CHANGES IN OLIVE OIL QUALITY OF CHÉTOUI VARIETY ACCORDING TO ORIGIN OF PLANTATION

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ABSTRACT

Chétoui is the second main olive variety cultivated in the north of Tunisia and shows a high capacity of adaptation to various pedoclimatic conditions. The aim of this work was to study changes in oil composition of such variety according to origin of plantation. Thus, olives at the same stage of maturation were harvested from seven regions in the north of the country for oil extraction and analysis. Three consecutive crops from years 2000, 2001 and 2002 were considered. The analytical parameters studied were fatty acid composition, triacylglycerol molecular species and amounts of polyphenols and o-diphenols. The results showed considerable variability in oil composition because of the effect of cultivar–environment interaction.

INTRODUCTION

Oil production is influenced by climatic, genetic and agronomic factors and by their interactions. Recent work has shown that climatic factors such as temperature and precipitation have an effect on plant physiologic behavior and, consequently, on chemical characteristics of its oil (Aparicio *et al.* 1994; Pannelli *et al.* 1994; Moussa and Gerasopoulos 1996; Ryan *et al.* 1998). Thus, olive oil has become a subject of special attention and a considerable amount of research has been conducted to ensure its purity, authenticity and quality (Montedoro 1993; Kiritsakis *et al.* 1998; Ranalli *et al.* 1998; Sacchi *et al.* 1998; Ranalli *et al.* 1999).

Chétoui is the second olive oil variety cultivated in Tunisia. It is widespread in the north of the country, occuring in plains as well as in mountain regions, and shows a high capacity of adaptation to various pedoclimatic conditions. The aim of this work, therefore, was to study the changes in oil composition of Chétoui according to origin of plantation.

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Journal of Food Lipids **13** (2006) 88–99.

MATERIALS AND METHODS

Oil Samples

Olives of the Chétoui variety, at the same stage of maturation, were harvested from seven regions in the north of Tunisia for oil extraction and analysis. We considered three consecutive crop years: 2000, 2001 and 2002. The climatic characteristics of production areas are reported in Figs. 1 and 2.

Oil Extraction

Oil extraction was carried out in similar industrial extraction conditions using an Abencor analyzer (MC2 Ingenierias y Sistemas, Sevilla, Spain). Olives (1.5–2.0 kg) were crushed with a hammer mill and were then slowly mixed for 30 min at 25C. The paste so obtained (0.5 kg) was centrifuged at 3500 rpm over 3 min. The oil was separated by decanting, was transferred into dark glass bottles and was stored in the dark at 4C.

Analytical Methods

Determination of free fatty acids, peroxide value (Pv), UV absorption characteristics and fatty acid composition was carried out according to the analytical methods described in Regulation European Economic Commission (EEC)/2568/91 and EEC/1429/92. Free fatty acid, given as percentage of oleic acid, was determined by titration of a solution of oil dissolved in ethanol/ether (1:1, v/v) with ethanolic potash. Pv, expressed in milliequivalents of active oxygen per kilogram of oil (meq/kg), was determined as follows: a mixture of oil and chloroform/acetic acid 2:3 (v/v) was left to react with a saturated solution of potassium iodide in the dark; the free iodine was then titrated with a sodium thiosulfate solution. K_{232} and K_{270} extinction coefficients were calculated from absorption at 232 and 270 nm, respectively, with a spectrophotometer (model 35, Beckman Instruments, Inc., Fullerton, CA), using pure cyclohexane as a blank.

Fatty acid composition, calculated as the percentage of the total fatty acids, was determined by gas chromatography with an HP-4890D chromatograph (Hewlett-Packard Company, Wilmington, DE) equipped with a flame ionization detector, after conversion to methyl esters. The methyl esters were obtained according to the method of Metcalfe *et al.* (1966).

The triacylglycerol molecular species of olive oil were separated by high-performance liquid chromatography using a reversed-phase C_{18} column (lichrospher 100 RP-18, Waters, Milford, MA) according to the technique of Semporé and Bézard (1986).

Total polyphenols and o-diphenol amounts were quantitated colorimetrically (Ranalli *et al.* 1999). Phenolic compounds were isolated by a

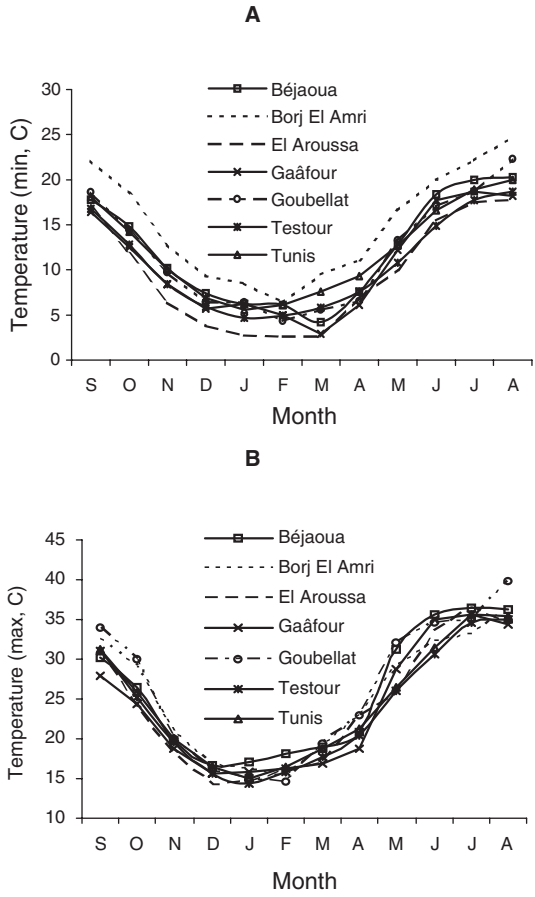

FIG. 1. (A) MINIMAL (MIN) REGISTERED TEMPERATURES IN THE SEVEN CULTURE SITES AND (B) MAXIMAL (MAX) REGISTERED TEMPERATURES IN THE SEVEN CULTURE SITES

Monthly values are the mean of three consecutive crops (2000–2002). S, September; O, October; N, November; D, December; J, January; F, February; M, March; A, April; M, May; J, June; J, July; A, August.

3-time extraction of a solution of oil in hexane with a water/methanol mixture (60:40, v/v). The Folin-Ciocalteau reagent (Merck Schuchardt OHG, Hohenbrunn, Germany) was added to a suitable aliquot of the combined extracts, and the absorption of the solution at 725 nm was measured. Values were given as milligrams of caffeic acid per kilogram of oil (Vàsquez 1978; Gutfinger 1981).

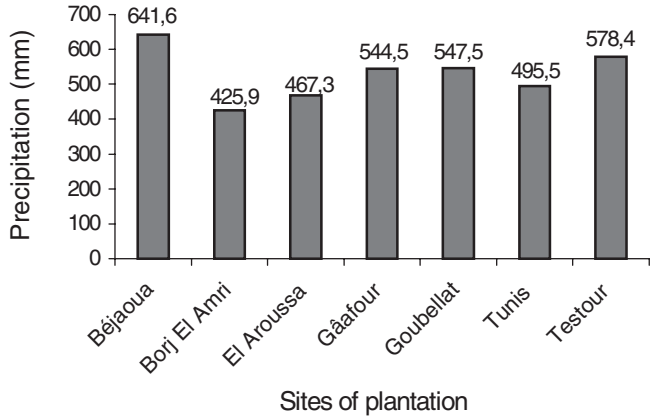

FIG. 2. TOTAL PRECIPITATION (mm) REGISTERED IN THE SEVEN CULTURE SITES
The values are the mean of three consecutive crops (2000–2002).

TABLE 1.
ANALYTICAL CHARACTERISTICS OF FRESH VIRGIN OLIVE OILS FROM CHÉTOUI CULTIVAR GROWN IN SEVEN DIFFERENT GEOGRAPHIC AREAS

	Geographical region						
	Béjaoua	Borj El Amri	El Aroussa	Gâafour	Goubellat	Tuniz	Testour
FA	0.60 ± 0.14	0.55 ± 0.07	0.40 ± 0.00	0.40 ± 0.14	0.75 ± 0.07	0.50 ± 0.00	0.50 ± 0.14
Pv	6.00 ± 1.41	5.75 ± 0.64	5.46 ± 0.70	5.19 ± 0.43	7.00 ± 0.78	7.75 ± 1.06	6.25 ± 0.35
K_{232}	2.18 ± 0.19	2.07 ± 0.15	2.14 ± 0.20	1.79 ± 0.22	1.99 ± 0.11	1.37 ± 0.39	2.04 ± 0.20
K_{270}	0.20 ± 0.01	0.21 ± 0.00	0.21 ± 0.01	0.19 ± 0.01	0.22 ± 0.03	0.15 ± 0.02	0.23 ± 0.01

FA, free acidity (% oleic acid); Pv, peroxide value (meq O_2/kg); K_{232}, extinction coefficient at 232 nm; K_{270}, extinction coefficient at 270 nm.

RESULTS AND DISCUSSION

Free Fatty Acids, UV Spectrophotometric Indices, Pv

As shown in Table 1, these analytical parameters are practically unaffected by the region of olive cultivation. In all samples examined, the free fatty acid content was much lower than the upper limit of 1% established for the best commercial quality olive oil, designated as “extra” virgin (Regulation EEC 2568/91).

The Pv of the oils analyzed were below the limit of 20 meq of oxygen/kg of oil, which is accepted as the limit for extra-quality virgin olive oil (International Olive Oil Council 2003). The specific extinction coefficient

at 232-nm wavelength, K_{232}, is related to the primary oxidation of oil and is an indication of conjugation of polyunsaturated fatty acids, whereas K_{270} is an indication of carbonylic compounds (aldehydes and ketones) in olives and is related to the secondary oxidation products (Boskou 1996; Garcia *et al.* 1996). UV-specific extinction determination permits an approximation of the oxidation process in unsaturated oils (Gutiérrez *et al.* 1992). The values of these parameters were all good in oils analyzed and were below the limits established for extra virgin olive oils (EEC Regulations). These results are consistent with the findings of Ranalli and Angerosa (1996) and Kiritsakis (1998). In fact, they reported that cultivar or origin area had no significant influence on these analytical parameters, which are basically affected by factors causing damage to the fruits (e.g., olive fly attacks or improper systems of harvesting, transport and storage of olives).

Fatty Acid Composition

The major fatty acids present as acylglycerols in Chétoui olive oil were oleic (C18:1), linoleic (C18:2), palmitic (C16:0) and stearic (C18:0) acids (Table 2). Oleic acid was the main monounsaturated fatty acid in olives and is present in higher concentrations (63.1–71.3%) than other acids. Palmitic acid content varied between 10.6 and 12.8% according to the plantation zones. Chétoui olives also contained low amounts of linolenic acid (C18:3), arachidic acid (C20:0) and traces of palmitoleic acid (C16:1) (Table 2).

Polyunsaturated fatty acids are very important for human nutrition. Linoleic acid was the dominant polyunsaturated fatty acid in Chétoui olives ranging from 14.3 to 20.4%, while linolenic acid (C18:3) ranged from 0.7 to 0.8%. As shown in Table 2, the fatty acid composition of olive oils varies widely, depending on the region of cultivation and climate. Also, noted that olive fruit from cooler areas contained oil with more unsaturated fatty acids than the fruit from dry and warm areas.

Variations in oleic and linoleic acid content observed in olive oil samples obtained from Chétoui cultivar (Table 2) are probably related to both genetic factors and environmental conditions during fruit development and maturity (Fedeli 1977; Lavee and Wodner 1995). Variations in the fatty acid content of oils are also related to fruit maturity. Delay in harvesting tends to increase the content of unsaturated fatty acids, especially linoleic, at the expense of palmitic acid (Cimato 1990). These results are in agreement with the findings of other researchers (Rana and Ahmed 1981; Bruni *et al.* 1994; Deidda *et al.* 1994; Osman *et al.* 1994; Schiratti 1999). Several agronomic parameters modify the fatty acid composition of olive oil. The most studied aspects include cultivar and origin, fruit ripening, harvest period and pedoclimatic conditions of production.

TABLE 2.
CHANGES IN THE FATTY ACID COMPOSITION (AS PERCENTAGE OF TOTAL FATTY ACIDS) OF CHÉTOUI OLIVES ACCORDING TO ORIGIN OF PLANTATION

Area of production	Saturated		Monounsaturated			Polyunsaturated	
	Palmitic C16:0	Stearic C18:0	Arachidic C20:0	Palmitoleic C16:1	Oleic C18:1	Linoleic C18:2	Linolenic C18:3
Béjaoua	12.8 ± 0.0	2.6 ± 0.1	0.4 ± 0.0	0.6 ± 0.1	63.1 ± 0.3	19.9 ± 0.2	0.8 ± 0.1
Borj El Amri	11.6 ± 0.2	2.9 ± 0.2	0.5 ± 0.0	0.4 ± 0.0	66.5 ± 0.9	17.3 ± 0.6	0.7 ± 0.0
El Aroussa	11.8 ± 0.3	2.7 ± 0.2	0.5 ± 0.0	0.4 ± 0.1	67.2 ± 1.4	16.7 ± 0.4	0.7 ± 0.1
Gâafour	11.1 ± 0.2	2.5 ± 0.3	0.4 ± 0.0	0.3 ± 0.1	69.2 ± 0.6	15.7 ± 0.3	0.7 ± 0.6
Goubellat	10.6 ± 0.1	2.9 ± 0.2	0.5 ± 0.0	0.4 ± 0.4	64.5 ± 1.3	20.4 ± 1.2	0.8 ± 0.3
Tunis	11.6 ± 0.2	3.0 ± 0.3	0.5 ± 0.1	0.4 ± 0.2	65.5 ± 0.9	17.9 ± 0.9	0.8 ± 0.0
Testour	10.8 ± 0.1	2.4 ± 0.2	0.4 ± 0.1	0.3 ± 0.1	71.3 ± 0.3	14.3 ± 0.9	0.7 ± 0.5

Triacylglycerol Content

Results for triacylglycerol contents, expressed in percentage of total triacylglycerols of oil samples, are shown in Table 3. The main triacylglycerols were 1,2,3-trioleylglycerol (OOO), 2,3-dioleyl-1-palmitoylglycerol (POO) and 2,3-dioleyl-1-linoleylglycerol (LOO). Other minor triacylglycerols were 2,3-dioleyl-1-stearoylglycerol (SOO), 2-oleyl-3-palmitoyl-1-stearoylglycerol (SOP), 1-linolenoyl-2-oleyl-3-palmitoylglycerol (LnOP), 1,2-dilinoleyl-3-palmitoylglycerol (LLP), 1, 3-dioleyl-2-linolenoylglycerol (OLnO), 1-linolenoyl-2-linoleyl-3-oleylglycerol (LnLO) and 1,2,3-trilinoleylglycerol (LLL).

In relation to the main triacylglycerols (OOO, POO and LOO), Testour oil showed the highest value for OOO (37.38%) and POO (18.02%), respectively, and had the lowest value for LOO (19.03%), whereas olive oil from Tunis showed the lowest values for OOO (29.59%) and POO (15.11%), respectively, and had the highest value for LOO (24.74%) (Table 3). Table 3 shows that, as for fatty acids, the composition of triacylglycerol species of olive oil obtained from the Chétoui variety varies widely, depending on pedoclimatic conditions and on the region of cultivation. Our results are in agreement with those of previous research (Cortesi 1993; Fedeli 1997; Ollivier *et al.* 2000; Abaza *et al.* 2001).

Total Phenols and O-Diphenols

Olive oil is the only vegetable oil that contains appreciable amounts of polyphenols (which are represented basically by o-diphenols) acting as antioxidant substances and conferring to it a greater stability against oxidation during storage (Argenson 1999). Figure 3 shows that the contents of total phenols and o-diphenols of olive oils vary widely according to the production area. Borj El Amri oil has the highest contents for polyphenols and o-diphenols (571.13 mg/kg and 249.14 mg/kg, respectively), whereas Béjaoua oil has the lowest (258.11 mg/kg and 126.25 mg/kg, respectively).

As reported by different authors, the amount of total phenols, which is 200–500 mg/kg on the average, shows a great variability from 50 to 1000 mg/kg (Boskou 1996), depending on various factors such as cultivar, climate and environmental factors, ripeness and processing, after storage of the oil (Parlati *et al.* 1994; Tous and Romero 1994; García *et al.* 1996; Alessandri 1997; Gutiérrez *et al.* 1999).

The results show that the climatic conditions, in particular the rainfall trend during the growing and the ripening of the olive fruits, influence the concentration of phenolic compounds, evaluated colorimetrically and expressed as the amount of total phenols. In fact, a positive linear relationship ($r = 0.796$) existed between phenol content and precipitation for the virgin

TABLE 3.
TRIACYLGLYCEROL CONTENT (%) OF OLIVE OIL FROM CHÉTOUI VARIETY ACCORDING TO ORIGIN OF PLANTATION

Triacylglycerol molecular species (% of total triacylglycerol)	Geographical region						
	Béjaoua	Borj El Amri	El Aroussa	Gâafour	Goubellat	Testour	Tunis
LLL	0.55 ± 0.20	0.44 ± 0.07	0.43 ± 0.04	0.58 ± 0.04	1.11 ± 0.07	0.29 ± 0.03	0.25 ± 0.18
OLLn	0.47 ± 0.32	0.37 ± 0.03	0.31 ± 0.04	0.36 ± 0.02	0.49 ± 0.08	0.38 ± 0.00	0.35 ± 0.09
LLO	7.54 ± 1.55	5.54 ± 0.76	5.66 ± 0.46	6.84 ± 0.54	9.54 ± 0.55	4.38 ± 0.06	4.12 ± 2.68
OOLn	0.88 ± 0.12	1.10 ± 0.11	0.93 ± 0.61	0.97 ± 0.03	1.09 ± 0.11	0.98 ± 0.14	1.27 ± 0.00
PLnO	1.16 ± 0.09	1.28 ± 0.01	1.17 ± 0.07	1.37 ± 0.10	1.93 ± 0.30	0.92 ± 0.05	1.35 ± 0.52
PLL	0.56 ± 0.43	0.47 ± 0.06	0.38 ± 0.02	0.35 ± 0.01	0.39 ± 0.04	0.41 ± 0.04	0.76 ± 0.04
OOL	22.95 ± 1.60	21.49 ± 2.86	21.02 ± 0.63	21.45 ± 0.14	22.82 ± 0.42	19.03 ± 0.09	24.74 ± 4.08
POL	8.96 ± 1.63	8.48 ± 1.08	8.06 ± 0.10	8.26 ± 0.01	9.08 ± 0.64	7.55 ± 0.08	9.82 ± 1.28
OOO	33.31 ± 1.57	36.13 ± 4.18	36.13 ± 0.22	35.19 ± 1.18	30.62 ± 2.98	37.38 ± 0.41	29.59 ± 0.31
POO	15.72 ± 1.96	15.83 ± 5.04	17.17 ± 1.08	16.23 ± 0.51	15.16 ± 0.06	18.02 ± 0.24	15.11 ± 3.76
SOO	2.01 ± 0.42	2.79 ± 1.37	2.97 ± 0.30	2.43 ± 0.05	2.32 ± 0.39	2.93 ± 0.19	5.47 ± 0.69
SPO	4.26 ± 1.34	4.24 ± 0.17	3.97 ± 0.03	4.33 ± 0.48	3.76 ± 0.73	5.57 ± 0.21	5.01 ± 1.91
AOO	0.64 ± 0.52	0.73 ± 0.46	0.90 ± 0.03	0.79 ± 0.04	0.79 ± 0.13	1.19 ± 0.08	1.76 ± 0.65

LLL, 1,2,3-trilinoleylglycerol; OLLn, 1-oleyl-2-linoleyl-3-linolenoylglycerol; LLO, 1,2-dilinoleyl-3-oleylglycerol; OOLn, 1,2-dioleyl-3-linolenoylglycerol; PLnO, 1-palmitoyl-2linolenoyl-3-oleylglycerol; PLL, 2,3-dilinoleyl-1palmitoylglycerol; OOL, 1,2-dioleyl-3-linoleyglycerol; POL, -palmitoyl-2-oleyl-3-linoleylglycerol; OOO, 1,2,3-trioleylglycerol; POO, 2,3-dioleyl-1-palmitoylglycerol; SOO, 2,3-dioleyl-1-stearoylglycerol; SPO, 1-stearoyl-2-palmitoyl-3-oleylglycerol; AOO, 2,3-dioleyl-1-arachidoylglycerol.

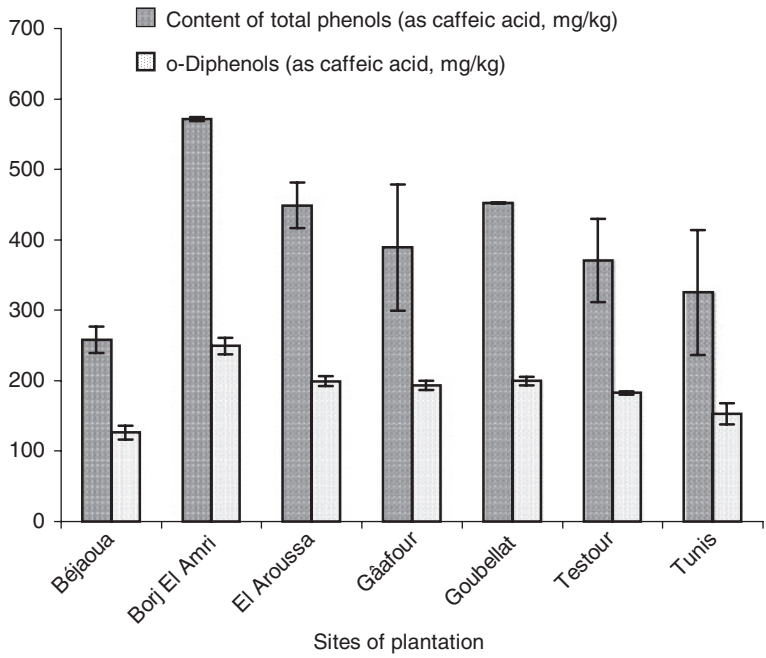

FIG. 3. CHANGES IN POLYPHENOL AND O-DIPHENOL AMOUNTS OF OLIVE OILS FROM CHÉTOUI VARIETY ACCORDING TO ORIGIN OF PLANTATION

olive oils from Chétoui ($y = -0.5691x + 757.62$). These results are similar to those of Pannelli *et al.* (1994) who observed that climatic factors, in particular precipitation, influence the quality of the olive oil, mainly some constituents of aliphatic alcohols, headspace components and phenols.

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