SHORT COMMUNICATION

Effect of Saline Irrigation Water on Olive Oil Composition

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Virgin olive oils were obtained in Egypt from fruits of olive trees irrigated with waters of different salinity concentration (control, 1800, 3600 and 6000 ppm) during the 1992 season. The effect of water salinity on olive oil fatty acid, fatty acid location in triacylglycerol moiety, triacylglycerol, sterol and tocopherol composition was determined. Oleic acid slightly increased and linoleic decreased in the total fatty acid composition, as well as on glycerol carbon-2 and -1(3), with increased water salinity. Trioleoyl, stearoyldioleoyl and palmitoyldioleoyl glycerols are slightly increased with increased water salinity. Total tocopherol was 87.7 mg/kg in the control and increased to 147.0 mg/kg for water with 1800 ppm salinity. At higher salinity concentration, total tocopherol decreased to 107.2 and to 89.1 mg/kg for water salinities of 3600 and 6000 ppm, respectively. The same trend was observed for α, β and γ-tocopherols. Campesterol and β-sitosterol were increased with water salinity of 1800 ppm and decreased when water salinity increased further. Stigmasterol increased at water salinity of 3600 ppm and decreased sharply when the salinity was increased to 6000 ppm. These olive oil composition studies showed that although water salinity may have some compositional effects, there was no major adverse effect on fatty acid, triacylglycerol, triacylglycerol fatty acid location, sterol and tocopherol composition for oil from olives of trees grown with water with a salt composition of up to 6000 ppm.

KEY WORDS: Fatty acids, irrigation, olive oil, stereospecific analysis, sterols, tocopherols, triacylglycerols.

Olive oil (*Olea europaea* L., *Oleaceae*) is the major edible vegetable oil produced in the Mediterranean basin (Spain, Italy, Greece, Tunisia, Morocco and Libya). Olive production also is rapidly expanding in Egypt, where the cultivated area planted in olive groves has increased greatly in the last five years. Most of this new area is reclaimed land that is irrigated with saline water (1800–6000 ppm salt). Olive oil composition has been studied by many authors (1–19). However, few reports have considered the effect of saline water on oil quality. Here we report the composition of virgin olive oils from olive groves that were irrigated with saline water.

EXPERIMENTAL PROCEDURES

Materials. Crude olive oil was pressed from fruit (5 kg) and stored at −10°C before analysis. The olive fruits were obtained from olive trees in Egypt (Picual variety) irrigated by water of normal salt concentration or by saline water at 1800, 3600 and 6000 ppm salt. Normal (control) water contained 320 ppm salt.

Methods. The triacylglycerols (TAG) were purified by solid-phase extraction of the crude oil. TAG composition was determined by reversed-phase high-performance liquid chromatography (RP-HPLC). These methods, plus protocol for lipolysis and fatty acid analysis by gas chromatography (GC), were described previously (20).

Sterol composition was determined by the method described elsewhere (21), with a slight modification. Sample size was 100 mg of crude olive oil, and derivatization was carried out with *bis*(trimethylsilyltrifluoroacetamide) (Regis Chemical Co, Morton Grove, IL). A Varian 3400 GC containing an SP-2380 (0.25 mm × 30 m) capillary column (Supelco, Inc., Bellefonte, PA) was used for analysis. The conditions for the analysis were: initial column temperature, 270°C for 20 min, followed by an increase to 290°C at 3°C/min; injector temperature 275°C; and the flame-ionization detector (FID) temperature was 300°C.

Tocopherols were determined directly as described previously (22), except that the crude oil was diluted 1:1 with hexane. The HPLC pumps were a Thermo Separation system (Thermo Separation Product, Fremont, CA). Tocopherols were detected by an Applied Biosystem 980 programmable fluorescence detector (Applied Biosystems, Ramsey, NJ). The HPLC system was equipped with a Waters Bondapak NH_2 (3.9 × 300 mm) column (Millipore Waters Chromatography, Milford, MA). The solvent system consisted of hexane/isopropanol (99:1, vol/vol). The mobile phase was pumped at 1 mL/min. Conditions for the HPLC–fluorescence detector were an emission wavelength of 345 nm, an excitation wavelength of 298 nm and a range of 1.

RESULTS AND DISCUSSION

The olive orchards had been irrigated for six years, with one grove irrigated with the control water and one grove each with saline water of 1800, 3600 and 6000 ppm salt, respectively. The irrigation occurred two hundred times per year according to the following system: January and December, one time per week; February and November, two times per week; March and October, three times per week; April and September, one time every two days; May, June and August, one time per day. The amount of water used in each irrigation was 80 L per tree. The oil content per olive fruit was 20% regardless of irrigation water salinity. Each oil sample investigated was a triplicate mixture (1:1:1, vol/vol/vol) of three samples of extracted oil. Fatty acid composition of olive oils from normal and saline irrigation treatments is tabulated in Table 1. Oleic acid, the most abundant fatty acid in all samples of olive oil (66.6–70.6%), showed a slight increase in concentration for trees irrigated with saline water as compared to trees irrigated with the control water. Palmitic acid was 16.4% in the control, and the concentration had a minor decrease to 14.8% for olive trees irrigated with saline water. Linoleic acid decreased from 11.5% in the control to 8.4, 7.9 and 9.1% for 1800, 3600 and 6000 ppm salt in irrigation water,

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TABLE 1

Effect of Irrigation Water Salinity on Fatty Acid Composition[a] and Location[b] in Triacylglycerols of Olive Oil (Picual variety)

Olive oil fatty acid composition/location	Water salinity (%) at control (320 ppm)	at 1800 ppm	at 3600 ppm	at 6000 ppm
Fatty acid composition				
16:0	16.4	14.8	14.8	14.9
16:1	2.5	2.0	2.2	1.6
18:0	2.2	3.8	3.3	3.1
18:1	66.6	69.8	70.7	70.6
18:2	11.5	8.4	7.9	9.1
18:3	1.1	1.3	1.2	0.6
Fatty acid location on glycerol carbon-2				
14:0	0.3	0.3	0.2	0.2
16:0	0.8	0.9	1.3	0.9
16:1	1.8	1.7	2.0	1.3
18:0	0.1	0.3	0.3	0.3
18:1	81.3	84.7	83.6	84.1
18:2	14.7	11.3	11.7	12.3
18:3	1.0	0.9	1.0	1.0
Fatty acid location on glycerol carbon-1(3)				
16:0	24.2	21.7	21.6	21.9
16:1	2.8	2.2	2.3	1.8
18:0	3.4	5.6	4.7	4.5
18:1	59.3	62.3	64.2	63.9
18:2	9.4	6.9	6.0	7.7
18:3	1.2	1.4	1.3	0.4

[a]Fatty acid composition (Ref. 20).
[b]Fatty acid location on glycerol 1(3): [(3 area % in triglyceride) − (area % in monoglyceride)]/2 (Ref. 20).

respectively. Thus, there was no major change in fatty acid composition due to saline water irrigation.

The fatty acid location in the glyceride is presented in Table 1. Oleic acid was more abundant at glycerol carbon-2 (81.3–84.7%) than at glycerol carbon-1(3) (59.2–64.2%). However, oleic acid was still the predominant acid at all three positions. Linoleic acid was more abundant at glycerol carbon-2 (11.3–14.7%) than on glycerol carbon-1(3) (6.0–9.4%). Palmitic acid was predominantly located on glycerol carbon-1(3) (21.6–26.4%). These data are in agreement with that mentioned by Brockerhoff and Yurkowski (3), Brockerhoff *et al.* (4), and Christie *et al.* (17). Inspection of the fatty acid location composition data shows only a slight oleic acid increase and linoleic acid decrease with respect to glycerol carbons for the normal saline level as compared to saline irrigation water for the oil TAG. The other fatty acids showed no trend with regard to location in the oil TAG with respect to water salinity. Apparently, oils of fruits from trees irrigated with saline water show only minor changes in fatty acid location on each glycerol moiety, i.e., oleic acid increased and linoleic acid decreased slightly at glycerol carbon-2 and carbon-1(3), respectively.

TAG of olive oil samples under investigation were separated and analyzed quantitatively by RP-HPLC with FID. These data are tabulated in Table 2. The data in Table 2 show POO as the major TAG in the control olive oil (29.9%), followed by 26.9% OOO, 8.3% LOO, 7.9% POP, 7.7% LOP and 3.7% SOO (where P, O, L, S represent palmitic, oleic, linoleic and stearic acids, respectively) and TAG of the other olive oil samples have the same order, but slightly different concentrations. The TAG OOO, POO and SOO increased slightly, from 26.9% in the control for

TABLE 2

Effect of Irrigation Water Salinity on Triacylglycerol (TAG) Composition[a] of Olive Oil (Picual variety)

Olive oil TAG	Water salinity (%) at control (320 ppm)	at 1800 ppm	at 3600 ppm	at 6000 ppm
LLL	0.3	0.1	0.1	0.1
LnLO	0.5	0.2	0.2	0.3
LnLP	0.3	0.1	0.1	0.2
LLO	1.7	1.0	1.0	1.3
LnOO	1.9	1.3	1.3	1.5
LLP	1.4	0.7	0.6	0.9
LnOP	1.2	0.7	0.8	0.2
LnPP	0.1	0.8		0.1
LOO	8.3	7.3	7.2	7.7
LLS	3.0	3.1	3.1	2.5
LOP	7.7	5.8	5.9	6.5
Unknown	2.2	1.9	2.1	1.7
PLP	1.1	0.8	0.8	0.9
OOO	26.9	30.2	31.3	31.4
POO	29.9	31.8	31.7	30.9
POP	7.9	7.1	7.3	6.8
PPP	0.3	0.5	0.4	0.3
SOO	3.7	5.1	4.4	4.1
SOP	0.9	1.4	1.2	1.3
PPS	0.5	0.5	0.5	0.5
PSS	0.3	0.5	0.3	0.4
SSS	0.1	0.1	0.1	0.2

[a]TAG composition determined by reversed-phase high-performance liquid chromatography (Ref. 20).
[b]Abbreviations: P, palmitic acid; S, stearic acid; O, oleic acid; L, linoleic acid; Ln, linolenic acid. Positional TAG isomers are not separated.

TABLE 3

Effect of Irrigation Water Salinity on the Sterol and Tocopherol Composition of Olive Oil (Picual variety)[a]

Olive oil sterol/tocopherol composition	Water salinity (%)			
	at control (320 ppm)	at 1800 ppm	at 3600 ppm	at 6000 ppm
Sterols				
Total (mg/kg)	2666.7	2799.1	2937.7	1954.7
Campesterol (%)	9.5	3.6	6.4	7.4
Stigmasterol (%)	1.9	0.7	2.9	0.9
β-Sitosterol (%)	88.6	95.7	90.7	91.7
Tocopherols				
Total (mg/kg)	87.7	147.0	107.2	89.1
α-Tocopherol (%)	86.1	82.8	70.2	85.7
β-Tocopherol (%)	4.1	3.5	12.8	11.0
γ-Tocopherol (%)	9.8	13.7	17.0	3.3

[a]Sterol and tocopherol analysis methods given in the Experimental Procedures section.

OOO to 30.2, 31.3 and 31.4%; from 29.9% in the control for POO to 31.8, 31.7 and 30.9%; and from 3.7% in the control for SOO to 5.1, 4.4 and 4.1%, for the olive oil obtained from fruit of olive trees irrigated with water of salinity 1800, 3600 and 6000 ppm, respectively. TAG LOP was decreased as a result of high-salinity water, whereas TAG POP is erratic but decreased slightly. Apparently, irrigation water salinity had little effect on TAG composition of the olive oils. The measured TAG abundance order for olive oil agreed with the results of other authors (2,11,14, 16,19).

Sterol and tocopherol compositions, determined in olive oils from trees irrigated with control and high-salinity waters, are presented in Table 3. Campesterol was 253.1 mg/kg in the sample for trees irrigated with the control water. For high-salinity water irrigation, the sterol content increased to 369.4 mg/kg for water at 1800 ppm salinity. However, when the irrigation water salinity increased further, the campesterol content decreased to 144.7 mg/kg for water of 6000 ppm salinity. The same trend was found in the case of β-sitosterol. Stigmasterol was 50.5 mg/kg for the control and decreased with increased salinity, except for 3600 ppm salinity, where stigmasterol increased to 84.3 mg/kg.

The total tocopherol was 87.7 mg/kg in the control and increased to 147.0 for water of 1800 ppm salinity, but then decreased at higher salinity concentrations to 107.0 and 89.1 mg/kg for salinity of 3600 and 6000 ppm. Nevertheless, total tocopherol remained slightly higher for olive oils from trees irrigated with high-salinity water than with control water. α-Tocopherol was 75.5 mg/kg for control water and increased sharply to 121.7 mg/kg in the case of water salinity of 1800 ppm. For water salinity of 3600 and 6000 ppm, α-tocopherol was nearly the same as the control. β-Tocopherol was 3.6 mg/kg in the control and increased with water salinity, and the most increase was found for water salinity of 3600 ppm (13.7 mg/kg), followed by 6000 ppm (9.8 mg/kg) and 1800 ppm (5.1 mg/kg). γ-Tocopherol was 8.6 mg/kg oil in the control and increased to 20.2 mg/kg for water salinity of 1800 ppm and to 18.2 mg/kg for water salinity of 3600 ppm. γ-Tocopherol was less for salinity of 6000 ppm than for the control.

In conclusion, water with up to 6000 ppm salt had no adverse effect on olive oil fatty acids, fatty acid location in TAG, TAG composition, and sterol and tocopherol composition.

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