**Effect of Spanish-style processing on the quality attributes of *HydroSOStainable*
green olives**

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Abstract

Background: Three treatments of regulated deficit irrigation (RDI) were assayed on olive trees for table olives production. RDI provides *hydroSOStainable* crops. The effect of RDI treatments on the quality of raw and table olives was determined based on their: weight, pit weight, fruit/pit ratio, size, texture, colour, mineral content, antioxidant activity, total phenol content and organic acid and sugar profile.

Results: *HydroSOStainable* olives showed the most attractive shape and colour: highest fruit weight, roundest fruit, hardest texture and a lightest and greenest colour than control olives. Minerals, antioxidants, phenols and organic acids and sugars of *hydroSOStainable* olives were similar to control olives. After processing to table olives, Ca, K, antioxidants and phenols contents decreased, whereas sugars and organic acids profiles changed in both types of olives.

Conclusions: *HydroSOStainable* table olives offer environmental and quality advantages over control olives given the reduced use of fresh water and favourable morphological traits, which are more attractive for consumers.

Keywords

“Manzanilla”, *Olea europea* L., regulated deficit irrigation, antioxidant activity, total phenol content, minerals.

INTRODUCTION

Olive trees are a millenarian crop that was extended by Romans, Phoenicians and Arabs through the Mediterranean countries. There are different olive varieties; some of them are used to extract olive oil and others for table olives because of their physical properties (volume, shape, firmness, etc.). Table olives are one of the most consumed appetizers in the world; in fact, in the last five years, an amount of 2.5 million tons per year have been consumed. Twenty-one percent of these table olives were produced in Spain, which is the main producer and exporter of table olives in the world; moreover, Andalusia (in particular, Seville) is the main region in Spain producing table olives ¹.

“*Manzanilla*” is the most valued table olive variety because of its high productivity and its good fruit quality. In Spain, it is typical to harvest olives when they are green to process them following the Spain-style while in the United States, it is traditional to process them using the Californian-style by oxidation of mature olives. “*Manzanilla*” olives have medium aptitude for oil extraction whereas its oil has good quality and stability; therefore, this variety is perfect to be processed to table olives ². “*Manzanilla*” olives have a thin peel and the flesh is delicate, hard, pulpy, tasty, and non-fibrous ³. Furthermore, the removal of the flesh from the pit is very easy ²; this characteristic is important for industry because make easier the pitting process.

Raw olives are firm and bitter, so some processes are necessary to make them edible. Table olives could be processed using different techniques, and Spanish-style is the most common in Spain. It consists in: (i) treatment of debittering, to hydrolyse ouleoperin, (ii) washing process, to remove alkali, and (iii) lactic acid fermentation ⁴.

During alkali treatment, some components, such as tocopherol and free fatty acids, diffuse from olive peel to the surrounding liquid.; this process increases the cellular membrane permeability and contributes to a decreased peel firmness ⁵.

Table olives composition is different from other fermented vegetables due to their high content of phenolic compounds and fatty acids, mainly oleic acid (monounsaturated), thus, it can be considered a functional food. Table olives bioactivity could be influenced by many factors, such as cultivation technique and type of process to turn raw olives into table olives ⁶.

Although olive trees were traditionally rain-fed, some years ago periodic irrigation was implemented in this crop because of the intensification of agriculture. This practise generates some benefits on olives production and was established following FAO (Food and Agriculture Organization of the United Nations) recommendations ⁷; and, it is essential in regions where rain is concentrated only in autumn-winter (specific microclimatic conditions) ^{8, 9}. Nowadays, regulated deficit irrigation (RDI) is a watering technique that is widely studied due to an increasing water scarcity. Many studies have concluded that different RDI treatments can affect some table olives characteristics, such as phenolic composition, antioxidant activity, fatty acids composition, volatile compounds, phytoprostanes, etc. ¹⁰.

RDI table olives belong to a group of vegetable products named *hydroSOSustainable*. These products are characterized by having unique characteristics: (i) high intensity of some key sensorial attributes, (ii) high content of some nutritional

and functional components, and (iii) reduced use of water, which is a benefit for both farmers (economic benefit) and for the environment (water sustainability)^{11, 12}.

Different studies have been carried out to improve the quality of different varieties of RDI olives at different locations^{13, 14}, and it is very important to determine the effect of each new watering technique on fruit quality. Therefore, the main aim of this research was to investigate the effect of three new RDI treatments applied to olive trees on the quality attributes of olives, particularly their morphology, physico-chemical properties, antioxidant activity, mineral composition, organic acids, and sugar composition. These parameters were studied in raw and table olives (after processing using the Spanish-style); thus, the second aim of this research was to investigate the effects of processing on the quality attributes of “*Manzanilla*” olives.

MATERIALS AND METHODS

Plant material, growing conditions and experimental design

Olives were collected from a farm, Doña Ana, which is located in Dos Hermanas (Seville, Spain). Table olives trees (*Olea europea* L. cv Manzanilla) were 30-year-old. Further detail of collection and experimental design can be found in Corell *et al.*¹⁴.

Irrigation scheduling was performed following pressure chamber technique and the threshold values of midday stem water potential before and after pit hardening period. Three different irrigation treatments and a control were carried out:

- (i) *optimum water status* (T0); trees were watered to avoid any water stress (-1.2 MPa before pit hardening and -1.4 MPa after pit hardening);
- (ii) *moderate deficit irrigation* (T1); trees were watered following same way as T0 but during pit hardening period threshold value was -2 MPa;
- (iii) *severe deficit irrigation (short time)* (T2); same scheduled than in control trees were followed, but threshold value was -3 MPa during half time of pit hardening; and,
- (iv) *severe deficit irrigation (long time)* (T3); trees were watered following same way than T2 but threshold value of -3 MPa were maintained until end of pit hardening period.

Stem water potential at midday (Ψ) was measured using a pressure chamber (PMS Instrument Company, USA), **Table 1** shows the average of the minimum values observed in each treatment. In order to describe the accumulative effect of the water deficit, the water stress integral was calculated from the Ψ data¹⁵ during the period of

beginning pit hardening until harvest (Eq. (1)). Eq. (1) used a reference of -1.4 MPa. The expression used was:

$$SI = | (\Psi - (-0.2)) \times n | \quad (1)$$

where: SI is the stress integral, Ψ is the average midday stem water potential for any interval, n is the number of the days in the interval.

Sample processing

Two harvesting seasons were evaluated: 2015 and 2016. For each RDI treatment and season, four batches were done for later analysis as raw fruit (raw olives, RO). Each batch consisted of 5 kg of olives in 2015 and 50 kg in 2016 season. Remaining harvested fruits were mixed and transported to *Cooperativa Nuestra Señora de las Virtudes* (La Puebla de Cazalla, Seville, Spain) to be processed as table olives, TO, using the Spanish-style method as described by Cano-Lamadrid *et al.*³. Once processed sampling of table olives followed the same procedure described for RO.

Morphological analyses

Each treatment was formed by four batches. Twenty-five olives from each batch were randomly selected for conducting measurements. Thus, 100 olives for each treatment were analysed and used for all physico-chemical analyses in each of the two seasons.

Weight and size

Longitudinal and equatorial diameters were measured on each olive using a digital calliper (model 500-197-20 150 mm; Mitutoyo Corp., Aurora, IL, USA). Whole olives

were weighed (model AG204 scale; Mettler Toledo, Barcelona, Spain) and, then, each pit was removed and weighted.

Colour determination

Colour determinations were made using a colorimeter (model CR-300, Minolta, Osaka, Japan) which uses an illuminant D65 and 10° observer. Colour was measured three times per olive at 25 ± 1 °C. Colour results were given as CIE $L^*a^*b^*$ coordinates. This system define colour in a three-dimensional space: (i) L^* indicates lightness (0-100 values); (ii) a^* is green-red coordinate, taking green and red colours negative and positive values, respectively; and, b^* is blue-yellow coordinate, taking blue and yellow colours negative and positive values, respectively.

Texture

Texture analysis was carried out according to Szychowski *et al.*¹⁶. Briefly, two methods were used:

- (i) Puncture test (PT), using a stainless-steel needle probe P/2N (2 mm thickness) into the whole fruit (0.5 mm s^{-1} ; 7 mm of penetration) trying to avoid that the needle touches the pit of olives; and,
- (ii) Magness-Taylor test (MTT) with a stainless-steel cylindrical probe SMSP/2 of 2 mm diameter. To conduct this test, the peel of the olives was removed in approximately 1 cm^2 (0.3 mm s^{-1} ; 5 s of penetration) on olive flesh.

Analysis of texture were conducted at 25 ± 2 °C using a Texture Analyser TA-XT2i (Stable Micro Systems, Surrey, U.K.). Analyses were conducted in 25 olives *per* batch and results were expressed in N.

Mineral analysis

A representative amount of olives from each batch was freeze dried. Mineral analysis was carried as described by Carbonell-Barrachina *et al.*¹⁷. A multi-place digestion block (Digest 20, Selecta) was used to digest 0.5 g of freeze dried olives. Samples were digested for 2 h at 130 °C using 5 mL of 65 % HNO₃ (w/v). Later, samples were diluted with ultra-high-purity deionised water (1:10 and 1:50) and afterwards cooled at room temperature.

Determination of Ca, Mg, K, Cu, and Zn in the mineralised samples was performed using a Unicam Solaar 969 atomic absorption-emission spectrometer (Unicam Ltd., Cambridge, U.K.). Potassium was analysed using atomic emission, while the rest of elements were analysed by atomic absorption. Calibration curves and blank reagent were used in each analytical batch. The analyses were run in triplicate.

Antioxidant activity (AA) and total phenol content

Extraction of antioxidants was done with methanol as described previously by Cano-Lamadrid *et al.*¹⁰. Three methods were used to evaluate the AA of the studied olives samples. Radical scavenging activity was evaluated using DPPHⁱ radical (2,2-diphenyl-1-picrylhydrazyl) method, as described by Brand-Williams *et al.*¹⁸. The absorbance decrease was measured at 515 nm. The free radical scavenging capacities were determined using the ABTS⁺ (azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) method described by Re *et al.*¹⁹, and FRAP (ferric reducing antioxidant power) method, as described by Benzie and Strain²⁰. Absorbance was measured at 734 nm and 593 nm

for ABTS⁺ and FRAP, respectively. Analysis were carried out in a UV–visible spectrophotometer (Helios Gamma model, UVG 1002E). Calibration curves (3.5-5.0 mmol Trolox L⁻¹) with good linearity ($R^2 \geq 0.999$) were used for the quantification of the AA by these methods. Analyses were run in triplicate and results were expressed as mmol Trolox kg⁻¹ of fresh weight, fw.

The extracts used to measure total phenolic content (TPC) were the same as those previously describe for the AA analysis ¹⁰. TPC was quantified using Folin-Ciocalteu reagent, as described by Gao *et al.* ²¹. Absorbance was measured using an UV-visible spectrophotometer (Helios Gamma model, UVG 1002E) at 765 nm. Gallic acid was used to prepare calibration curves. This analysis was run in triplicate and results were expressed as gallic acid equivalents (GAE) per kg⁻¹ fw.

Organic acids and sugars

Organic acids and sugars profiles were determined according to Cano-Lamadrid *et al.* ¹⁰. Briefly, 2 g of freeze dried olive sample were mixed with phosphate buffer 50 mM (pH= 7.8) and centrifuged (Sigma 3 – 18 K; Sigma Laborzentrifugen, Osterode and Harz, Germany). Then, 10 µL of the filtered supernatant (0.45 µm filter) were injected into a Hewlett Packard (Wilmington DE) series 1100 high-performance liquid chromatography (HPLC) using 0.1 % orthophosphoric acid elution buffer. Organic acids separation was made using a Supelcogel TM C-610H column (30 cm × 7.8 mm) with a pre-column (Supelguard 5 cm × 4.6 mm; Supelco, Bellefonte, PA). Absorbance was measured with a diode-array detector (DAD) at 210 nm for organic acids. Sugars were separated and detected in the same run but they were monitored using a refractive index

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detector (RID). Calibration curves were made using standards of different organic acids and sugars provided by Sigma (Poole, UK). Analyses were run in triplicate and results were expressed as g kg⁻¹ fw.

Statistical analysis

Results were the average results from 2 seasons, and include, 3 replications for each one of the four batches included in each irrigation treatment. One-way analysis of variance (ANOVA) was carried out to study the effect of RDI treatments on TO and RO, and then Tukey's multiple range test was used to compare the means. The effect of Spanish-style processing was also studied. Statistical differences were considered significant when $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics v21.0 Core System software package (SPSS Inc. an IBM Company).

RESULTS AND DISCUSSION

Irrigation

Apply regulated deficit irrigation was possible using crop water status, through midday Stem Water Potential. Four irrigation treatments were applied with different levels and durations of stress. As **Table 1** shows, irrigation treatments showed different levels of stress, with T0 showing the lowest values of minimum Stem Water Potential and Stress Integral, and T3 showed significantly higher levels of stress. Levels of stress varied mainly depending of tree load, in 2015 the load of the trees was 15% of the 2016, this could explain the difference between the values of the two seasons studied.

Morphological analysis

Weight, size, dry matter content, texture (peel and flesh) and colour of RO and TO are shown in **Table 2**. Raw olives from T2 had the highest fruit weight (4.66 g), while T3 had the lowest weight (4.13 g). Previous studies reported similar results showing that strongest RDI treatments decreased the weight of olive fruits, but moderate treatments yielded larger fruits ^{3, 7, 10}. T3 olives had the highest fruit/pit ratio (6.45); this ratio increased as irrigation decreased.

The shape of RO changed with RDI; the differences between the longitudinal and the equatorial diameters was bigger for T0 and T1 fruits as compared to fruits from the other treatments. In this way, T3 the roundest olives (highest equatorial and smallest longitudinal diameter). Although not many differences were found in diameters, there was a trend showing that RDI treatments lead to rounder olives than control; this can be

an advantage of RDI on fruit shape because consumers usually prefer rounded “Manzanilla” olives¹⁰.

Regarding dry matter content (DMC) of RO, T0 and T2 had the lowest contents while T1 and T3 had the highest. These results were logical because a higher moisture content is expected in fruits from trees with abundant irrigation volume, leading to higher moisture content, and consequently, lower content of dry matter. These results agreed with the previously reported by Cano-Lamadrid *et al.*^{3, 10}.

The texture tests showed that T3 RO had the hardest peel (PT) and flesh (MTT), while no differences were found among the hardness of the other types of olives. Flesh was the softest while the hardest one was that from T3 trees; which again is logical due to the highest DMC of T3 fruits. Texture of olives is a main attribute for consumer's acceptance and for the industry; thus, from a texture point of view, T3 RO are very interesting because had strong peel and hard flesh.

Colour results showed differences in lightness (L^*) and the green-red coordinate (a^*). T3 olives were the lightest and greenest ones. These results agreed with those of a previous study with the same olive variety (but different irrigation treatments) in which the most severe treatment yielded the lightest and greenest olives¹⁰.

“Table” olives morphological characteristics were similar than that of RO. T3 yielded the roundest, hardest, lightest, and greenest TO, although T3 fruits had the lowest fruit and pit weight. The fruit/pit ratio in TO did not show differences among control, T1, and T2; whereas T3 fruits had the smallest ratio.

Clear differences have been found before and after processing for: fruit weight, fruit/pit ratio, equatorial and longitudinal diameters, DMC, texture attributes (PT and MTT), lightness, green and yellow colours intensity; in all of them the values of these parameters decreased after processing. These differences could be due to osmotic dehydration by the effect of addition of NaCl ²² and the solubilisation of the components from the olive flesh to the surrounding fermentation liquid.

Mineral analysis

Mineral composition of RO and TO it is shown in **Table 3**. Magnesium, zinc and copper showed mean contents of approximately 0.10 g kg⁻¹ fw, 2.10 mg kg⁻¹ fw and 1.70 mg kg⁻¹, respectively; no statistically significant differences were found for RDI treatments or processing. Calcium and potassium were also not affected by irrigation, but processing decreased their concentration (from 0.52 to 0.36 g kg⁻¹ fw and from 4.81 to 1.06 g kg⁻¹ fw respectively).

The decrease on Ca content could be explained because of the ion exchange and, consequently, the formation of some salts like CaCl₂ or calcium lactate²³. Ca and K are highly soluble in the acidic surrounding media, and it can be replaced by Na in the olive flesh and can be lost during the washing step. These results agreed quite well with those of a study with different olive varieties, in which K and Ca concentrations during fermentation and also reported their decrease²⁴. In this study they explained the decrease by the elution due to the washing steps of processing.

Antioxidant activity and total phenol content

Antioxidants can be defined as compounds that have the ability to reduce pro-oxidant agents. This property is important to consumers, so it is interesting to analyse their concentration in food matrices. Antioxidant compounds can act by different mechanisms; thus, the combination of different analytical protocols in the same food matrix is the best way to describe antioxidant activity in detail²⁵. Therefore, three different electron-transfer-based methods (ABTS⁺, DPPH[•], FRAP) were used in this study.

Fresh olives are recognised as a highly antioxidant fruit. In fact, high values of antioxidant activity (27.1, 48.7, and 24.8 mmol Trolox kg⁻¹ fw for ABTS⁺, DPPH^I, FRAP, respectively) and total phenolic content, TPC (19.4 g GAE kg⁻¹ fw) were found in “Manzanilla” RO (**Table 4**). In addition, TPC showed a significant positive relationship (Pearson correlation) with all antioxidants methods (0.432 for ABTS⁺, 0.582 for DPPH^I and 0.386 for FRAP).

During processing to TO, the TPC and the values of antioxidant activity decreased, and indeed, the type of processing significantly influenced such losses. The Spanish-style green olives experienced loss of antioxidant activity of 72, 80, and 38 % for ABTS⁺, DPPH^I, and FRAP, respectively, and 70 % for TPC. According to literature ²⁶, Spanish-style processing of green olives affects the loss of TPC depending on the ripening stage of fresh olives, the debittering method employed, and the fermentation type used. During fermentation, the contents of some phenols (hydroxytyrosol, tyrosol, and oleoside-11-methyl ester) decrease because of diffusion to the preservation liquid due to acidic pH. Another important change during fermentation is the conversion of oleoside-11-methyl ester to elenoic acid, which is rapidly broken down due to the acidic conditions ²⁶.

Regarding irrigation treatments, no significant statistical differences were found neither on raw nor table olives. Other authors reported similar results also in TO, but after application of different RDI treatments ¹⁰.

Organic acids and sugars

Table 5 showed contents of organic acids and sugars in RO. Citric, tartaric, malic, and succinic acids were found at concentrations of 0.27, 0.11, 0.46 and 0.16 g kg⁻¹ fw, respectively. On the other hand, sucrose (1.72 g kg⁻¹ fw), glucose (2.55 g kg⁻¹ fw), and fructose (1.39 g kg⁻¹ fw) were the sugars identified in this raw material. Concentrations of organic acids and sugars in TO are shown in **Table 6**, and it can be observed that no significant effects were found as a consequence of the irrigation treatment; thus, mean values of all 4 treatments will be discussed. In that matrix (TO), the organic acids found were phytic acid (mean value of all treatments 6.88 g kg⁻¹ fw), lactic acid (1.60 g kg⁻¹ fw) and acetic acid (0.62 g kg⁻¹ fw), while maltoheptaose, mannitol, and glycerol were the main sugars found (2.16, 2.70 and 0.98 g kg⁻¹ fw respectively).

Concentration of organic acids and sugars was not significantly affected by any RDI treatment neither on the RO (**Table 5**) nor on TO (**Table 6**). The main observed changes were found in the profiles of organic acids and sugar due to processing. Lactic acid bacteria transform sugars in RO into CO₂, lactic acid and other organic acids²⁷. It is important to study the profile of organic acids in RO because some of them are related with degradation or synthesis of other compounds, such as malic and citric acids. These two organic acids play an important role on oil accumulation during Krebs cycle. Similar results were found in a study that identified citric, malic and succinic acids in different varieties of RO²⁸. In RO, sucrose, glucose, and fructose were identified and quantified. These sugars are naturally present in the olive flesh because of transport by phloem from mature leaves and by formation by photosynthesis and they are very

important for the fruit growth and lipid biosynthesis. These three sugars were also identified in other studies as the main sugars in RO ²⁹.

After processing, the profile of sugars and organic acids changed. Phytic acid, lactic acid, acetic acid, maltoheptaose, mannitol and glycerol appeared in TO. Previous studies also identified these compounds in different table olive varieties ^{4, 10, 30}.

Conclusions

The present study was the first one evaluating the effects of three watering techniques on olive trees to produce *HydroSOStainable* table olives. RDI treated olives had higher fruit weight, rounder fruits with hardest texture, with a lighter but greener colour than control olives; therefore, the *HydroSOStainable* table olives were attractive to consumers. Regarding mineral composition, antioxidant activity, total phenol content, and organic acids and sugars profiles, RDI fruits showed no statistical differences from control olives; thus, it can be said that *HydroSOStainable* table olives had equivalent composition to that of the control or conventional fruits. Besides, “Spanish-style” processing induced decreases on the contents of some minerals (Ca and K), antioxidant activity and TPC concentrations due to fermentation in all types of olives regardless of the watering system. Other effects of processing were significant changes on the organic acid and sugar profiles.

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Table 1. Minimum midday stem water potential ($\min \dot{E}_{\text{stem}}$) and water stress integral (SI) in each regulated deficit irrigation treatment in each year.

Treatment		Min $\dot{E}_{\text{stem}}$ (MPa)	SI (MPa $\times$ day)
ANOVA [†]			
2015		***	***
2016		***	*
Multiple range test Tukey			
2015	T0	-1.76 a ^b	1.4 b
	T1	-1.96 ab	2.7 ab
	T2	-1.84 ab	1.2 b
	T3	-2.4 b	4.7 a
Multiple range test Tukey			
2016	T0	-2.34 a	29.6 b
	T1	-2.76 ab	62.6 ab
	T2	-2.74 ab	50.4 ab
	T3	-3.52 b	87.4 a

[†] NS = not significant at $p < 0.05$; *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively. ^b Values (mean of 4 replications) followed by the same letter within the same column, were not significantly different ($p < 0.05$), according to Tukey's least significant difference test.

Table 2. Morphological analyses [fruit weight (fw), pit weight, fruit/pit ratio, equatorial diameter, longitudinal diameter, dry matter content (DMC), puncture test (PT), Magness-Taylor test (MTT), CIE $L^*a^*b^*$] of “Manzanilla” raw olives (RO) and table olives (TO) as affected by regulated deficit irrigation treatments.

	Fruit weight (g) [§]	Pit weight (g) [§]	Fruit/pit ratio [§]	Equatorial diameter (mm) [§]	Longitudinal diameter (mm) [§]	DMC (g dw kg ⁻¹ fw) [¶]	Texture [§]		Colour [§]		
							PT (N)	MTT (N)	L^*	a^*	b^*
ANOVA[†]											
Irrigation RO	***	***	***	**	*	**	***	***	*	***	NS
Irrigation TO	***	***	***	*	*	*	***	**	**	*	**
Spanish-style processing	***	NS	***	*	*	*	***	**	**	***	**
Multiple range test Tukey Raw Olives											
T0	4.43 b [‡]	0.76 a	5.83 b	19.3 b	21.3 a	328 b	1.28 b	13.1 b	57.3 ab	-12.9 a	38.3
T1	4.45 b	0.73 a	6.09 ab	19.2 b	21.3 a	341 a	1.35 b	12.9 b	56.9 b	-12.5 a	38.0
T2	4.66 a	0.74 a	6.29 ab	19.5 a	21.5 a	321 b	1.44 b	10.2 c	57.2 b	-12.4 a	37.9
T3	4.13 c	0.64 b	6.45 a	19.7 a	20.4 b	341 a	2.54 a	19.1 a	59.9 a	-19.1 b	38.2
Multiple range test Tukey Table Olives											
T0	4.20 a	0.75 a	5.60 a	19.0 ab	19.5 a	330 b	1.07 b	6.52 b	55.6 b	0.64 ab	36.4 ab
T1	4.02 a	0.73 a	5.51 a	18.7 b	19.2 a	338 a	1.28 b	5.95 b	55.3 b	0.54 b	36.9 a
T2	3.97 a	0.73 a	5.44 a	18.8 ab	18.9 a	332 b	1.40 b	4.92 c	55.4 b	0.70 a	36.2 b
T3	2.81 b	0.61 b	4.60 b	19.2 a	14.9 b	341 a	1.85 a	7.25 a	56.4 a	0.62 ab	37.0 a
Multiple range test Tukey Spanish-Style processing											
Raw olives	4.42 a	0.72	6.14 a	19.4 a	21.1 a	317 a	1.65 a	13.8 a	57.8 a	-14.2 b	38.1 a
Table olives	3.75 b	0.71	5.28 b	18.9 b	18.1 b	309 b	1.40 b	6.03 b	55.7 b	0.62 a	36.7 b

[†] NS = not significant at $p < 0.05$; *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively. [‡] Values followed by the same letter within the same column and ANOVA treatments (RO, TO, Spanish-Style processing), were not significantly different ($p < 0.05$), according to Tukey's least significant difference test. [§] $n = 200$. [¶] $n = 16$.

Table 3. Minerals (macro-elements and micro-elements) content of “*Manzanilla*” raw olives (RO) and table olives (TO) as affected by regulated deficit irrigation treatments.

	Macro-elements [§]			Micro-elements [§]	
	Ca (g kg ⁻¹ fw)	K (g kg ⁻¹ fw)	Mg (g kg ⁻¹ fw)	Zn (mg kg ⁻¹ fw)	Cu (mg kg ⁻¹ fw)
ANOVA[†]					
Irrigation RO	NS	NS	NS	NS	NS
Irrigation TO	NS	NS	NS	NS	NS
Spanish-style processing	***	***	NS	NS	NS
Multiple range test Tukey Raw Olives					
T0	0.47 [‡]	4.96	0.13	2.07	1.72
T1	0.51	4.84	0.14	2.17	1.87
T2	0.54	4.70	0.12	2.29	2.06
T3	0.54	4.75	0.13	2.07	1.62
Multiple range test Tukey Table Olives					
T0	0.40	0.95	0.15	2.01	1.98
T1	0.27	1.07	0.14	2.12	1.72
T2	0.40	1.10	0.13	1.83	1.45
T3	0.37	1.12	0.14	2.19	1.80
Multiple range test Tukey Spanish-Style processing					
Raw olives	0.52 a	4.81 a	0.13	2.15	1.79
Table olives	0.36 b	1.06 b	0.14	2.03	1.74

[†] NS = not significant at $p < 0.05$; *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively. [‡] Values followed by the same letter within the same column and ANOVA treatments (RO, TO, Spanish-Style processing), were not significantly different ($p < 0.05$), according to Tukey's least significant difference test. [§] $n = 16$.

Table 4. Antioxidant activity and total phenol content (TPC) of “*Manzanilla*” raw olives (RO) and table olives (TO) as affected by regulated deficit irrigation treatments.

	ABTS ⁺ (mmol Trolox kg ⁻¹ fw) [§]	DPPH ⁱ (mmol Trolox kg ⁻¹ fw) [§]	FRAP (mmol Trolox kg ⁻¹ fw) [§]	TPC (g GAE kg ⁻¹ fw) [§]
ANOVA[†]				
Irrigation RO	NS	NS	NS	NS
Irrigation TO	NS	NS	NS	NS
Spanish-style processing	***	***	***	***
Multiple range test Tukey Raw Olives				
T0	27.1 [‡]	48.7	24.8	19.4
T1	26.3	48.9	25.1	19.6
T2	26.3	48.1	24.5	20.4
T3	26.3	49.2	24.7	19.6
Multiple range test Tukey Table Olives				
T0	6.67	9.55	15.5	5.77
T1	6.88	9.38	15.2	5.81
T2	6.70	9.71	15.2	5.74
T3	6.87	9.75	15.3	5.82
Multiple range test Tukey Spanish-Style processing				
Raw olives	26.5 a	48.7 a	24.8 a	19.8 a
Table olives	6.78 b	9.60 b	15.3 b	5.79 b

[†] NS = not significant at $p < 0.05$; *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively. [‡] Values followed by the same letter within the same column and ANOVA treatments (RO, TO, Spanish-Style processing), were not significantly different ($p < 0.05$), according to Tukey's least significant difference test. [§] $n = 16$.

Table 5. Sugars and organic acids of “*Manzanilla*” raw olives (RO) as affected by regulated deficit irrigation treatments.

Irrigation treatment	Citric acid[†]	Tartaric acid[†]	Malic acid[†]	Succinic acid[†]	Sucrose[‡]	Glucose[‡]	Fructose[‡]
	(g kg⁻¹ fw)						
ANOVA[†]							
	NS	NS	NS	NS	NS	NS	NS
Multiple range test tukey							
T0	0.25	0.12	0.43	0.14	1.59	2.55	1.34
T1	0.30	0.11	0.48	0.15	1.83	3.07	1.54
T2	0.27	0.11	0.45	0.16	1.75	1.84	1.30
T3	0.27	0.11	0.47	0.20	1.71	2.75	1.39

[†] NS = not significant at $p < 0.05$. [‡] $n = 16$.

Table 6. Sugars and organic acids of “*Manzanilla*” table olives (TO) as affected by regulated deficit irrigation treatments.

Irrigation treatment	Phytic acid[‡]	Lactic acid[‡]	Acetic acid[‡]	Maltoheptaose[‡]	Mannitol[‡]	Glycerol[‡]
(g kg⁻¹ fw)						
ANOVA[†]						
	NS	NS	NS	NS	NS	NS
Multiple range test Tukey						
T0	7.53 ^b	1.64	0.53	2.30	3.15	1.23
T1	6.44	1.57	0.63	2.10	2.52	0.91
T2	6.82	1.61	0.66	2.14	2.58	0.89
T3	6.73	1.59	0.64	2.10	2.55	0.90

[†] NS = not significant at $p < 0.05$. [‡] $n = 16$.