Scientia Horticulturae 128 (2011) 23–29

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Study on the impact of wastewater irrigation on the quality of oils obtained from olives harvested by hand and from the ground and extracted at different times after the harvesting

M. Gharsallaoui[a,*], C. Benincasa[b], M. Ayadi[a], E. Perri[b], M. Khlif[a], S. Gabsi[c]

[a] Olive Tree Institute, BP 1087, Sfax 3000, Tunisia
[b] C.R.A. Istituto Sperimentale per l'Olivicoltura, via Li Rocchi 111, 87036 Rende (Cs), Italy
[c] National School of Engineering, Gabes, Tunisia

ARTICLE INFO

Article history:
Received 3 April 2010
Received in revised form
14 December 2010
Accepted 17 December 2010

Keywords:
Wastewater reuse
Olive tree irrigation
Fallen olives
Olives storage
Oil quality

ABSTRACT

Nowadays, lots of efforts are made in Tunisia for the exploitation of wastewater in agriculture in order to face a very elevated mobilization of resources in water (90%). At Sfax, a Governorate placed in the South of Tunisia, the annual rainfall rarely exceeds 200 mm, so the climate is fairly arid. The significant water deficit can be reduced with the reuse of treated wastewater (TWW). The Sfax wastewater originated from the municipal wastewater treatment plant (WWTP) localized at 5 km in the south of Sfax, Tunisia. This WWTP is an aerated lagoon process receiving industrial wastewaters. Its treatment capacity is 24,000 m^3/day. Part of TWW is sent to the olive crops of El Hajeb, as part of a proposed wastewater use in agriculture. Already the wastewater is used to irrigate olive trees and intercrops such as cotton, oats and sorghum silage (Charfi et al., 1999). The aim of the present work was to determine the impact of the irrigation utilizing wastewater on the quality of the oil. The oils analysed were extracted from olives hand-picked directly from the tree and from olives that have fallen under the trees. Moreover, a study on the olive storage has been made in order to evaluate in which way the collection of the fruit could influence the quality of the oil.

The results obtained showed that:

- Olive trees benefit from this contribution of water;
- irrigation by wastewater has a significant effect in the fatty acid composition;
- oils relative to olive trees irrigated with wastewaters are more sensible to the oxidization especially after olive storage;
- oils coming from olive trees irrigated with wastewaters are richer in polyphenols;
- oils extracted from fallen olives are of poor quality essentially after olives storage and when olive trees are irrigated by wastewater.

1. Introduction

Tunisia is one of the very few countries that have elaborated and implemented a national policy for wastewater reuse. Wastewater reuse in agriculture is regulated by the Water Law of 1975 and by the decree of 1989 (Decree No. 89-1047). The reclaimed water has been used mainly for irrigation because some underground water can no longer be used due to an overdraft and saline water intrusion. The use of wastewater is now an integral part of the national water resources strategy (Al-Atiri et al., 2002). Treated water is used for the cultivation of citrus, olives, fodder and cotton as well as for golf courses and hotel gardens.

Abbreviations: WWTP, wastewater treatment plant; TWW, treated wastewater; WW, well water; ONAS, National Sanitation Office; BOD, biochemical oxygen demand; COD, chemical oxygen demand; SS, suspended solid; GI, germination index; EC, electrical conductivity; WW-Fr, olives picked straight from the tree coming from plot irrigated by WW; TWW-Fr, olives picked straight from the tree coming from plot irrigated by TWW; WW-Fl, olives fallen under the tree coming from plot irrigated by WW; TWW-Fl, olives fallen under the tree coming from plot irrigated by TWW; K232, absorption characteristic at 232 nm; K270, absorption characteristic at 270 nm; PV, peroxide value; FAMEs, fatty acid methyl ester.

* Corresponding author. Tel.: +216 74241240; fax: +216 74241033.
E-mail address: mariem.gharsallaoui@yahoo.fr (M. Gharsallaoui).

0304-4238/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2010.12.015

The olive tree (*Olea europaea* L.) is the most important evergreen tree in Tunisia with 60 million olive trees covering 1.6 million hectares of land (Hannachi et al., 2007), where it is grown traditionally in rain-fed conditions. In recent years, there has been a growing interest in olive oil, thanks to its antioxidant and health-improving properties (Visioli and Galli, 1998; Tuck and Hayball, 2002; Bouaziz et al., 2005; Covas et al., 2006; Kanadaswami et al., 2005; Smith et al., 2005; Bendini et al., 2007; Bogani et al., 2007) that has led to an augmentation in olive production, especially by means of the irrigation. On the other hand, Tunisia, like arid and semi-arid countries, has to face the increase of the scarcity of water (Marecos Do Monte et al., 1996; Angelakis et al., 1999; Hochstrat et al., 2006). Moreover, water of good quality is used to irrigate crops more sensitive to water shortage (Marecos Do Monte et al., 1996; Khabou et al., 2009). In these conditions, the reuse of treated wastewater (TWW) may lead to higher and more consistent levels of olive production, thus minimizing the exploitation of fresh water resources (U.S. Environmental Protection Agency (USEPA), 1992; Gregory, 2000; Palese et al., 2006).

The use of TWW in agriculture is one of the strategies adopted for increasing water supply in arid and semi arid countries. Evidently the wastewater utilization should be managed within certain restrictions imposed for environmental protection and for the safeguard public health.

Several studies focused on the effect of irrigation with conventional water on olive oil composition (Tovar et al., 2002; Berenguer et al., 2006; Baccouri et al., 2007a; Gomez-Rico et al., 2007; Servili et al., 2007) yet only a few studies took into account the effect of TWW as a water source of irrigation on the olive oil quality (Palese et al., 2006; Bedbabis et al., 2009). Therefore, the scope of this work was to study the effect of irrigation with TWW on “Chemlali” olive oil quality. This study focuses also on the determination of the quality of oils extracted from hand picked olives and from olives fallen under the trees irrigated with reclaimed water.

2. Material and methods

2.1. Study site

The experimental site, El Hajeb, is located at 10 km in the south west of Sfax city (34°43′N, 10°41′E) in central eastern Tunisia. The site under investigation belongs to the Mediterranean bioclimate. The climate is characterized by hot and dry summers and by a relatively cold winter. The annually precipitation is very irregular and varies from year to year. The irrigated area of El Hajeb is part of the large estate of Chaal, managed by the office of the lands. It covers an area of 700 ha spread over three properties:

- Henchir-Ghalia: that covers 450 acres;
- Henchir-Bessis that covers 76 ha;
- Henchir Avocato that covers 166 ha.

These three properties are characterized by sandy soils (84.4% of sand; 9.8% of clay and 5.8% of silt). Eighteen year old trees spaced 24 m × 24 m were used in a randomized complete block design with two different treatments and tree replications. Each experimental plot consisted of 3 × 3 trees. Olives were sampled by hand and from fallen fruits from all the trees belonging to the experimental plots at a known ripening degree. On the oils produced analysis were performed in order to check all the quality parameters. The average annual rainfall, occurring mostly in autumn and winter, was 125.9 and 296.5 mm respectively for the 2004/2005 and 2006/2007 year crop (Table 1). Table 1 reports also the monthly values of the mean temperatures recorded during the same years.

Table 1
Monthly average temperature and rainfall registered during the crop years of the experiment.

Month	Temperature (°C)		Rainfall (mm)	
	2004/2005	2006/2007	2004/2005	2006/2007
January	13.05	14.35	0	30.20
February	12.50	10.70	0	70.30
March	14.10	16.05	37.10	18.80
April	20.40	19.75	6.20	50.40
May	20.95	21.20	1.00	18.40
June	25.20	33.10	2.20	0.20
July	28.85	31.75	0	0
August	31.40	31.00	2.40	2.40
September	25.30	26.55	12.40	60.00
October	25.40	27.10	10.60	21.00
November	20.45	18.25	17.60	12.40
December	20.45	19.60	36.40	12.40

2.1.1. Chemical characteristics of TWW and WW

TWW has domestic and industrial origins and is treated at secondary level using biological processes that consist of eliminating the biodegradable matters by their transformation into microbial residues.

Secondary treatment involves the removal of biodegradable dissolved and colloidal organic matter using an aerobic biological treatment process.

Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end products (CO_2, NH_3 and H_2O).

The characteristics of TWW and well water (WW) are reported in Table 2. The pH of the TWW and WW was 7.60 and 7.95 respectively falling within the 6–9 range, appropriate for irrigation reuse (Rattan et al., 2005).

The electrical conductivity was 6.30 dS/m for TWW and 4.60 dS/m for WW indicating, respectively, a high and moderate level of salinity (Rhoades et al., 1992; Weisman et al., 2004). Moreover, both TWW and WW had chloride sodium features with high cation and anion percentages (essentially sodium and chloride). In both TWW and WW, chloride concentration was higher than the threshold reported by Chartzoulakis (2005) in the guidelines for olive irrigation. The concentration of almost all nutrient elements was higher in TWW than that found in WW, except for calcium and magnesium (Table 2). The biological oxygen demands were below the Tunisian thresholds for water reuse (30 mg/l) (Table 2). But this

Table 2
Chemical characteristics of TWW and WW (National Sanitation Office, Sfax, Tunisia).

Chemical characteristics	TWW	WW	Tunisian norm
pH	08.00	7.95	6.5–8.5
EC (dS/m)	6.30	4.70	7
Salinity (g/l)	4.66	3.50	–
NH_4^+ (mg/l)	37.90	2.24	–
NO_3^- (mg/l)	15.90	1.11	50
P_{total} (mg/l)	10.30	0.80	0.05
K^+ (mg/l)	38	30	50
Na^+ (mg/l)	470	355	300
Cl^- (mg/l)	1999	1580	600
Ca^{2+} (mg/l)	95.80	184.50	–
Mg^{2+} (mg/l)	83.80	126.20	–
Pb^{2+} (mg/l)	<0.004	0	0.100
Cd^{2+} (mg/l)	<0.004	0	0.005
Zn^{2+} (mg/l)	0.42	0.10	5
Mn^{2+} (mg/l)	0.50	0.19	–
COD (mg/l)	273	0	90
BOD (mg/l)	22	0	30
SS (mg/l)	56	0	30

BOD, biochemical oxygen demand; COD, chemical oxygen demand; SS, suspended solid; EC, electrical conductivity.