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Quality of Olive Oil Obtained by Regulated Deficit Irrigation

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Abstract: Olive oil is one of the basic products in the Mediterranean diet, and, due to its nutritional value, it is becoming more and more widespread in the world. Even though it has traditionally been a rainfed crop, farmers are currently transforming their plantations into super-high-density orchards to increase production. However, the increasingly acute drought in Mediterranean countries forces the establishment of water control mechanisms that allow restriction the contribution of water without undermining the properties of the products obtained. Under this concept, hydroSOS crops and products arose. This study aims to analyze the influence of the application of deficit irrigation on the olive oil obtained from the *Arbequina* and *Arbosana* varieties. The sensory parameters descriptive profile and consumers satisfaction degree were measured using trained and consumers' panels, and the chemical parameters peroxide index, fatty acids, and volatile profile were analyzed using the methods from the International Olive Oil Council and gas chromatography. The experimental results showed that applying this type of irrigation leads to an oil that is more valued by consumers, with a higher concentration of aromatic compounds related with a greener aroma (hexanol, *trans*-2-hexen-1-ol, hexanal), a higher content of polyunsaturated fatty acids, and greater antioxidant capacity. Deficit irrigation strategies led to environmentally friendly olive oil with high acceptance by Spanish consumers.

Keywords: *Olea europaea*; *Arbequina*; *Arbosana*; consumer study; sensory analysis; hydroSOS

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1. Introduction

Olive oil is one of the most recognized Spanish products worldwide. In 2021, the olive grove harvested area in Spain occupied 2.62 million ha, representing 52% of the total harvested surface in the European Union and 25% worldwide [1]. Olive production is located mainly in the Mediterranean basin due to its good adaptation to climatic conditions of this region [2]. The olive oil sector is a fundamental pillar in the Spanish agri-food system, as indicated by the fact that the Spanish olive oil production accounts for 70% and 45% of European and world productions, respectively. Olive oil represents 93% of the total olive production, with the other 7% belonging to table olives [3]. Olive oil consumption has increased worldwide due to its beneficial health properties (e.g., healthy fatty acids profile and high content of antioxidant compounds) [4]; this reputation has led the Food and Agriculture Organization of the United Nations to recommended its consumption [5].

In last years, the olive oil cultivation system is suffering changes, from traditional rainfed orchards to super-high-density orchards, which have high needs of irrigation water; this new type of olive orchards has been growing ~25% each year [6]. Super-high-density orchards generate environmental problems, such as the lack of diversity because local varieties are not well-adapted to this practice [7], or the increase in the demand for irrigation water [8]. In this sense, different agricultural management strategies have been developed to reduce the volume of irrigation water needed, but without jeopardizing the oil yield, such as sustained deficit irrigation (SDI), which is based on a uniform water restriction during the production cycle of the olive trees, and regulated deficit irrigation (RDI), in which the water restriction is only applied in the less susceptible phenological periods, such as pit hardening in the case of the olive trees [9]. These irrigation techniques require precise irrigation control facilities, as well as knowledge of the different parameters on which the irrigation water reduction can be applied, such as the evapotranspiration coefficients [10].

In order to contribute to the United Nations Sustainable Development Goals, specifically, with goal n° 12 "Responsible consumption and production" [11], the hydroSOStainable brand was created by the Food Safety and Quality research group of the Miguel Hernández University to increase the visibility of producers that incorporate these irrigation strategies. Sánchez-Bravo et al. [12] established an index to grant this brand correctly, attending to different parameters, such as composition, climatological conditions, and irrigation water consumption.

Several effects have been observed and reported in olive-based products when deficit irrigation was implemented in their production. It is important to mention that the quality of olive oil is measured using both the chemical and sensory information as defined by the International Olive Oil Council. For instance, in olive oil, the reduction in irrigation water has generated an increase in oil yield and tocopherols content [13,14], maintaining physicochemical and sensory quality [15,16]. Regarding table olives prepared by the Spanish style method [17], effects on some morphological changes were observed [18], as well as in their antioxidant activity and total phenolic content [9]. With this type of product, a consumer study was carried out to know how deficit irrigation treatment could modify consumers' perception and preference, showing that the application of water stress did not generate changes in the preference and liking of different sensory attributes [19].

Despite the high number of consumer studies already conducted using conventional olive oil [20,21], there is still a lot of work to be performed to inform consumers about the benefits behind the quality mark "hydroSOStainable products" and their opinion when comparing products obtained using hydroSOStainable strategies with well-known commercial oils highly accepted, bought, and used by consumers.

The aim of this study was to compare the consumers' opinions, the sensory profiles, and the main qualities and nutritional parameters of two hydroSOStainable olive oils (*Arbequina* and *Arbosana* varieties) with a control sample (*Arbequina* conventional). To reach this aim, the volatile composition, the fatty acids profile, and the antioxidant and total phenolic content were analyzed using GC-MS, GC-FID, and spectrophotometry, respectively. In addition, trained and consumer panels were used to evaluate the sensory profile and the consumers' liking for the three oils under study.

2. Materials and Methods

2.1. Olive Oil Samples

Three olive oil samples were obtained from Experimental Orchard "Finca La Matilla" (Carmona, Seville, Spain: 37.429459, −5.725373). The orchard has a super-high density (4.0 m × 1.5 m), and 60 trees organized in 3 lines (30 m) were used for each of the three treatments evaluated. Climatic data were taken from the *La Rinconada* meteorological station.

This farm only had conventional irrigation for the *Arbequina* trees, while they had changed to hydroSOStainable strategies in both *Arbequina* and *Arbosana* olive trees; these are two of the most cultivated olives varieties in super-high-density cultivation. Thus, the experimental design lacked an *Arbosana* control, but it was important to compare these three types of olive oil because they were cultivated in the same soil and under the same climatic conditions.

A drip irrigation system was used, treatment was controlled independently, and water was supplied based on calculated water needs. Stem water potential at midday (Ψ) was weekly determined using a pressure chamber (PMS Instrument Company, Albany, OR, USA) in 4 trees per irrigation treatment. The irrigation treatments were controlled following the pressure chamber technique and the threshold value of midday stem water potential—2.0 MPa during stage II [9]. Two irrigation treatments were applied:

- ✓ conventional irrigation (control treatment), which had an optimum water status. Trees were watered to supply 110% of crop evapotranspiration (ETc) [10]; a total of 498 L m^{-2} were applied, and;
- ✓ hydroSOS irrigation treatment, trees were under non-limited water conditions during stage I (beginning of fruit development) and III (rehydration), while regulated deficit irrigation (RDI) was applied during stage II pit hardening (70% of reduction in the total water irrigation applied in the control treatment (349 L m^{-2} were applied)).

Olives were harvested when commercial maturity was achieved. Then, olive oil was produced using an olive mill model Frantoino Bio (Toscana Enologica Mori, Florence, Italy) at 40–50 kg h^{-1}, with an aqueous two-phase oil extraction system.

2.2. Consumer Study

A consumer study was carried out at Seville University with 96 olive oil consumers; consumption of this product at least three times in a week was the only recruitment requirement [17,19]. The questionnaire was virtual, using RedJade software (RedJade Sensory Solutions, LLC); this software was also used to make the randomized serving model, collect information, and conduct data processing. Each consumer evaluated the three olive oil samples under study, each one codified with three-digit numbers. The questionnaire was developed in three parts: (i) liking of different specific attributes (olive oil odor, olive oil flavor, color, fruity, bitter, pungent, aftertaste, and global score) using 9-point scales (1 = dislike it extremely to 9 = like it extremely); (ii) how consumers evaluate the intensity of attributes above mentioned, using 9-point Just About Right (JAR) scales, where 1 = much too little, 9 = much too much, and 5 = just about right; and, finally, (iii) preference questions that included a CATA (Check All That Apply) question to know which attributes the consumer considered more important to decide whether a particular olive oil was of quality and of their preference. Furthermore, all the participants had a forced-answer question to know which sample was the most preferred and about their purchase intention.

2.3. Descriptive Sensory Analysis

A descriptive sensory analysis of the olive oils under study was carried out by a trained panel from the Food Quality and Safety research group at Miguel Hernández University; the panel analyzed the following positive attributes: fruity, maturity, floral, different types of green flavor (artichoke, herbaceous and pepper), tomato, bitter astringent, and pungent. Additionally, the sensory panel analyzed the most important negative attributes (oxidized, rancid, fusty, musty, and muddy) in olive oil. This panel (5 males and 3 females) was trained using oils with the most common defects (oxidized, rancid, fusty, musty, and muddy) in one session before the test. The scale used ranged from 0 (no intensity) to 10 (extremely high intensity) with 0.5 increments. Oil samples under study were presented in official blue glass cups [22] at 28 °C, codified with three-digit numbers, and served to panelists in random order generated by RedJade software.

2.4. Quality Classification

Physico-chemical quality parameters of olive oils were determined using the methods recommended by the International Olive Council, IOC [23]. Three parameters were analyzed: (i) free acidity index [24], (ii) peroxide index [25], and (iii) ultra violet extinction coefficients (K_{232}, K_{270} and ΔK) [26]. All these analyses were conducted using a UVG1002E UV-vis spectrophotometer (Helios, Cambridge, UK).

2.5. Volatile Compounds

Volatile compounds were isolated from the headspace of the EVOOs using the solid phase micro-extraction (SPME) technique [27]. Ten mL of the sample was added in a 15 mL glass vial with 10 µL of 1000 ppm benzyl acetate solution as internal standard. A DVB/CAR/PDMS 50/30 µm fiber (Supelco Company, Bellefonte, PA, USA) was inserted in the headspace for 60 min, and the sample was heated at 40 °C to simulate the mouth temperature. The volatile compounds profile was obtained using a Shimadzu GC-2030 gas chromatograph coupled with a Shimadzu TQ8040 NX mass spectrometer detector. To separate the compounds, a SLB-5 MS column (Teknokroma, Barcelona, Spain) of 30 m length, 0.25 mm internal diameter, and 0.25 µm film thickness was used. The ramp temperature of the oven was as follows: (i) oven started at 40 °C, maintained 3 min; (ii), ramp of 5 °C min^{-1} up to 100 °C; and (iii), ramp of 3 °C min^{-1} up to 300 °C, maintained for 3 min.

The parameters of the mass spectrometer were: mass range 35–350 m/z, scan speed 5000 amu s^{-1}, event time 0.100 s, interface temperature 280 °C, and ion source temperature 230 °C. A commercial alkane standard mixture (C6-C20; Sigma-Aldrich, Steinheim, Germany) was used to calculate the retention indexes. NIST 17 mass spectral and retention index libraries were used for the identification of compounds. Only compounds with spectral similarity >90% and with a deviation of fewer than 10 units of linear retention similarity were considered correct hits [28].

2.6. Fatty Acids Profile

Olive oil fatty acids were methylated following the International Organization for Standardization method [29]. The fatty acid C13:0 (0.04 mg mL^{-1}) was used as internal standard, and the fatty acid profile was determined using the methodology previously reported by García-Garví et al. [27]. Briefly, methylated samples were injected in a Shimadzu GC-2030 gas chromatograph, equipped with a Supelco SP®-2380 capillary column (length 60 m, internal diameter 0.25 mm, and film thickness 0.20 µm) coupled with a flame ionization detector (FID). The temperatures of injector and detector were 250 °C and 260 °C, respectively, and a 1:20 split ratio was used. Helium was used as carrier gas (28.4 cm s^{-1} linear velocity), and the make-up gas was nitrogen (40 mL min^{-1}). The FID detector used 35 and 350 mL min^{-1} of hydrogen and air, respectively. The oven temperature program started at 70 °C and finished at 250 °C, increasing at a rate of 3 °C min^{-1}, and maintained the final temperature for 3 min. Identification of fatty acids methyl esters (FAMEs) was conducted by comparing retention times of sample compounds with those of the FAME Supelco MIX-37 standards (Supelco Company, Bellefonte, PA, USA).

2.7. Total Antioxidant Activity and Total Phenolic Content

The total phenolic content (TPC) and antioxidant activity (AA) were analyzed with the same olive oil extract, according to García-Garví et al. [27] method. Briefly, 3 g of olive oil was shaken for 2 min with 5 mL of extractant (methanol/water (80:20, *v:v*)), and the hydrophilic phase was filtered through 0.45 µ regenerated cellulose filters (25 mm, Sartorius, Madrid, Spain). This action was carried out twice with the lipophilic phase of each sample, and both hydrophilic phases were mixed and evaporated in a rotatory vacuum evaporator at 35 °C. The residue was recovered with 1.5 mL of methanol.

Total phenolic content (TPC) was determined using the Folin–Ciocalteu method [30], expressing results as mg gallic acid equivalents (GAE) L^{-1} of olive oil. The antioxidant activity was measured by two methods: $ABTS^{+\bullet}$ [2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)] and $DPPH^{\bullet}$ (2,2-diphenyl-1-pirylhydrazyl) [31], expressing results as mmol Trolox eq L^{-1} of olive oil. All these analyses were conducted using a UVG1002E UV-vis spectrophotometer (Helios, Cambridge, UK).

2.8. Statistical Analysis

The processing of the results was initially carried out with one-way analysis of variance (ANOVA) followed by Tukey's multiple range test. Differences were considered statistically significant at $p < 0.05$. Penalty analysis was also conducted for affective data; it is a method that helps interpreting the data of the JAR analysis, describing how close to the optimal is the intensity of key sensory attributes, according to the consumers' opinion. The software used to perform the statistical analyses was XLSTAT Premium 2016 (Addinsoft, New York, NY, USA).

3. Results and Discussion

3.1. Consumers Study

The results of the satisfaction degree of the consumers with the key sensory attributes of olive oils together with their overall liking are presented in Table 1. Eight positive descriptors (e.g., fruity) were analyzed, and significant differences were found in all of them. A trained panel evaluated the three oils under study and concluded that no defects were present; thus, defects were not included in the affective study. Consumers showed a higher satisfaction degree for all the studied descriptors in the *Arbequina* hydroSOS oil; the highest differences were found for the olive oil's odor (1.4 points of difference) and olive oil's color (2 points of difference).

Table 1. Consumers liking values of key sensory attributes of the olive oils under study.

Sensory Attribute	ANOVA †	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS
Olive oil odor	***	5.4 ^{b,‡}	6.8 ^{a}	6.0 ^{b}
Olive oil flavor	***	5.5 ^{b}	6.4 ^{a}	5.8 ^{a,b}
Fruity	*	5.0 ^{b}	5.9 ^{a}	5.6 ^{a,b}
Bitterness	*	4.6 ^{b}	5.5 ^{a}	5.0 ^{a,b}
Pungent	*	4.6 ^{b}	5.5 ^{a}	5.3 ^{a,b}
Aftertaste	*	5.3 ^{b}	6.3 ^{a}	5.8 ^{a,b}
Olive oil color	*	5.1 ^{b}	7.1 ^{a}	6.6 ^{a}
Overall liking	**	5.3 ^{b}	6.3 ^{a}	5.8 ^{a,b}

†, *, **, and *** significant at $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively. ‡ Values followed by the same letter, within the same row and factor, were not significantly different, according to Tukey's least significance test.

Consumers showed a higher preference for the two hydroSOS oils, with 46% of the consumers preferring the *Arbequina* sample compared to 30% of them preferring the *Arbosana* and only 24% preferring the control sample. The IOC does not consider the oil color as a quality parameter, and thus they do not incorporate the descriptor "color" in their tasting questionnaire. However, there is no doubt that color is an important descriptor for the characterization of an oil, and it is also important for consumer opinion and their purchase intentions [23]. It is important to note that the two hydroSOS samples had higher satisfaction values compared to the control sample. The color was considered by consumers as the second most important sensory parameter (55%, indicated that color was a key factor for them in deciding whether they liked the sample) in driving their satisfaction on the olive oil, just after the characteristic oil flavor (85%), and was very close to aftertaste (52%).

The penalty analysis (PA) test is a sensory data analysis to identify the potential directions for the improvement of products, i.e., it helps in determining attributes that can be improved to satisfy consumer demands and needs. Considering the results of this test, the best EVOO was the *Arbequina* hydroSOS oil (B); consumers only thought that it was slightly too bitter. However, for the control sample (*Arbequina* conventional, A), more than 30% of consumers considered color, odor, flavor, bitterness, fruity, and aftertaste to have lower intensities than expected. Finally, the *Arbosana* hydroSOS oil (C) was also penalized by consumers for having low odor, flavor, fruity, aftertaste, and having too much bitterness (Figure 1).

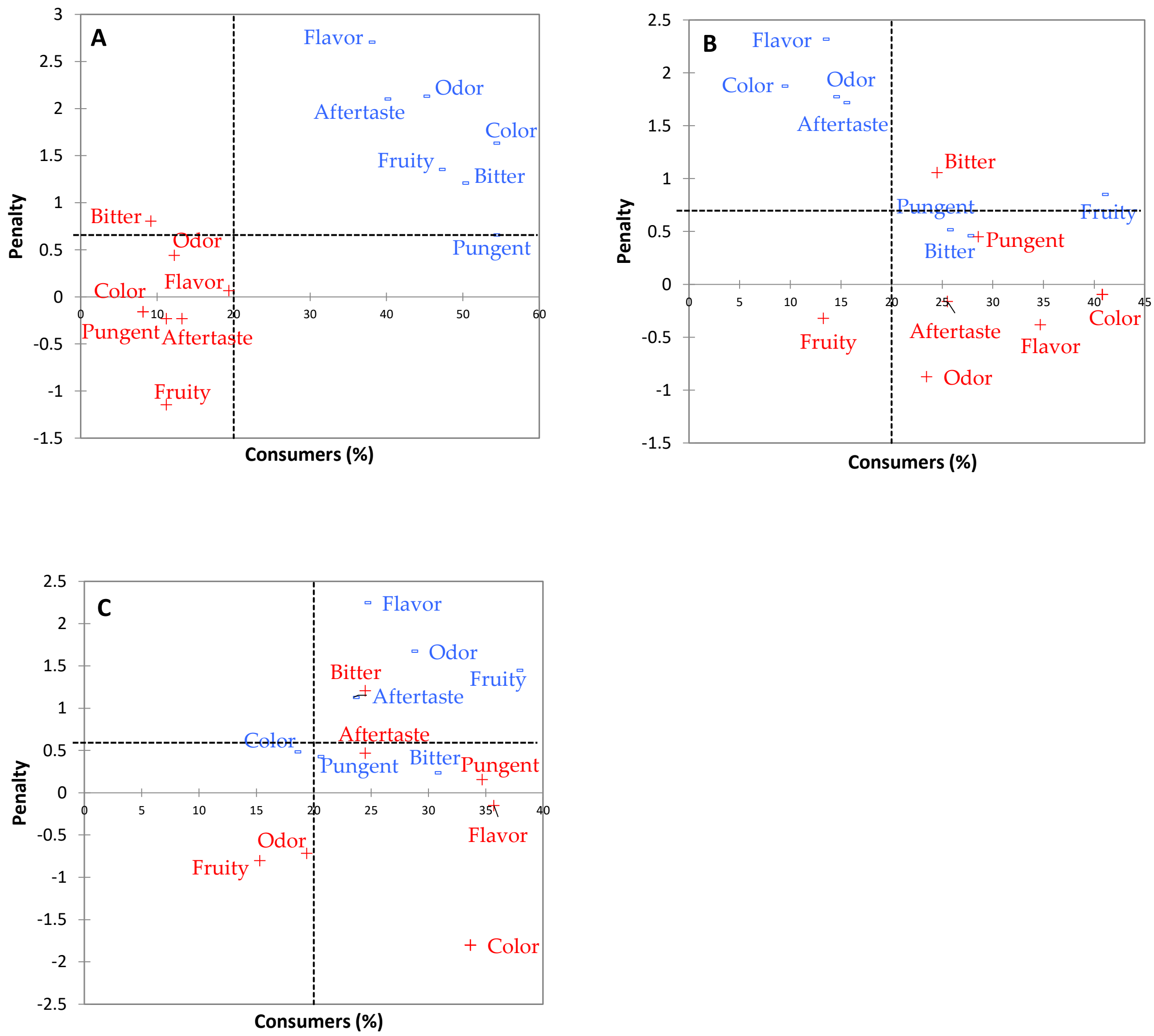

Figure 1. Penalty analysis (x-axis: effect on the average; y-axis: percentage of consumers) of conventional Arbequina (**A**), hydroSOS Arbequina (**B**), and hydroSOS Arbosana (**C**) extra virgin olive oils. Blue (-) and red (+) colors are used for those attributes having too low or too high intensity, according to consumer opinion.

3.2. Descriptive Sensory Analysis

There were statistically significant differences in six out of the eleven attributes evaluated (Table 2). In general, the hydroSOS olive oils had higher intensities of tomato flavor and higher pungencies but lower bitterness compared to the control sample. The *Arbequina* hydroSOS oil had the lowest value of fruity (3.0) while the *Arbosana* hydroSOS oil had the highest intensity of ripeness (6.6). Ripe oil flavors are related to the highest ripening state of olive oils at the moment of the oil extraction and remind consumers about ripe olives.

In previous studies, no significant effects of the irrigation treatment on the sensory profile of olive oils were found [32,33]; these differences can be due to, among other factors, the intensity of the water stress generated in the olive trees or the time when water restriction was applied.

The trained panel did not find any defects (oxidized, rancid, fusty, musty, and muddy) in the samples under study. Considering this sensory information, the samples under study can be classified as extra virgin olive oils (EVOOs).

Table 2. Descriptive sensory profiles of the olive oils under study as described by a trained panel; a scale from 0 (no intensity) to 10 (extremely high intensity), with increments of 0.5, was used.

Sensory Attribute	ANOVA †	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS
Fruity	**	3.8 [a,‡]	3.0 [b]	3.8 [a]
Maturity: Green	**	4.9 [a]	5.0 [a]	3.4 [b]
Maturity: Ripe	*	5.1 [b]	5.0 [b]	6.6 [a]
Floral	N.S.	0.1	0.2	0.1
Green (artichoke)	N.S.	0.4	0.1	0.2
Green (herbaceous)	N.S.	0.2	0.2	0.1
Green (pepper)	N.S.	0.2	0.9	0.1
Tomato	*	0.5 [b]	1.1 [a]	1.4 [a]
Bitter	**	1.4 [a]	0.5 [b]	0.5 [b]
Astringent	N.S.	0.1	0.1	0.1
Pungent	*	1.0 [b]	1.5 [a]	1.9 [a]
Oxidized	N.S.	0	0	0.1
Rancid	N.S.	0	0	0
Fusty	N.S.	0	0	0
Musty	N.S.	0	0	0
Muddy	N.S.	0	0	0
Commercial Classification		EVOO	EVOO	EVOO

† N.S. 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 row, were not significantly different, according to the Tukey's least significant test.

3.3. Quality Parameters

All of the samples were classified as Extra Virgin Olive Oil (EVOO) because they met all IOC requirements (International Olive Council) regarding commercial category regulation [23] (Table 3). The experimental values of the free acidity (expressed as % of oleic acid) showed that *Arbequina* conventional olive oil had the highest value, 0.485%, and both hydroSOS samples had lower values (0.212% and 0.281%). This quality parameter was related with the oil extraction process [34], ripeness stage of olives, and stability against oxidation [35], and the IOC maximum threshold was 0.8% for the EVOOs category. Other authors showed that deficit irrigation strategies could cause slight decreases on the amount of free fatty acids, which are linked to the free acidity [13,32].

Table 3. Commercial quality parameters established by International Olive Council for olive oils.

Parameters	ANOVA†	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS	Values IOC
Free acidity (%)	*	0.485 [a,‡]	0.212 [b]	0.281 [b]	≤0.8
Peroxide Index (meq O_2 Kg^{-1})	*	13.67 [b]	16.46 [a]	13.40 [b]	≤20
K_{232}	*	1.28 [b]	1.45 [a,b]	2.06 [a]	≤2.5
K_{270}	N.S.	0.066	0.066	0.046	≤0.22
ΔK	N.S.	−0.012	0.003	0.006	≤0.01
Commercial Classification		AOVE	AOVE	AOVE	AOVE

† N.S. not significant at $p > 0.05$. * significant at $p < 0.05$. ‡ Values followed by the same letter, within the same row and factor, were not significantly different, according to the Tukey's least significant test. IOC: International Olive Council.

The peroxide index, a quality parameter related to the occurrence of damaged olives, initial oxidation [36], and/or incorrect extraction process [37], showed significant differences among the studied oils; the maximum allowed values were set at 20 meq O_2 kg^{-1}. In this sense, all samples were below this threshold, with the *Arbequina* hydroSOS oil having the highest value (16.46 meq O_2 kg^{-1}). Servili et al. [38] determined that the application of deficit irrigation generated only minor changes in peroxide value, not affecting significantly to the classification of the obtained oils.

The ultraviolet extinction coefficients (K_{232}, K_{270} and ΔK) were affected by the storage conditions [39]. In this way, K_{232} was related with primary oxidation, produced by the generation of hydroperoxides of linoleic acids, conjugated dienes, and carboxylic compounds, while K_{270} was related with to the secondary oxidation produced by the generated conjugated trienes [40]. For an olive oil to be considered as EVOO, the maximum values set by IOC for these parameters (K_{232}, K_{270}, and ΔK) were 2.50, 0.22, and 0.01, respectively. In this case, only statistically significant differences were found for the K_{232} parameter, although all values were below the previously mentioned IOC threshold. Similar results were previously reported by García-Garví et al. [27].

3.4. Volatile Compounds

Volatile compounds are responsible for key positive aromas and flavor notes of EVOO, including fruity, floral, green, and tomato [27,41]; however, they are also responsible for the defects, if present. In this case, eleven volatile compounds were found in the olive oils under study, with four of them having significant differences (Table 4).

Table 4. Volatile compounds profile obtained by GC-MS in olive oil (mg 100 mL^{-1}).

Compound	Sensory Descriptor [42,43]	ANOVA †	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS
Hexanal	Green apple	**	51.59 ^{c,‡}	102 ^{b}	116 ^{a}
trans-2-Hexenal	Bitter almonds, green fruity	*	332 ^{b}	339 ^{b}	369 ^{a}
trans-2-Hexen-1-ol	Grass, astringent, bitter	**	164 ^{b}	199 ^{a}	202 ^{a}
1-Hexanol	Fruity	**	576 ^{b}	688 ^{a}	695 ^{a}
2,4-Hexadienal	Fresh, green, floral	N.S.	1.78	1.89	1.68
Hexanoic acid	Sweet, rancid, sour	N.S.	1.03	0.59	0.72
cis-3-Hexen-1-ol acetate	Green, fruity	N.S.	125	119	122
Hexyl acetate	Green, apple, fruity	N.S.	35.4	35.05	33.3
Limonene	Citrus	N.S.	9.06	8.88	11.86
Nonanal	Nutty, citrus	N.S.	8.01	8.93	8.37
Ethyl dodecanoate	Waxy, floral, fruity	N.S.	0.29	0.23	0.19
TOTAL		*	1305 ^{b}	1501 ^{a}	1559 ^{a}

† N.S. not significant at $p > 0.05$. * and ** significant at $p < 0.05$ and 0.01, respectively. ‡ Values followed by the same letter, within the same row and factor, were not significantly different, according to the Tukey's least significance test.

The control sample (*Arbequina* conventional) had the lowest total concentration (576 mg 100 mL^{-1}), while both of the hydroSOS EVOOs had higher and equivalent values. Bubola et al. [13] concluded that different irrigation strategies significantly changed the volatile profile of Croatian olive oils. Similar results have been also reported by other authors [13,27,33]. The four predominant compounds were (in order of abundance): 1-hexanol, *trans*-2-hexenal, *trans*-2-hexen-1-ol, and *cis*-3-hexen-1-ol acetate.

In all samples under study, 1-hexanol was the most abundant compound, and it is one of the compounds contributing to the fruity character of the EVOOs [42]. 1-Hexanol, *trans*-2-hexenal, and *trans*-2-hexen-1-ol were more abundant in both hydroSOS EVOO, especially in the *Arbosana* one. *trans*-2-Hexenal and *trans*-2-hexen-1-ol were mainly associated with green fruity and green grass flavor notes [15,42], respectively.

3.5. Fatty Acids Profile

Thirteen fatty acids were found in samples under analysis (Table 5). The predominant fatty acid was oleic acid (C18:1 c9), as expected, with contents ranging from 61.68 and 70.31% in *Arbequina* hydroSOS and conventional oils, respectively; these values of oleic acid were similar to those previously reported in oils from the same variety [44,45]. At the same time, *Arbequina* hydroSOS had the highest concentrations of palmitic acid (C16:0) and linoleic acid (C18:2 n6c). Some authors evaluated the effects of climatic and agricultural practices such as irrigation on fatty acid profiles [32,44,45], and the most affected compounds were the oleic and palmitic acids. To avoid fraudulent mixtures with other oil types, the IOC established the maximum and minimum contents of each fatty acid in EVOOs [23]. In this sense, oleic acid must be between 55% and 85%, palmitic acid between 7% and 20%, and linoleic acid between 2.5% and 21%. All three olive oils under analysis here had fatty acid concentrations within these official limits.

Table 5. Fatty acids profile of olive oils.

Fatty Acid	ANOVA †	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS
C14:0	N.S.	0.01	0.02	0.01
C16:0	***	13.28 [c,‡]	17.43 [a]	16.74 [b]
C16:1 c9	**	0.13 [b]	0.14 [a]	0.067 [c]
C16:1 c9	***	1.22 [b]	1.53 [a]	1.53 [a]
C17:0	*	0.08 [c]	0.15 [a]	0.18 [a]
C17:1	***	0.16 [c]	0.28 [b]	0.35 [a]
C18:0	***	2.53 [a]	1.86 [c]	2.15 [b]
C18:1 c9	***	70.31 [a]	61.68 [c]	66.92 [b]
C18:1 t11	**	2.10 [b]	3.17 [a]	2.85 [a]
C18:2 n6c	***	9.39 [b]	12.70 [a]	8.29 [c]
C18:3 n3	***	0.39 [c]	0.61 [a]	0.44 [b]
C20:1 n9	N.S.	0.30	0.33	0.31
C22:0	N.S.	0.11	0.12	0.16
SFA	***	16.01 [b]	19.57 [a]	19.24 [a]
MUFA	**	74.21 [a]	67.12 [b]	72.03 [a]
PUFA	***	9.78 [b]	13.31 [a]	8.73 [b]

† N.S. 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 row, were not significantly different, according to the Tukey's least significant test. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Monounsaturated fatty acids (MUFAs) were the most abundant family in the three samples under study, with the *Arbequina* hydroSOS oil having the lowest total content of 67.12%. However, this same sample had the highest content of polyunsaturated fatty acids (PUFAs), which compensated for the decrease in MUFAs. These two families (MUFAs and PUFAs) are related with several health benefit characteristics of the Mediterranean diet, such as neuronal mitochondrial protection [46]. On the other hand, in this particular case, the application of a deficit irrigation strategy in a super-high-density olive orchard significantly increased the content of saturated fatty acids (SFAs).

3.6. Antioxidant Activity and Total Phenol Content

The antioxidant activity of the oils under analysis are shown in Table 6, and statistically significant differences were found for both studied methods: $ABTS^{+}$ and $DPPH^{\bullet}$. In general, the experimental values found in the current study were similar to those reported by other authors in olive oils obtained from *Arbequina* [27,47] and other olive varieties [44]. *Arbequina* hydroSOS showed the highest values of both methods, although differences were only significant for $ABTS^{+}$, implying that water stress in *Arbequina* olive trees could produce an increase in the antioxidant activity of the final olive oils.

In a similar way, the *Arbequina* hydroSOS olive oil had the highest value of the TPC (111 mg GAE L^{-1}). This increment could be due to a defensive strategy against hydric stress generated by the deficit irrigation applied, as has been previously observed and reported by other authors [48]. Furthermore, it is necessary to mention that it has been clearly demonstrated that the accumulation of phenolic compounds can be influenced by climatic conditions and/or agricultural practices, including the implementation of deficit irrigation strategies [49,50].

Table 6. Antioxidant activity and total phenolic obtained in olive oils.

	ANOVA †	*Arbequina* Conventional	*Arbequina* HydroSOS	*Arbosana* HydroSOS
$ABTS^{+}$ (mmol Trolox L^{-1})	**	0.273 [b,‡]	0.402 [a]	0.275 [b]
$DPPH^{\bullet}$ (mmol Trolox L^{-1})	**	0.407 [a,b]	0.515 [a]	0.347 [b]
TPC (mg GAE L^{-1})	**	90.3 [b]	111 [a]	76.1 [b]

†, ** significant at $p < 0.01$. ‡ Values followed by the same letter, within the same row, were not significantly different, according to the Tukey's least significant test. TPC: Total phenol content.

4. Conclusions

HydroSOS olive oils had higher concentrations of key volatile compounds (e.g., 1-hexanol and *trans*-2-hexen-1-ol) determining oil greenness. Additionally, these environmentally friendly oils had higher antioxidant capacities in the products due to their higher total polyphenol contents and their contents of polyunsaturated fatty acids. Finally, this study demonstrated that consumers like hydroSOS olive oils due to adequate intensities of fruity, the characteristic olive oil odor and flavor, and aftertaste. It can be stated that deficit irrigation applied to olive cultivation can save an important volume of water (~30% of applied water) and has demonstrated to produce extra virgin olive oils of a good quality that are highly appreciated by consumers. This information is essential to: (i) demonstrate that consumers appreciate hydroSOStainable products, (ii) convince more farmers of the potential of these products, and to start implementing deficit irrigation strategies.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. None of the data shared in this article can lead to the identification of any of the participants.

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