ol and *trans*-2-hexen-1-ol for the second function (9.63 eingvalue, 78.2% of cumulative variance, $r = 0.952^{***}$): Fig. 2 and Table 3.

3.2. Sensorial profiling

The sensorial descriptors of the oils, expressed in arbitrary units (A.U.), are shown in Table 4. ‘Green’ notes ranged from 16.0 (‘Leccino’ RM in 1998) to 36.5 (‘Leccino’ VZ in 1998); ‘floral’ notes from 8.4 (‘Leccino’ RZ in 1998) to 18.6 (‘Casaliva’ CO in 1999); ‘fruity’ notes from 18.8 (‘Leccino’ RM in 1998) to 37.4 (‘Casaliva’ FA in 1999); ‘taste’ notes from 6.3 (‘Leccino’ VZ in 1998) to 28.5 (‘Casaliva’ CO in 2000); ‘satisfaction’ from 0.0 (‘Leccino’ VZ in 1998) to 31.0 (‘Casaliva’ LF in 1999).

The cultivars were separated by GLM for seven sensorial descriptors: lawn (35.9%***), olives (20.2%**), bitter (15.8%*), ‘fruity’ notes (15.7%*) and satisfaction (27.9%***). Butter (18.1%*) and satisfaction (14.4%*) were influenced by the ‘cultivar per year’ interaction, while no particular descriptor was clearly affected by the year (Tables 4 and 5).

Table 2
Oil aromatic profiling from two cultivars: comparison among 59 samples for cultivar and year (within brackets: number of samples).

Compound (mg/kg)	Cultivar		Year		
	Casaliva (30) (from 10[a] sites)	Leccino (29) (from 11 sites)	1998 (23) (from 14[a] sites)	1999 (17) (from 11 sites)	2000 (19) (from 10 sites)
n-Octane	7.901a[b]	6.546a	2.963a[b]	6.443a	13.116b
Ethyl acetate	7.212a	9.295a	1.691a	20.013b	5.620a
2-methyl-Butanal	2.298a	4.447b	1.056a	5.768b	3.976b
3-methyl-Butanal	3.292a	7.612b	1.944a	8.981b	6.428b
Ethanol	18.975a	23.641b	20.691b	40.442c	4.813a
Pentan-3-one	16.446a	21.229a	14.441a	30.212b	13.858a
1-Penten-3-one	8.725a	10.205b	7.486a	9.174a	12.081b
Hexanal	39.865b	22.513a	10.353a	51.968c	38.277b
2-methyl-Propan-1-ol	0.553a	0.864b	0.293a	1.014b	0.929b
trans-2-Pentenal	5.540a	5.283a	0.401a	9.321b	7.986b
1-Penten-3-ol	25.170b	15.941a	9.059a	32.490c	24.035b
3-methyl-Butan-1-ol	6.380a	6.158a	3.772a	5.851b	9.673c
trans-2-Hexenal	848.177b	653.733a	250.565a	942.706b	1190.241c
Pentan-1-ol	1.090b	0.374a	0.170a	1.672b	0.589a
cis-2-Penten-1-ol	16.066b	10.596a	7.103a	20.157c	14.907b
Hexan-1-ol	14.915a	14.352a	17.792b	20.177b	5.865a
cis-3-Hexen-1-ol	10.155a	8.871a	4.258a	14.026b	11.871b
trans-2-Hexen-1-ol	41.537a	54.342b	28.983a	82.189b	39.905a
Acetic acid	0.710a	0.626a	0.382a	0.855a	0.850a
Octan-1-ol	0.851a	1.083a	0.657a	1.103a	1.215a
Total alcohols	135.692a	136.223a	92.779a	219.122b	113.802a
Total aldehydes	899.173b	693.588a	264.319a	1018.745b	1246.907c
Total ketons	25.171a	31.435b	21.927a	39.386b	25.939a
Total C_5 compounds	55.501b	42.025a	24.050a	71.143c	59.009b
Total C_6 compounds	954.650b	753.812a	311.951a	1111.067b	1286.158b
Total C_6 from LA	54.780b	36.865a	28.145a	72.145c	44.142b
Total C_6 from LnA	899.869b	716.947a	283.807a	1038.921b	1242.016c
Total volatiles	1075.860b	877.712a	384.062a	1304.564b	1406.234b
Total phenols[c]	248.811b	148.068a	154.542a	164.381a	284.703b

[a] Number of orchards (due to olive tree alternate bearing, oil samples were not always available every year and in a few cases the oil quantity was not enough to run all the analyses).
[b] Rows: values with the same letter are not statistically different at $P = 0.05$, separately for cultivar and for year.
[c] From Tura et al. (2007).

Even if the eingvalue (by LDA) was inferior to 1, showing a low discriminant ability, nevertheless some descriptors could be highlighted: lawn, leaf and bitter.

About the 'year' effect, 2000 was partially separated by LDA on the first function (1.47 eingvalue, 74.6% of variance, $r = 0.772^{**}$) mainly for five descriptors: 'olives', 'lawn', 'leaf', 'sweet', and 'astringency' (Fig. 3 and Table 6).

Also the 'cultivar × year' interaction was partially separated by LDA on the first two functions: all oils of 2000 were separated from 'Leccino' and 'Casaliva' of the other two seasons, mainly by

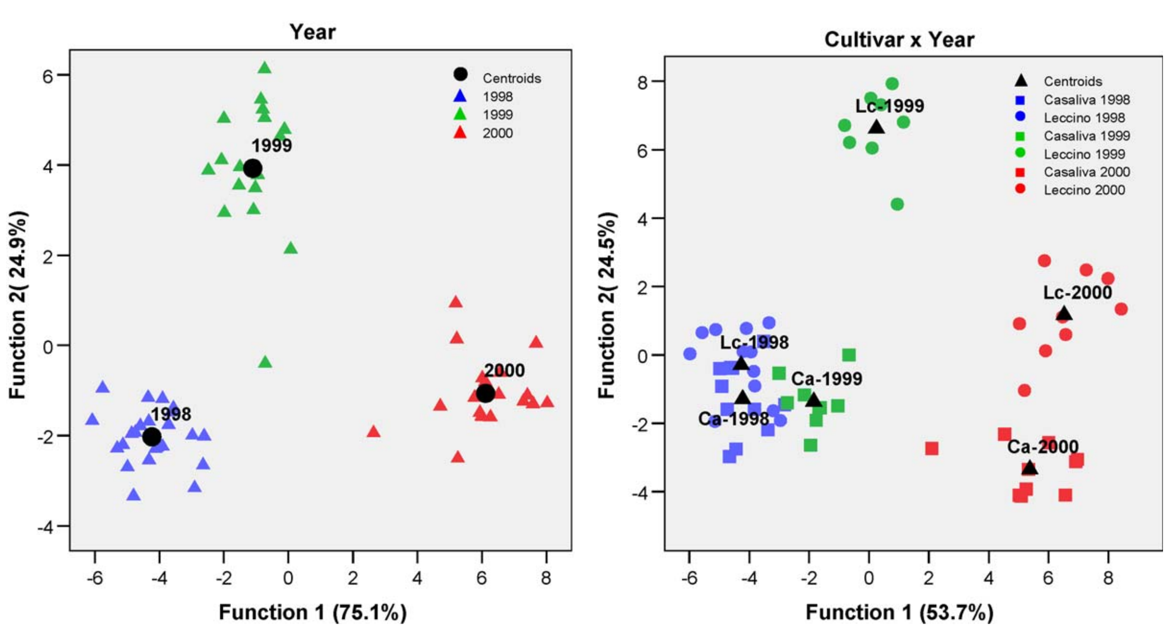

Fig. 2. Oil aromatic profiling from two cultivars: discrimination for year and 'cultivar × year' interaction (within brackets: percent of variance explained by function; see Table 3 for values and coefficients of discriminated functions).

Table 3
Oil aromatic profiling: coefficients of discriminating functions for cultivar, year and 'cultivar × year' interaction (see Fig. 2).

Model	Function	Eingvalue	% variance	% cumulative	Correlation	λ Wilks	χ^2	df	Sig.
Cv	1	2.880	100.0	100.0	0.862	0.258	63	21	0.000
Year	1	20.420	75.1	75.1	0.976	0.006	235	42	0.000
	2	6.757	24.9	100.0	0.933	0.129	94	20	0.000
Cv × year	1	21.095	53.7	53.7	0.977	0.000	396	105	0.000
	2	9.626	24.5	78.2	0.952	0.003	258	80	0.000
	3	6.406	16.3	94.5	0.930	0.032	153	57	0.000
	4	1.423	3.6	98.1	0.766	0.237	64	36	0.003
	5	0.743	1.9	100.0	0.653	0.574	25	17	0.101

	CV	Year		Cv x year				
	Fx[a] 1	Fx 1	Fx 2	Fx 1	Fx 2	Fx 3	Fx 4	Fx 5
n-Octane	0.286	0.091	−0.190	0.039	−0.311	−0.004	0.314	0.127
Ethyl acetate	0.587	−0.388	0.331	−0.521	−0.404	0.672	0.432	−0.008
2-methyl-Butanal	0.076	1.683	−1.170	1.638	−0.076	−0.971	1.246	0.472
3-methyl-Butanal	−0.656	−0.567	1.143	−0.410	0.759	0.507	−1.232	-0.386
Ethanol	−0.044	−1.387	0.619	−1.239	0.576	0.465	0.334	0.020
Pentan-3-one	0.058	−0.245	0.275	−0.205	0.241	0.299	0.587	−0.005
1-Penten-3-one	−0.496	0.276	−0.494	0.476	0.702	−0.784	0.486	0.246
Hexanal	0.684	0.161	0.473	−0.082	−0.705	0.811	−0.038	−0.245
2-methyl-Propan-1-ol	−0.162	1.021	0.297	0.907	0.280	−0.012	−0.592	0.174
trans-2-Pentenal	−1.120	0.591	0.469	0.775	0.908	0.076	0.011	−0.202
1-Penten-3-ol	0.509	0.236	0.216	−0.193	−1.375	0.916	−0.199	−0.968
3-methyl-Butan-1-ol	−0.342	0.520	−0.831	0.398	−0.680	−0.539	0.136	−0.583
trans-2-Hexenal	0.905	0.538	0.378	0.557	0.143	0.339	0.251	0.646
Pentan-1-ol	−0.595	0.948	0.075	1.026	0.590	−0.310	−0.379	−0.103
cis-2-Penten-1-ol	1.144	−0.797	−0.236	−0.605	0.060	−0.395	−0.346	1.448
Hexan-1-ol	0.901	−0.119	−0.360	−0.135	−0.432	−0.260	−0.202	1.030
cis-3-Hexen-1-ol	−0.910	−0.099	−0.205	0.013	0.432	−0.569	−0.784	−0.332
trans-2-Hexen-1-ol	−0.914	0.219	0.356	0.367	0.896	0.063	0.562	−0.573
Acetic acid	−0.211	−0.330	−0.057	−0.331	0.057	−0.016	0.261	−0.323
Octan-1-ol	−0.298	0.742	−0.368	0.846	0.274	−0.600	−0.144	0.136
Total phenols[b]	0.818	0.282	0.311	0.124	−0.359	0.573	0.707	0.264

[a] Fx: function.
[b] From Tura et al. (2007).

'lawn', 'olives', 'sweet', 'astringency' and 'satisfaction' for the first function (1.68 eingvalue, 42.9% of variance, $r = 0.792^{**}$), and by 'leaf' and 'olives' descriptors for the second function (1.13 eingvalue, 71.7% of cumulative variance, $r = 0.728^{*}$): Fig. 3 and Table 6.

4. Discussion

Data on the influence of environment, climate and cultivar on the sensorial profile of olive oils are rather scarce and the findings from the few reports are often heavily biased by experimental

Table 4
Oil sensorial profiling from two cultivars (three-year average): number of samples, value range, mean, standard deviation (arbitrary unites: A.U.) and expected variance component due to cultivar, year and their interaction.

Descriptor	*N*	Range (A.U.)	Mean (A.U.)	S.D. (A.U.)	Variance (%)		
					Cultivar	Year	Cv x Y
Lawn	59	1.695–10.297	5.255	2.397	35.9	6.3	4.2
Leaf	59	2.403–12.897	5.167	2.552	7.9	5.8	0.0
Olives	59	0.857–12.900	5.132	2.551	20.2	3.5	7.7
Flowers	59	4.393–12.544	5.293	n.r.	3.0	0.0	0.0
Banana	59	3.984–8.609	4.976	n.r.	0.0	0.0	0.0
Tomato	59	3.491–11.231	5.427	n.r.	3.1	0.0	0.0
Almond	59	3.679–11.281	5.516	n.r.	0.0	2.1	0.6
Artichoke	59	3.356–9.528	5.296	n.r.	0.0	0.0	2.7
Apple	59	4.687–11.121	5.035	n.r.	0.0	0.0	9.7
Walnut	59	3.620–13.722	5.305	n.r.	5.3	0.0	2.4
Hay	59	3.286–15.624	5.288	n.r.	5.8	0.4	0.0
Butter	59	3.984–9.996	5.155	n.r.	0.0	0.0	18.1
Bitter	59	0.582–10.010	4.936	2.500	15.8	0.0	2.8
Sweet	59	3.349–11.500	5.412	2.101	5.4	7.9	0.5
Pungent	59	0.889–10.782	4.934	2.269	6.6	5.8	0.0
Astringency	59	3.441–8.790	5.207	n.r.	0.0	4.7	3.9
Green notes	59	15.949–36.541	26.311	5.161	13.6	4.0	0.0
Floral notes	59	8.377–18.614	10.448	n.r.	0.0	0.0	11.9
Fruity notes	59	18.835–37.412	26.087	3.904	15.7	0.3	3.6
Taste notes	59	6.300–28.455	15.077	5.118	10.7	7.1	0.0
Satisfaction	59	0.000–31.049	15.208	7.372	27.9	3.3	14.4

n.r.: not reported because frequency distributions were not normal according to Kolmogorov–Smirnov test ($P = 0.05$).

Table 5
Oil sensorial profiling from two cultivars: comparison among 59 samples for cultivar and year (within brackets: number of samples).

Descriptor (A.U.)	Cultivar		Year		
	Casaliva (30) (from 10[a] sites)	Leccino (29) (from 11 sites)	1998 (23) (from 14[a] sites)	1999 (17) (from 11 sites)	2000 (19) (from 10 sites)
Lawn	6.433b[b]	4.035a	4.265a[b]	5.685b	6.067b
Leaf	5.716a	4.599a	4.703a	4.868a	5.997a
Olives	6.091b	4.140a	4.932ab	6.238b	4.386a
Flowers	5.559a	5.017a	5.578a	5.329a	4.914a
Banana	5.026a	4.925a	4.962a	4.809a	5.144a
Tomato	5.812a	5.029a	5.411a	5.527a	5.358a
Almond	5.346a	5.692a	5.027a	5.556a	6.073a
Artichoke	5.097a	5.501a	5.030a	5.615a	5.332a
Apple	5.149a	4.918a	4.857a	5.226a	5.079a
Walnut	5.797a	4.797a	5.310a	5.240a	5.358a
Hay	4.757a	5.837a	5.728a	5.369a	4.682a
Butter	5.023a	5.292a	5.305a	4.915a	5.188a
Bitter	5.788b	4.055a	4.368a	5.043a	5.527a
Sweet	4.994a	5.845a	5.537ab	6.121b	4.627a
Pungent	5.398a	4.454a	4.232a	5.369a	5.396a
Astringency	5.238a	5.175a	4.802a	5.781b	5.184ab
Green notes	27.800b	24.770a	25.037a	26.777a	27.436a
Floral notes	10.581a	10.309a	10.883a	10.244a	10.103a
Fruity notes	27.424b	24.704a	25.190a	27.355a	26.039a
Taste notes	16.424b	13.684a	13.402a	16.193a	16.107a
Satisfaction	18.681b	11.615a	12.088a	18.149b	16.354b

[a] Number of orchards (due to olive tree alternate bearing, oil samples were not always available every year and in a few cases the oil quantity was not enough to run all the analyses).
[b] Rows: values with the same letter are not statistically different at $P = 0.05$, separately for cultivar and for year.

materials (oil samples) where the genetic origin is not known or not separated by the geographic origin, e.g. in D'Imperio et al. (2007), Casale et al. (2007) and Cosio et al. (2006).

The lack of significant differences in volatiles composition and sensorial data of the oils from the different orchards found in this trial could be explained by the heavy influence of the lake Garda climate over the limited extension of the assessed area (Fig. 1). It has to be added that in a preliminary study on genotype–environment–year-interaction on 'Garda lake' oils, no significant relations were also found among antioxidants compounds and physical characteristics of the cultivation site, i.e. landscape, altitude, soil depth, texture, available water content (Failla et al., 2002; Tura et al., 2007). These findings are in contrast with the large variability induced by the localization of the farm on the oils of the same cultivar as reported in Temime et al. (2006a), even if they failed to describe the environments.

Despite Angerosa et al. (1999) underlined the cultivar as the primary source of volatiles and climate and environment coming in second place, the present data showed the prominent importance of the season. It should be taken in account that in this trial the same maturity index was applied over the years, thus excluding the possible influence of the season on the degree of ripening. A possible sound explanation of the role played in this trial by the season should be found in the diverse weather conditions during olive ripening (see Fig. 1 for thermal and rainfall courses). In 1998 (high rainfall in summer and cool temperatures in spring and autumn, Tura et al., 2008b) there was a general low content of volatile compounds and sensory notes. In 1999 (high rainfall in

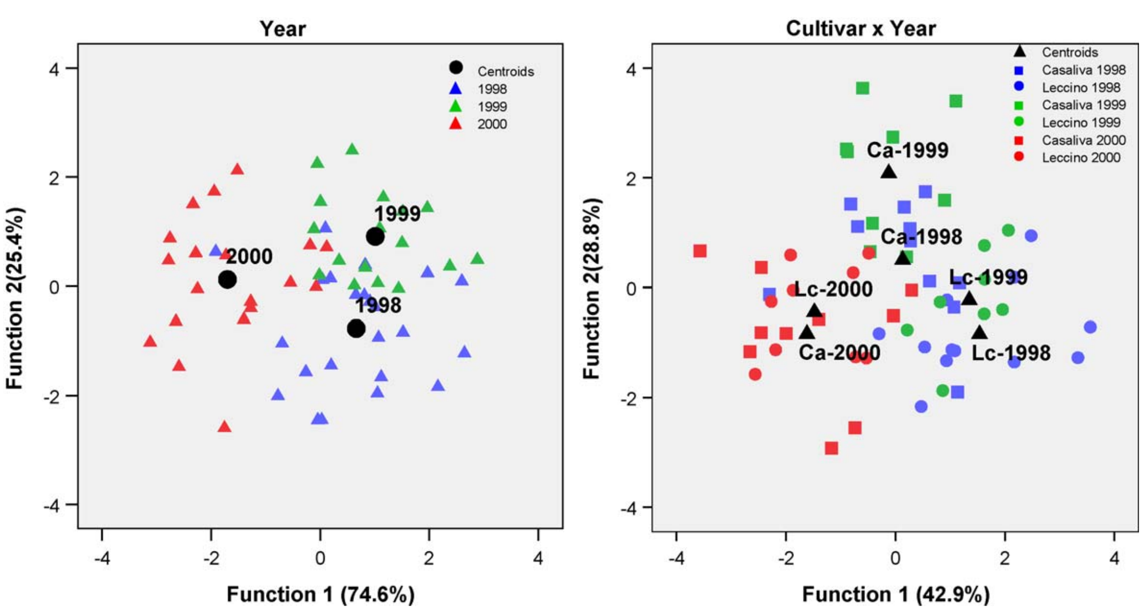

Fig. 3. Oil sensorial profiling from two cultivars: discrimination for year and 'cultivar 9 × year' interaction (within brackets: percent of variance explained by function; see Table 6 for values and coefficients of discriminated functions).

Table 6
Oil sensorial profiling: coefficients of discriminating functions for cultivar, year and 'cultivar × year' interaction (see Fig. 3).

Model	Function	Eingvalue	% variance	% cumulative	Correlation	λ Wilks	χ^2	df	Sig.
Cv	1	0.594	100.0	100.0	0.610	0.627	23	17	0.162
Year	1	1.473	74.6	74.6	0.772	0.269	63	34	0.002
	2	0.501	25.4	100.0	0.578	0.666	20	16	0.243
Cv × year	1	1.680	42.9	42.9	0.792	0.070	124	85	0.004
	2	1.127	28.8	71.7	0.728	0.187	78	64	0.050
	3	0.570	14.6	86.3	0.603	0.398	43	45	0.113
	4	0.346	8.8	95.1	0.507	0.624	22	28	0.562
	5	0.190	4.9	100.0	0.400	0.840	8	13	0.786

Descriptor	CV	Year		Cv × year				
	Fx[a] 1	Fx 1	Fx 2	Fx 1	Fx 2	Fx 3	Fx 4	Fx 5
Lawn	0.603	−0.885	−0.123	−0.880	−0.010	−0.219	−0.180	0.343
Leaf	−0.336	−0.846	−0.030	−0.455	−0.789	−0.115	0.433	0.095
Olives	0.032	1.947	0.172	1.378	1.059	0.123	−0.141	−0.034
Flowers	−0.014	0.144	0.033	0.068	0.226	−0.280	0.072	−0.071
Banana	0.023	0.405	0.170	0.367	0.137	0.264	0.153	0.190
Tomato	−0.068	0.142	−0.262	0.203	−0.120	0.088	−0.283	−0.001
Almond	−0.174	−0.382	0.257	−0.275	−0.303	0.473	0.080	−0.407
Artichoke	−0.347	−0.186	0.158	−0.197	0.158	−0.533	0.188	−0.737
Apple	0.023	0.411	0.206	0.326	0.343	−0.441	0.546	0.423
Walnut	0.241	0.230	−0.673	0.290	−0.218	0.107	−0.585	0.657
Hay	−0.135	0.072	−0.038	0.112	−0.045	0.026	−0.047	−0.153
Butter	−0.086	0.210	−0.127	0.167	0.208	−0.522	0.058	−0.005
Bitter	0.312	−0.210	−0.267	−0.322	0.043	0.201	−0.641	−0.145
Sweet	−0.007	0.745	0.131	0.688	0.188	0.388	0.107	0.288
Pungent	−0.029	−0.260	0.400	−0.282	0.072	−0.147	0.505	−0.070
Astringency	−0.188	0.571	0.647	0.584	0.121	0.565	0.709	0.157
Satisfaction	0.406	−0.354	0.971	−0.605	0.445	0.408	0.332	−0.336

[a] Fx: function.

spring and autumn) a high content in some volatiles, and sensory notes. In 2000 (a warm spring, a cool summer and winter, low rainfall for all season) a high level of some volatiles, total phenols, and low values of volatiles and sensorial descriptors were shown.

Also Vichi et al. (2003) were able to discriminate the same monovarietal oils following their geographical origin, thus underling the effect of the environment over the genetic factor.

Combing the influence of the season to the different volatile and sensorial profile of the two cultivars, the strong 'cultivar × year' interaction was expected. Indeed, 'Casaliva' oils showed an higher content of volatiles (aldehydes and compounds from LOX) and phenols, higher 'green', 'fruity' and 'taste' notes than 'Leccino', while the latter showed a lower contents and a higher response to the different seasonal conditions (Fig. 2).

However, it is to be noted that despite oils were well differentiated by their aromatic compounds content, the sensory evaluation often failed to discriminate the oils, even if assessed by three different panels.

5. Conclusions

This study carried out for three years on two olive cultivars grown in 16 orchards in 'Garda bresciano' area (northern Italy) has shown that aromatic quality of virgin olive oils depends mainly from the year and than from the cultivar. The cultivation sites (orchards) did not affect oil composition and profile. The volatiles content was more important in characterizing the cultivar and/or the year than the sensory evaluation by panel test. This fact points out the importance of determining the chemical composition together with the sensorial profile of oils, even if the latter was not so important in this trial for the characterization and classification of oils according to cultivar and year.

Even if a three-year range could be a limited span of time for general conclusions, in this particular mesoclimatic conditions a warm ripening season as well as sufficient rain in spring and autumn seems to play a positive effect on volatile compounds content and, possibly, to the overall sensorial evaluation of oils.

Moreover, also the interaction 'cultivar × year' was significant in discriminating the oils. This fact suggests that the differences induced by the year are an essential factor that could be underlined in order to address the marketing of extra virgin olive oils, particularly for Protected Designation of Origin productions.

Finally, these findings should be compared to oils of the same cultivars from other olive growing regions in order to test the influence of different macroclimates and to confirm and/or increase our knowledge on factors influencing the oil quality and appreciation.

Notes

*Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.
*** Significant at $P \leq 0.001$.

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