Influence of Ecological Cultivation on Virgin Olive Oil Quality

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ABSTRACT: The quality of oil extracted from ecologically cultivated olives of the Picual variety was compared with oil extracted from Picual olives cultivated using conventional methods. Olive trees were grown in a two-section plot. Fruits from each plot were harvested at various stages of ripeness, and acidity value, peroxide index, ultraviolet absorption at 232 and 270 nm, stability to oxidation, sensory analysis, fatty composition, and contents of tocopherols, phenolic compounds, and sterols were determined on oil extracted from each treatment. The results showed that the organic virgin olive oil was of a superior quality to the conventional virgin olive oil in all the quality parameters analyzed.

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KEY WORDS: Ecological cultivation, quality, virgin olive oil.

Agronomic factors, as well as elaboration, packing and preservation, have an influence on olive oil quality. Olive oil quality prior to fruit arrival at the mill is influenced by variety, cultivation techniques, and the environmental conditions of the olive grove (1). Organic olive oil is considered to be that extracted from the fruit of an ecologically cultivated grove,which is elaborated and stored in officially registered mills and packagers. In considering the standards of organic agriculture, high quality can be expected of organic olive oils (2–4).

In spite of the growing interest in organically cultivated fruits and vegetables in national and international markets, there are few reports on the qualitative (5), nutritional (6–8), and organoleptic (9,10) characteristics of these products. To our knowledge, there are no reports dealing with any kind of organic olive oil even though there has been a threefold increase in land devoted to the production of organic olive oil in Andalucía (from 2,685 Ha, to more than 9,000 Ha) in the past 2 yr. This increase accounts for more than 50% of total land devoted to all organic agriculture in Spain.Thus, lack of information led us to the present study. Our objective was to characterize differences in quality in virgin olive oil, extracted from the same variety, grown under ecological conditions or conventional cultivation methods.

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MATERIALS AND METHODS

Materials. Samples of the olive variety Picual were taken from a 65-Ha plot in Luque (Córdoba, Spain) near Baena. The plot was divided into two sections: one using ecologic cultivation methods and the other employing conventional methods. The trees were planted on a 10 × 10 m grid. The organic section was fertilized with liquid herbal manure (alfalfa, thyme, and rosemary as compost) applied at 100 to 200 mL/Ha in spring; animal manure, oil-foot, and leaves were used in the autumn. The most common pest of this area, “Prays” (*Prays oleae* Bern), was treated with *Bacillus thuringiensis*; and the “Fly” (*Dacus oleae* Rossi) was controlled with natural pyrethrins. The most widespread disease, “Repilo” (*Cycloconium oleaginum* Cast), was treated with Bordeaux mixture. In addition, *Opius concolor szpl* was released as a predator of the Fly and *Chrysopa carnea steph* as a predator of Prays.

In the conventionally grown olive groves, urea and potassium nitrate were used as fertilizers. Pests were treated using malathion [*O,O*-dimethyl and *S*-(1,2-diethoxycarbonylethyl) dithiophosphate, Agrodan S.A., Madrid, Spain], at a level of 20–25 kg/Ha; and Formothion, [*O,O*-dimethyl and *S*-(*N*-formyl-*N*-methylcarbamoyl) dithiophosphate, Sandoz, Barcelona, Spain], 33% wt/vol, at a level of 1 to 1.5 L/Ha. Diseases were treated with Bordeaux mixture. Simazine, [2-chloro-4,6-bis(ethylamino)-1,3,5-triazine, Sipcam Inagra, Valencia, Spain], 50% wt/vol, at a level of 4 L/Ha was used as a preemergent herbicide. Glyphosato *N*-phosphoromethyl)-glycine, Sipcam Inagra), 12% wt/vol, at 2 L/Ha with Oxifluorfen, [2-chloro-1-(3-ethoxy 4-nitrophenoxy)-4-trifluoromethylbenzene, Rhône-Poulenc, Madrid, Spain], 24% (wt/vol) at 4 L/Ha was used a postemergent herbicide in the autumn.

Samples of olive fruit were harvested at four stages of maturity with ripeness indexes (R.I.): 3.5, 4, 4.5, and 5. In order to establish treatments, 5-kg olive samples were collected at weekly intervals. R.I. were determined, and harvested fruits were immediately subjected to the Abencor extraction process (11). This method reproduced the industrial process of milling, beating, centrifuging, and decanting on a laboratory scale. The apparatus consisted of three essential elements: the mill, the thermobeater, and the pulp centrifuge.

Analytical methods. (i) R.I. This was determined according to the guidelines of the Estación de Olivicultura y

Elaiotecnia, Jaén, which define ripeness as a function of fruit color in both skin and pulp (12). Samples of olives, 100 from each treatment, were taken at random and were classified into the following categories: 0—olives with intense green or dark green epidermis (*a*); 1—olives with yellow or yellow-green epidermis (*b*); 2—olives with reddish yellow epidermis (*c*); 3—olives with reddish or light violet epidermis (*d*); 4—olives with black epidermis, and totally white pulp (*e*); 5—olives with black epidermis, and violet pulp to the midpoint (*f*); 6—olives with black epidermis, and violet pulp almost to the pit (*g*); 7—olives with black epidermis, and totally dark pulp (*h*). The R.I. was calculated from Equation 1, where alphabetic variables indicate the number of fruits in each category.

$$\text{R.I.} = (a \times 0 + b \times 1 + c \times 2 + d \times 3 + e \times 4 + f \times 5 + g \times 6 + h \times 7)/100 \quad [1]$$

(ii) Chemical analysis. The measurements of free acidity (% of oleic acid), peroxide index (meq peroxidic oxygen/kg), and specific extinction coefficients K_{232} and K_{270} (absorbancies 1%, 1 cm, at 232 and 270 nm), fatty acids, and sterols were carried out according to European Official Methods of Analysis (13). Total polyphenol and orthodiphenols were determined by colorimetry using the Folin-Deni reagent or ammonium molybdate (14). Tocopherols were evaluated by high-performance liquid chromatography according to the IUPAC Regulation No. 2432 (15).

(iii) Measurement of oxidative stability. Stability of virgin olive oils was determined by Rancimat (Metrohm Co., Basel, Switzerland) analysis at 100°C with an air flow of 10 L/h. The results are expressed as induction time in hours (16).

(iv) Sensory analysis. Sensory analysis was performed at the Instituto de la Grasa by an analytic panel consisting of 10 to 12 specially selected and trained tasters working under regulated and controlled conditions. The descriptive technique and the overall assessment technique were carried out according to European Official Methods of Analysis (13). The de-

TABLE 1
Quality Parameters and Significant Differences in the Means of the Same Treatment (q) and Between Treatments (r)[a]

		Ripeness index				
Parameter	Culture	3.5	4	4.5	5	Mean
Acidity (as % of oleic acid)	Conventional	0.4c	0.6b	1.1a	1.1a(q)	0.8
	Ecological	0.2c	0.2c	0.4a	0.4a	0.3
		***	***	***	***(r)	**
Peroxide ($mg\ O_3/kg$)	Conventional	4.7d	4.6d	7.4b	7.8a	6.1
	Ecological	4.2b	4.0b,c	3.9c	4.8a	4.2
		***	***	***	***	*
K_{232} (1%, 1 cm)	Conventional	1.6a,b	1.5b	1.7a	1.7a	1.6
	Ecological	1.6a	1.6a	1.5a	1.4b	1.5
		NS	NS	**	***	NS
K_{270} (1%, 1 cm)	Conventional	0.1a	0.1a	0.1a	0.1a	0.1
	Ecological	0.1a	0.1a	0.1a	0.1a	0.1
		NS	NS	NS	NS	NS
Stability (Rancimat)	Conventional	83.4a	64.6b	30.9c	29.2c	52.0
	Ecological	111.4a,b	113.2a	57.6c	60.2c	85.6
		***	***	***	***	**
Organoleptic score	Conventional	7.0a	6.5a	5.4b	4.5c	5.8
	Ecological	7.8a	7.8a	7.1b	6.9b	7.4
		**	***	***	***	**
Green fruit	Conventional	1.3a	0.7b	0.6b	0.3b	0.7
	Ecological	2.5a	2.5a	1.3b	1.2b	1.9
		**	**	**	*	**
Mature fruit	Conventional	1.2b	1.2b	1.6a	1.8a	1.4
	Ecological	0.2b	0.7b	1.1a	1.2a	0.8
		**	**	NS	NS	**
Bitter	Conventional	1.5a	1.5a	1.0b	0.9b	1.2
	Ecological	2.7a	2.8a	1.0b	1.5b	2.0
		*	**	NS	*	*
Spicy	Conventional	2.0a	1.4b	0.8c	0.6c	1.2
	Ecological	2.6b	3.3a	1.1c	1.1c	2.0
		*	**	NS	*	*

[a]Overall means are shown. Different letters within the same row indicate a significant difference at 5% level (Duncan's test). Degree of differences within the same column (Student's test): NS = not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

scriptive analysis used a six-point intensity scale ranging from 0 (no perception) to 5 (extreme). Overall grading used a nine-point scale from 1 (lowest quality) to 9 (optimal quality). According to the total points obtained, oils were classified as "Extra" ≥ 6.5, "Virgin" ≥ 5.5, "Common" ≥ 3.5, and "Lampant" < 3.5.

*Statistical analysis.*The statistical variance analysis, Duncan tests, were used to compare different means. Student tests were used determine differences in the means obtained for the two cultivations at each ripeness stage. Paired comparison tests were used to show the overall effect of the type of cultivation (organic or conventional) in each parameter by means of the comparison of the two overall means obtained for each ripeness stage (17–19).

RESULTS AND DISCUSSION

Data shown in Table 1 demonstrated that the various quality parameters are influenced by the type of cultivation. Overall mean values of the oils from organically cultivated olive trees exhibited higher quality, e.g., lower acidity value, lower peroxide index, higher stability and higher organoleptic scoring. There was a significant difference in the peroxide index and very significant differences in acidity, stability, and overall organoleptic scoring. The specific extinction coefficients K_{232} and K_{270} were not statistically significant.

In both the conventional and the ecologic oils, acidity values increased as fruit ripened, and in both cases were 2.5 times higher at R.I. 5 than at 3.5. The upper limit of 1% for acidity values of "Extra" oils was surpassed in the last two ripeness stages in the conventional oil group. In terms of the peroxide index, organic and conventional oils were very different. Peroxide index in the organic oils remained almost constant, but it increased considerably in the last ripeness stages of the conventional treatment. The limit set for "Extra" oils is 20 meq O_2/kg of oil. The specific extinction coefficient K_{232} and K_{270} remained constant for all treatments. The limits for "Extra" oils for K_{232} of 2.40 and 0.20 for K_{270} were not reached. Stability values decreased in both groups of oils with ripeness, as a consequence of loss of polyphenols and *o*-diphenols. The

TABLE 2
Fatty Acid Content (%), α-Tocopherol, *o*-Diphenols, and Polyphenols (ppm)[a]

		Ripeness index				
Chemical component	Culture	3.5	4	4.5	5	Mean
Palmitic acid	Conventional	11.0a	11.0a	11.2a	10.7[q]	11.0
	Ecological	9.6a	9.5a	9.6a	10.2a	9.7
		**	**	**	NS[r]	*
Palmitoleic acid	Conventional	0.8a	0.8a	0.8a	0.8a	0.8
	Ecological	0.7a	0.6a	0.7a	0.7a	0.7
		*	**	*	*	*
Stearic acid	Conventional	4.5a,b	4.7a	4.1b	4.2b	4.3
	Ecological	3.9b	3.8b	4.5a	4.4a	4.1
		*	**	NS	NS	NS
Oleic acid	Conventional	78.3a	77.3a	74.5b	75.0b	76.3
	Ecological	88.8a	81.9a	79.5b	78.6b	80.2
		**	**	**	NS	**
Linoleic acid	Conventional	4.0b	4.5b	7.5a	7.3a	5.8
	Ecological	3.0a	3.0a	3.9a	4.0a	3.5
		*	*	***	***	*
Linolenic acid	Conventional	0.7b	0.8b	0.9a	0.9a	0.8
	Ecological	0.8a	0.8a	0.8a	0.8a	0.8
		NS	NS	NS	NS	NS
Arachidic acid	Conventional	0.4a	0.4a	0.4a	0.4a	0.4
	Ecological	0.4a	0.4a	0.4a	0.4a	0.4
		NS	NS	NS	NS	NS
α-Tocopherol	Conventional	154.4c	157.9c	185.8a	173.9b	168.0
	Ecological	211.7b	184.6c	228.3a	211.6b	209.0
		***	***	***	***	***
o-Diphenols	Conventional	8.9a	4.4b	2.9b	0.0c	4.0
	Ecological	13.2a	10.4b	4.8c	5.6c	8.5
		**	***	***	***	**
Polyphenols	Conventional	85.1a	69.2b	41.9c,d	21.4d	54.4
	Ecological	202.5a	143.4b	46.6c	14.0d	101.6
		***	***	NS	NS	***

[a]Abbreviations as in Table 1.

organoleptic values decreased in both groups as fruit ripened but were more notable in conventional oils. This decrease may be due to the loss of intensity and balance in the positive attributes such as green and mature fruit flavor. The overall mean "green-fruity" intensity was almost three times higher in the organic oils than in the conventional oils. The "mature fruity" intensity was higher in the first two ripening stages in conventional oils. However, organic oils remained within the "Extra" quality limits with an overall score of ≥6.5 for all ripening stages, whereas conventional oils kept this overall score only during the first two ripening stages.

Table 2 shows the content of fatty acids as well as of α-tocopherol, *o*-diphenol, and polyphenol of both oil groups. Over treatments, oleic acid concentration tended to be lower, and linoleic acid higher in conventional oils. There were almost no treatment effects on the levels of other fatty acids. There were extremely significant differences in α-tocopherol contents (higher values in organic oils) between the two groups of oils ($P < 0.001$). This resulted in a very significant difference ($P < 0.01$) in the overall mean values for both types, with α-tocopherol content being 1.3 times higher in the organic oils. The levels of *o*-diphenols and polyphenols followed a similar pattern in both types of oils but remained higher in the organic oils for all ripening stages. This gave rise to large differences between the overall mean values of the two oils.

The analysis of sterol composition is shown in Table 3. The main effects of treatments on individual sterol levels appeared to be directed upon Δ^5 avenasterol concentration, which was significantly greater in the conventional oils. Campesterol was slightly higher in the ecologic oil, but never surpassed 4% of total sterols (the maximum permitted for "Virgin" oils). However, total sterol content remained constant over all ripening stages in both types of

TABLE 3
Sterols Content (ppm)[a]

Sterols	Culture	Ripeness index 3.5	4	4.5	5	Mean
Cholesterol	Conventional	2.6a	1.8a	2.0a	2.2a(q)	2.2
	Ecological	2.2a	1.9a	2.8a	1.5a	2.1
		NS	NS	NS	NS(r)	NS
Campesterol	Conventional	43.4a	47.8a	41.8b	43.2a,b	44.0
	Ecological	48.1a	51.4a	46.4b	45.0b	47.7
		*	*	*	NS	*
Campestanol	Conventional	3.7b	4.6a	4.8a	3.8b	4.2
	Ecological	5.0a	4.5b	4.9a	4.1b	4.6
		***	NS	NS	*	NS
Stigmasterol	Conventional	9.6c	12.6c	15.2b	16.8a	13.5
	Ecological	9.8b	9.9b	13.0a	12.7a	11.3
		NS	**	**	**	*
Clerosterol	Conventional	13.2b	13.0b	14.2a,b	16.0a	14.1
	Ecological	14.4a	14.1a	13.8a	15.0a	14.3
		NS	NS	NS	NS	NS
β-Sitosterol	Conventional	1112b	1130b	1178a,b	1238a	1164
	Ecological	1142a	1213a	1156a	1150a	1165
		NS	NS	NS	NS	NS
Δ5-Avenasterol	Conventional	116.3a,b	121.6a	108.6c	110.7c	114.3
	Ecological	84.6b	93.8a	97.0a	96.0a	92.8
		***	***	**	**	**
Δ5,24-Stigmastadienol	Conventional	6.0a	5.9a	6.9a	5.9a	6.2
	Ecological	4.6a,b	5.0a,b	5.6a	5.2a,b	5.1
		*	NS	*	NS	*
Δ7-Stigmastenol	Conventional	2.5b	3.3b	5.2a	3.0b	3.5
	Ecological	3.9a	2.5a	4.0a	3.1a	3.4
		NS	NS	NS	NS	NS
Δ7-Avenasterol	Conventional	3.0b	2.9b	7.4a	5.8a	4.8
	Ecological	4.2a	2.8b	3.1b	4.3a	3.6
		*	NS	**	*	*
Totals	Conventional	1310b	1340a,b	1380a,b	1438a	1367
	Ecological	1316a	1363a	1344a	1330a	1338
		NS	NS	NS	*	NS

[a]Abbreviations as in Table 1.

oil, and there were no significant differences between treatments.

Consumer demand has caused an increase in the production of ecologic foods in Spain. These data suggest that ecologically grown olives produce higher-quality oil. Therefore, these data, which are unique in the literature, support this change in cultivation practices.

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