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Olive oil
Huile d'olive

Dossier

Chemical characterization of organic and non-organic virgin olive oils

Diego Luis García-González[1,*], Ramón Aparicio-Ruiz[1] and Maria Teresa Morales[2]

[1] Instituto de la Grasa (CSIC), Avda. Padre García Tejero 4, 41012 Seville, Spain
[2] Department of Analytical Chemistry, University of Sevilla, c/ Prof. García González 2, 41012, Sevilla, Spain

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Abstract – Organic food products have shown to have lower environmental impact and lower presence of chemical residues. Consumers generally have positive attitudes towards organic food because of superior taste, environment-friendliness, health, food safety and animal welfare. During last years, the demand of consumers for organic virgin olive oils have been increased as a result of their high quality image from nutritional and health aspects. In this work sixteen virgin olive oil samples, four obtained by organic and twelve from non-organic cultivation, were analysed by their quality parameters (acidity, peroxide value and UV absorption), fatty acids, sterols and volatile compounds. Quality parameters were not able to discriminate between organic and non-organic samples although significant differences were found in the values of acidity and K_{270}. Fatty acids and sterols content were able to discriminate samples according to their cultivar but did not show capacity differentiating the samples according to the cultivation system. The results of volatile analysis show that in general terms the organic virgin olive oils showed a higher concentration of volatile compounds, except for the aldehydes, whose concentration was higher in the non-organic oils, and the acids, whose concentration was similar in the both oil classes. The concentration of ketones, aldehydes, and alcohols showed significant variations ($p < 0.05$) between the two types of oils.

Keywords: Organic virgin olive oil / quality parameters / fatty acids / sterols / volatile compounds

Résumé – Caractérisation chimique des huiles d'olive vierges organiques et non organiques. Les aliments issus de l'agriculture biologiques ont démontré leur impact environnemental réduit et la présence plus faible de résidus chimiques. Les consommateurs ont généralement des attitudes positives envers les aliments biologiques en raison d'un goût supérieur, de leur écologie, de la santé, de la sécurité alimentaire et du bien-être animal. Durant les dernières années, la demande de consommateurs pour des huiles d'olive vierges biologiques a largement augmenté, conséquence de leur image de grande qualité nutritionnelle et de questions de santé. Dans ce travail, seize échantillons d'huile d'olive vierges, quatre issus de l'agriculture biologique et douze de cultures non-biologiques, ont été analysés au regard de leurs paramètres de qualité (acidité, valeur de peroxyde et absorption UV), de leurs acides gras, stérols et des composés volatils. Les paramètres de qualité n'ont pas permis de distinguer les échantillons biologiques des non-biologiques bien que des différences significatives aient été trouvées dans les valeurs d'acidité et de K_{270}. Les compositions en acides gras et stérols ont permis de distinguer des échantillons selon la variété cultivée, mais pas de différencier les échantillons selon le système de culture. Les résultats de l'analyse des composés volatiles montrent, en général, que les huiles d'olive vierges biologiques présentent une concentration plus élevée en composés volatils, exception faite des aldéhydes, dont la concentration était plus haute dans les huiles non-biologiques, et des acides, dont la concentration était semblable dans les deux catégories d'huiles d'olive. La concentration de cétones, aldéhydes et alcools a montré des variations significatives ($p < 0,05$) entre les deux types d'huiles.

Mots clés : Huile d'olive vierge / paramètres de qualité / acides gras / stérols / composés volatils

1 Introduction

Organic production mainly pursues several objectives such as to establish a sustainable management system for agriculture and to promote the production of products of high quality and a wide variety of food and other agricultural products that respond to consumer demand for goods, produced by methods and processes which are not detrimental to humans, animals and plants and harmful to the environment and welfare at large (Tsatsakis and Tsakiris, 2010). Organic agriculture has been shown to have lower environmental impact, due to lower

* Correspondence: dluisg@cica.es

pollution with chemicals and synthetic fertilizers and lower presence of chemical residues in organic products (Rosati *et al.*, 2014).

Although it has been described that the chemical composition of several organic foods is not significantly different from that of conventional foods for the main nutrients, several differences have been described on the minor components. Although there is no evidence that organic foods are more nutritious or healthier than conventional foods (Guéguen and Pascal, 2013), consumers generally have positive attitudes towards organic food products since typically associate benefits such as superior taste, environment-friendliness, health, food safety and animal welfare to organic food (Marian *et al.*, 2014).

Health is an important motivation for the consumption of organic foods, several human epidemiological studies associated consumption of organic foods with lower risks of allergies due to the presence of chemicals (Huber *et al.*, 2011). This issue was enough to increase an abrupt demand for organic agricultural products only a few decades ago.

It was the combined actions of the increasing demand from consumers for organically produced agricultural products and the less intensive use of land, as consequence of producing those foodstuffs, which resulted in a better balance between the demand for agricultural products and protection of the environment of the countryside. And the latest was inside the context of the European common agricultural policy (EU, 1992).

Such kind of regulation implies an immediate series of actions focused on indications stating or implying to purchasers that foodstuffs have been produced without the use of synthetic chemicals. An appropriate use of insect and pheromone traps and of approved pesticides with fewer side-effects to the environment, together with agricultural practices (*e.g.* tillage and use of compost made from vegetative residue, drip and deficit irrigation, *etc.*), are strategic choices in the decrease of risks to human health and ecosystems. With independence of high inputs of agrochemicals, their presence is also banned in all the olive oils, which makes the separation between organic and non-organic olive oils difficult enough in terms of concentration.

Most of the production of organic olive oils is not absorbed by domestic demand, which grows at a slow pace, and it is destined for delicatessens of non-producer countries. In this situation, it is important and necessary to establish the perceptions, values and motivations of consumers about organic olive oil, in order to adapt marketing strategies based on information obtained. A large survey carried out in Dutch grocery malls suggests that consumers' willingness to pay for organic olive oil is influenced by consumers' experience, awareness, perceptions regarding better quality and high price, and preference for the retail distribution of organic olive oil (Kalogeras *et al.*, 2009). Although all the studies seem to indicate that the demand for organic olive oil is strongly affected by socioeconomic characteristics such as income size and occupation status, and to a lesser extent by attitudes towards organic products, food safety and the environment, the demand for high quality is still in organic olive oils. There are, however, very few reports on the qualitative, nutritional and organoleptic characteristics of these products. Therefore, there is a need to verify the total quality of organically produced olive oils and to assess their quality versus conventional ones.

The aim of this paper is to carry out the chemical characterization of organic virgin olive oils of four main cultivars of Spain and to compare them with conventional virgin olive oils of the same cultivars by means of statistical procedures.

Table 1. Codes, cultivar, geographical origin and agronomical practice of virgin olive oil samples.

Code	Cultivar	Geographical origin	Agronomical practice
P1	Picual	Sierra de Cazorla (Jaén)	Organic
P2		Sierra de Cazorla (Jaén)	Non-organic
P3		Menjíbar (Jaén)	Non-organic
P4		Commercial	Non-organic
A1	Arbequin	Borjas Blancas (Lérida)	Organic
A2		Borjas Blancas (Lérida)	Non-organic
A3		Estepa (Sevilla)	Non-organic
A4		Commercial	Non-organic
H1	Hojiblanca	Sierra de Yeguas (Málaga)	Organic
H2		Sierra de Yeguas (Málaga)	Non-organic
H3		Estepa (Sevilla)	Non-organic
H4		Commercial	Non-organic
C1	Cornicabra	Monterrubio (Badajoz)	Organic
C2		Santos de Maimona (Badajoz)	Non-organic
C3		Mora de Toledo (Toledo)	Non-organic
C4		Commercial	Non-organic

2 Materials and methods

2.1 Samples

The set was composed of 16 samples of 4 Spanish cultivars (Arbequina, Cornicabra, Hojiblanca and Picual), four of them obtained by organic agricultural practices and twelve being from non-organic orchards of diverse geographical provenances (Tab. 1). Samples were taken directly from the cooperative societies to avoid possible undeclared mixtures with other oils before bottling. All the samples were analysed in duplicate.

2.2 Quality parameters

Free acidity, peroxide value and specific UV absorption at 232 nm (K_{232}), 270 nm (K_{270}) and ΔK were determined following the International Olive Council regulation describing the trade standard applying to olive oils and olive-pomace oils (IOC, 2013), and the EU regulation centered on the characteristics of olive oil and olive-residue oil and on their relevant methods of analysis (EC, 1991; EU, 2013).

2.3 Fatty acid determination

All the olive oil analyses were performed according to the official method of the EC no. 2568/91 (EC, 1991). Chromatographic analyses were carried out on a Varian 3900 chromatograph (Varian, Walnut Creek, CA, USA) equipped with a flame ionization detector (FID).

For the determination of fatty acid composition, the methylesters of fatty acids were prepared by vigorously shaking the solution of oil in hexane (0.2 g in 4 ml) with 0.4 ml 2 N methanolic KOH, and analysed by GC. A fused silica column SP-2380 (60 m length,0.25 mm, i.d. 0.2 μm film thickness; Sigma-Aldrich, Madrid, Spain) was used. Helium was employed as carrier gas with a flow rate of 1 ml/min. The temperatures of the injector and detector were set at 250 °C; the oven temperature program was as follows: 10 min at 170 °C, from 170 °C to 200 °C at 1.5 °C/min, 8 min at 200 °C. An injection volume of 1 μl was used. The fatty acids quantified, in percentages, were: palmitic acid (16:0); palmitoleic acid (16:1n-7); margaric acid (17:0); margaroleic (17:1n-8); stearic acid (18:0); oleic acid (18:1n-9); linoleic acid (18:2n-6); linolenic acid (18:3n-3); arachidic acid (20:0); gadoleic acid (20:1n-9); and behenic acid (22:0).

2.4 Sterols analysis

Saponification, isolation of the non-saponifiable fraction and the separation of the sterols of this fraction in olive oil samples was carried out according to the methods described by the Official Journal of the European Communities (EC, 1991). A internal standard solution (1 ml) of α-cholestanol in chloroform (1 mg/ml) was added to the samples (5 g olive oil) and saponified by refluxing with 50 ml ethanolic 2 M KOH for 30 min. After cooling at room temperature, 100 ml water was added. After phase separation in a separation funnel, the aqueous phase was washed three times with 80 ml diethyl ether. Finally, the diethyl fractions were collected and washed with three fractions of water (each 80 ml). These were then dried with anhydrous sodium sulphate, filtered and evaporated to dryness using a rotary evaporator at reduced pressure. The residue (the non-saponificable material) was dissolved in 1 ml chloroform. An extract (300 μl) was subjected to thin layer chromatography (TLC) on a silica gel plate and placed in a tank containing a hexane/ethyl ether mixture (65:35). After separation, the plate was sprayed with a 2,7-dichlorofluorescein solution in ethanol (0.2%), yielding bands corresponding to the different classes of minor components. The bands of sterols and alcohols were independently isolated and extracted with diethyl ether (40 ml). Extracts were evaporated to dryness in the rotary evaporator. The flasks were heated in an oven at 105 °C for 10 min and silanised with 200 μl of mixture of pyridine, hexamethyldisilazane and trimethylchlorosilane (9:3:1) and 1 μl of each solution was injected into the gas chromatograph. A fused silica HP-5 column (30 m., 0.32 mm i.d., 0.25 μm film thickness) was used for the analyses of sterols and alcohols. Helium was employed as carrier gas with an on-column pressure of 10 psi. The temperatures of the injector and FID were set at 290 °C and 320 °C, respectively.

2.5 Volatile compounds

Volatiles were analyzed by solid-phase microextraction gas chromatography. Olive oil samples (2 g) spiked with 2.6 mg/kg of 4-methyl-2-pentanol (internal standard) were placed in a 20 ml glass vial, tightly capped with a polytetrafluoroethylene (PTFE) septum, and left for 10 min at 40 °C to allow for the equilibration of the volatiles in the headspace. After the equilibration time, the septum covering each vial was pierced with a solid-phase microextraction (SPME) needle, and the fiber was exposed to the headspace for 40 min. When the process was completed, the fiber was inserted into the injector port of the gas chromatograph (GC). The temperature and time of the preconcentration step, carried out on a Combipal (CTC Analytics AG, Zwingen, Switzerland), were automatically controlled by the software Workstation version 5.5.2 (Varian, Walnut Creek, CA). The SPME fiber (1 cm length and 50/30 μm film thickness) was purchased from Supelco (Bellefonte, PA), and it was endowed with the Stable Flex stationary phase of divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS). The fiber was previously conditioned following the instructions of the supplier. The volatiles absorbed by the fiber were thermally desorbed in the hot injection port of a GC for 5 min at 260 °C with the purge valve off (splitless mode) and deposited onto a TR-WAX capillary column (60 m, 0.25 mm i.d., 0.2 μm coating; Teknokroma, Barcelona, Spain) of a Varian 3900 gas chromatograph with a flame ionization detector (FID). The carrier gas was hydrogen, at a flow rate of 1.5 ml/min. The oven temperature was held at 40 °C for 10 min and then programmed to rise 3 °C/min to a final temperature of 200 °C, where it was held for 10 min to eliminate the memory effect of the capillary column. The signal was recorded and processed with the WorkStation (version 5.5.2) software. Each sample was analyzed in duplicate. The identification of the volatile compounds was first carried out by mass spectrometry and later checked with standards. The assessment of the aroma notes and the determination of the recovery factors were carried out as explained in a previous work (Morales *et al.*, 2005; Tena *et al.*, 2007).

2.6 Statistical analysis

Univariate and multivariate algorithms were applied by means of Statistica 8.0 Release 7 (Statsoft, 2008). The statistical study of the differences between the classes of samples (organic *vs.* non-organic virgin olive oils) was carried out by applying the Brown-Forsythe test. This analysis gives quite accurate error rates even when the underlying distributions for the raw scores deviate significantly from the normal distribution (Olejnik and Algina, 1987). The visualization of sample differences was carried out by cluster analysis, which is an unsupervised tool to understand the information of data matrices, and to describe the similarities and dissimilarities among objects (Aparicio, 2000). Principal component analysis (PCA) and multidimensional scaling (MDS) were also applied to visualize the differences between samples.

3 Results and discussion

The first study was focused on the evaluation of the virgin olive oil quality parameters of free acidity, peroxide value and UV absorbency. In accordance with the International Olive Council standards (IOC, 2013), their values, whichever they were from organic or non-organic farms, were lower than the limits for extra-virgin olive oils (EVOOs), and hence all

Table 2. Quality parameters of the samples studied.

Code	Acidity	Peroxide value	K_{232}	K_{270}	ΔK
	Mean ± std[1]	Mean ± std[1]	Mean ± std[1]	Mean ± std[1]	Mean ± std[1]
P1	0.18 ± 0.01	7.21 ± 0.29	1.76 ± 0.00	0.20 ± 0.00	0.00 ± 0.00
P2	0.16 ± 0.00	4.36 ± 0.03	2.07 ± 0.00	0.16 ± 0.01	0.00 ± 0.00
P3	0.12 ± 0.03	10.73 ± 0.06	1.74 ± 0.00	0.12 ± 0.00	0.00 ± 0.00
P4	0.15 ± 0.00	7.71 ± 0.42	1.80 ± 0.01	0.15 ± 0.00	0.00 ± 0.00
A1	0.59 ± 0.00	17.67 ± 0.22	2.40 ± 0.00	0.20 ± 0.00	0.01 ± 0.00
A2	0.20 ± 0.00	10.83 ± 0.06	2.30 ± 0.00	0.20 ± 0.00	0.00 ± 0.00
A3	0.17 ± 0.00	10.49 ± 0.06	2.24 ± 0.02	0.11 ± 0.00	0.00 ± 0.00
A4	0.29 ± 0.00	7.17 ± 0.13	1.73 ± 0.01	0.09 ± 0.00	0.00 ± 0.00
H1	0.30 ± 0.00	11.89 ± 0.01	2.08 ± 0.01	0.22 ± 0.01	0.00 ± 0.00
H2	0.14 ± 0.00	5.71 ± 0.13	1.71 ± 0.00	0.12 ± 0.01	0.00 ± 0.00
H3	0.15 ± 0.01	7.68 ± 0.30	1.87 ± 0.01	0.11 ± 0.00	0.00 ± 0.00
H4	0.19 ± 0.02	8.41 ± 0.08	1.50 ± 0.00	0.18 ± 0.00	0.00 ± 0.00
C1	0.18 ± 0.00	12.78 ± 0.42	2.46 ± 0.00	0.18 ± 0.00	0.00 ± 0.00
C2	0.21 ± 0.00	10.51 ± 0.44	1.49 ± 0.00	0.10 ± 0.00	0.00 ± 0.00
C3	0.11 ± 0.01	11.97 ± 0.08	2.22 ± 0.01	0.19 ± 0.00	0.00 ± 0.00
C4	0.24 ± 0.01	17.76 ± 0.10	2.30 ± 0.00	0.17 ± 0.00	0.00 ± 0.00

[1]: Standard deviation; Codes shown in Table 1.

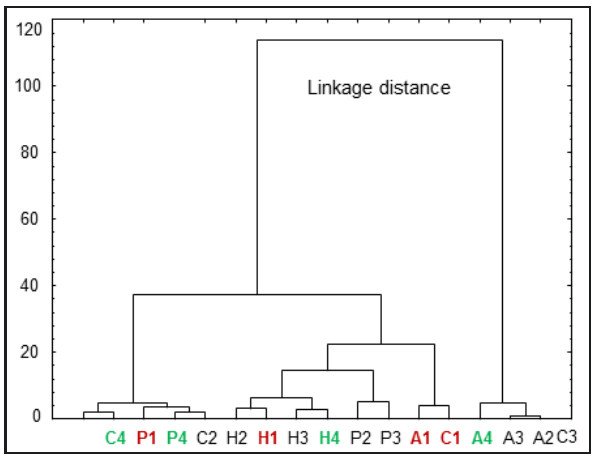

Fig. 1. Cluster analysis using quality parameters (note: Codes shown in Tab. 1).

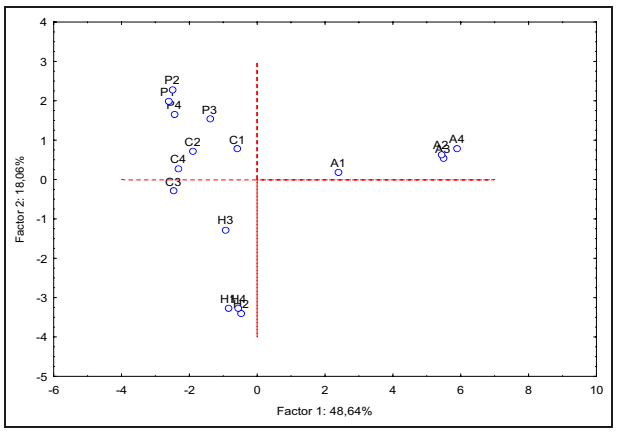

Fig. 2. Principal components analysis (PCA) of the samples characterized by fatty acids and sterols (note: Codes shown in Tab. 1).

the samples were classified as EVOOs (Tab. 2). An individual statistical analysis of these parameters in order to distinguish organic from non-organic VOOs showed, however, that there were significant differences in terms of free acidity and K_{270} by applying Brown-Forsythe test (p = 0.04 and 0.03, respectively) but there were not differences concerning the peroxide value, K_{232} and ΔK. The higher values of free acidity in organic EVOOs can be related with a certain infestation of the olives bactrocera oleae, prays oleae) and fungal diseases in the fruit (gloesporium, macrophoma, *etc.*) resulting from the absence of pesticides in the agricultural practices, while the values of K_{270} indicates a higher secondary oxidation as result of increasing amounts of conjugated trienes in organic EVOOs.

Those univariate statistical differences between organic and non-organic EVOOs are not pointed out when applying cluster analysis – an unsupervised multivariate statistical procedure – to the whole set of samples. Thus, Figure 1 shows the results of a cluster analysis where no differences between agricultural practices are observed, even produced in the same geographical location, but slightly between cultivars (var. Hojiblanca in particular).

The analysis of other chemical compounds responsible for purity (fatty acids and sterols) by principal component analysis (PCA) did not help to distinguish EVOOs in accordance with the agricultural practices but between cultivars (Fig. 2), which is already described in the bibliography (Aparicio and García-González, 2013; García-González *et al.*, 2013). This result points out that the absence of pesticides does not increase the hydrolysis phenomenon up to affect the percentage of unsaturated fatty acids in organic EVOOs. There were been found differences if the comparison had been between organic lampante-VOOs and non-organic EVOOs.

Volatiles are minor compounds of virgin olive oil that are responsible for aroma, and partially for flavor. The volatile profile may be different depending on the oil quality (Morales *et al.*, 2013). Thus, the virgin olive oils just obtained and characterized with an optimum quality contain volatile compounds that are exclusively formed through biochemical

Table 3. Volatile compounds analyzed in samples of virgin olive oil.

Code	Volatile	*Rt*	Code	Volatile	*Rt*	Code	Volatile	*Rt*
1	Heptane	0.16	18	Ethylbencene	0.82	35	E-3-hexen-1-ol	1.60
2	Octane	0.20	19	2-Methylbutyl acetate	0.83	36	Z-3-hexen-1-ol	1.65
3	Propan-2-one	0.21	20	E-2-Penten-1-ol	0.84	37	Nonan-2-one	1.66
4	Methyl acetate	0.23	21	1-Penten-3-ol	0.97	38	2,4-Hexadienal	1.70
5	Ethyl acetate	0.26	22	Heptan-2-one	1.04	39	E-2-hexen-1-ol	1.72
6	Butan-2-one	0.27	23	Limonene	1.07	40	Z-2-hexen-1-ol	1.74
7	2-Methylbutanal	0.28	24	3-Methylbutan-1-ol	1.13	41	E-2-octenal	1.76
8	3-Methylbutanal	0.29	25	E-2-hexenal	1.14	42	Acetic acid	1.82
9	Ethanol	0.32	26	Pentan-1-ol	1.27	43	1-Octen-3-ol	1.83
10	Ethyl propanoate	0.35	27	3-Methyl-2-buten-1-ol acetate	1.28	44	Methyl nonanoate metilo	1.93
11	Pentanal	0.38	28	Hexyl acetate	1.30	45	Decanal	1.95
12	Pentan-3-one	0.38	29	1,2,4-Trimethylbencene	1.33	46	E-2-nonenal	2.03
13	4-Methyl-2-pentanone	0.45	30	Octanal	1.37	47	Propanoic acid	2.04
14	Methylbencene	0.53	31	Z-3-hexenyl acetate	1.46	48	Octan-1-ol	2.10
15	2-Methyl-3-buten-2-ol	0.55	32	Z-2-penten-1-ol	1.47	49	Methyl decanoate metilo	2.19
16	Hexanal	0.67	33	6-Methyl-5-hepten-2-one	1.52	50	Pentanoic acid	2.49
17	2-methylpropan-1-ol	0.73	34	Hexan-1-ol	1.59	51	Heptanoic acid	2.94

Rt: Retention time relative to 4-methyl-pentan-2-ol.

Table 4. Average concentration (mg/kg) of volatile compounds in organic and non-organic virgin olive oils.

Volatile Series	Organic VOO mean ± std[1]	Non-organic VOO mean ± std[1]
Hydrocarbons	0.086 ± 0.029	0.051 ± 0.006
Ketones	0.389 ± 0.092	0.189 ± 0.013
Esters	0.623 ± 0.035	0.480 ± 0.092
Aldehydes	0.729 ± 0.099	0.963 ± 0.110
Alcohols	2.193 ± 0.370	1.556 ± 0.191
Acids	0.281 ± 0.061	0.284 ± 0.073

[1]: Standard deviation.

pathways, regulated by enzymes. On the contrary, the low quality virgin olive oils show a more complex volatile profile including a higher number of compounds that are responsible for off-flavours and explain the occurrence of sensory defects in these oils (*e.g.*, rancid, winey-vinegary, fusty, musty-humidity) (Morales *et al.*, 2005).

Table 3 shows the volatiles compounds identified in the samples, together with their codes and relative retention times using 4-methyl-pentan-2-ol internal standard. Five compounds were hydrocarbons, 7 ketones, 9 esters, 10 aldehydes, 16 alcohols, and 5 acids. Most of the latter were found in traces due to the fact that the oils were of good quality, and acids are characteristics of lampante virgin olive oils. The rest of volatile compounds are commonly present in virgin olive oils, including those of extra virgin category.

The results of volatile analysis show that in general terms the organic virgin olive oils showed a higher concentration of volatile compounds (Tab. 4), except for the aldehydes, whose concentration was higher in the non-organic oils, and the acids, whose concentration was similar in the both oil classes. The concentration values of ketones, aldehydes, alcohols showed significant variations between the two types of oils with a confidence level of 95%.

Table 5 shows the average values and the standard deviation of the concentrations quantified in organic and non-organic virgin olive oils for those compounds that showed a significant variation between the two kinds of samples ($p < 0.05$). In all cases the concentration values were higher for the organic oils. It is important to note that most of them contribute to the aroma with negative sensory notes. However, in all cases, excepting 1-octen-3-ol, the odour threshold was higher than their respective concentrations, thereby it is expected that these differences do not have a considerable sensory impact.

Considering the differences in the concentration of these compounds in the two groups, a Multidimensional Scaling Analysis (MDS) was applied to the data to check the ability of these compounds to differentiate organic and non-organic oils. Figure 3 shows the result of this statistical analysis. Samples were grouped in two classes, the non-organic oils having negative scores for the dimension 1, while the organic samples were located in the positive part of the axis. The latter were also characterized by a high degree of dispersion compared to the non-organic oils. This result may point out a greater influence of several agronomical factors (climate, soil, *etc.*) on non-organic samples, where the agricultural practices may be less homogenous.

The results shown in this study lead to the conclusion that the organic virgin olive oils presented slightly worse values in terms of quality parameters, which can be explain by the absence of treatment applied to the olive trees. Thus, the higher acidity of these samples point out more incidence of hydrolysis and a consequent higher concentration of free fatty acids. On the other hand, the unsaturated fatty acids, although did not show significant differences, they still allow the classification of samples under the basis of crop conditions. It is important to note that many volatiles compounds responsible for the oil sensory quality comes directly from some fatty acids, volatiles being the chemical

Table 5. Average concentration (mg/Kg) and standard deviation, odour threshold (mg/Kg) and sensory characteristics of the selected volatile compounds distinguishing organic and non-organic virgin olive oils.

Compound	Non-organic VOO mean ± std[1]	Organic VOO mean ± std[1]	Odour threshold	Sensory descritors
Propan-2-one	0.09 ± 0.01	0.25 ± 0.08	–	Fruity, pear
2-methyl propanol	0.006 ± 0.001	0.015 ± 0.005	1.0	Intense, wine
Methyl-2-butyl acetate	0.007 ± 0.001	0.016 ± 0.004	2.0	Green, banana
Heptan-2-one	0.005 ± 0.001	0.012 ± 0.003	0.30	Wet earth
Octanal	0.002 ± 0.0005	0.005 ± 0.0008	0.32	Fatty, pungent
1-Octen-3-ol	0.003 ± 0.0006	0.008 ± 0.0004	0.001	Mould, earth

[1]: Standard deviation.

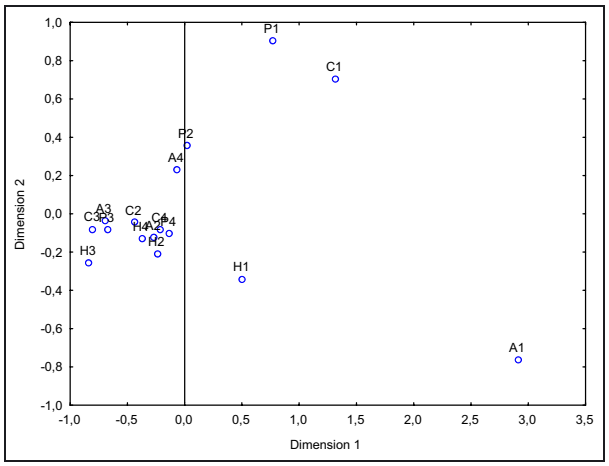

Fig. 3. Results of applying Multidimensional Scaling (MDS) to the concentration values of volatile compounds determined in organic and non-organic virgin olive oils (note: Codes shown in Tab. 1).

variable that allowed a better discrimination between organic and non-organic samples.

These results obtained from a small number of organic samples (4), although good representative of the mono-varietal organic Spanish VOOs, are going to be checked with a further study extended to a large set of samples from other geographical provenances, cultivars and so on.

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