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Effects of organic and conventional farming on the physicochemical and functional properties of jujube fruit

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ABSTRACT

Organic food is associated with improved nutritional properties, and this consumer expectation has led to increasing demand for organic fruits and vegetables. The objective of this study was to evaluate the changes in physical, chemical, and nutraceutical parameters of the jujube fruits 'Grande de Albatera' cultivar, grown under organic or conventional production systems. Results showed that the organic jujubes were smaller, with a slightly more intense yellow and red color, with higher contents of chlorophylls, carotenoids, sugars, organic acids, and total volatile compounds, but with lower protein and flavonoids, contents than conventional jujubes. Therefore, it can be concluded that the market quality of organic jujubes was similar to that of the conventional ones because fruits were smaller but with a more intense coloration. However, the flavor quality was better as they had more sugars, acids, and volatile compounds, making the flavor of fruits more attractive for consumers. Finally, there were no significant differences in the antioxidant attributes, as organic and conventional jujubes had similar total contents of phenols and antioxidant activity.

1. Introduction

Organic food is associated by the general public with improved nutritional properties, as well as to non-contaminating sustainable agricultural practices (Zanoli & Naspetti, 2002). This consumer perception has led to an increasing demand for organic fruits and vegetables (Raigón, Rodríguez-Burruezo, & Prohens, 2010). Many consumers believe that organic foods are healthier than conventionally produced foods and that they are produced in a more environmental friendly way (Zanoli & Naspetti, 2002). This consumer expectation challenges scientists with the aim of proving this hypothesis (Woese, Lange, Boess, & Bögl, 1997), tests must be done to compare the composition and quality of conventional and organic foods. According to Lester and Saftner (2011), the quality of fruits and vegetables can be categorized into market, sensory, and nutritional attributes; the last ones being mainly linked to high antioxidant activities (Gao, Wu, & Wang, 2013).

Jujube fruits are widely consumed in Asian countries as a food and food additive due to its high nutritional value (Almansa, Hernández, Legua, Nicolás-Almansa, & Amorós, 2016).

Jujube is an important plant in traditional Chinese medicine and is recommended for the treatment of some diseases, since have multiple beneficial health activities, such as anticancer, anti-inflammatory, hepatoprotective, gastrointestinal protective, antioxidant, antinsomnia, immunostimulating and neuroprotective effects (Guo et al.,. 2015).

There are many jujube cultivars, each one with different physicochemical, physiological and functional characteristics. Most studies have been done on Asian cultivars; however, the Spanish cultivars are still very poorly studied (Almansa et al., 2016; Hernández et al., 2016). Besides, it is known that the peel of these fruits may contain a great deal of compounds with high antioxidant activity and this content is higher in the peel as compared to the pulp (Wojdyło, Carbonell-Barrachina, Legua, & Hernández, 2016).

For all of this, the aim of this work was to study the effects of organic *versus* conventional farming on the composition and quality of Spanish jujubes 'Grande de Albatera' cultivar. The quality of jujubes has been studied following the similar three attributes categories established by Lester and Saftner (2011): (i) *market quality* (weight and size of fruits and stones, instrumental color, and contents of chlorophylls and carotenoids), (ii) *flavor and nutritional quality* (total soluble solids, sugars, organic acids, moisture, volatile compounds, proteins and mineral composition), and (iii) *nutraceutical compounds* (total antioxidant activity, and total contents of phenols, flavonoids, and flavonols). The nutraceutical parameters were evaluated separately in the peel and

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pulp to be able to recommend or not their consumption with or without peel.

2. Material and methods

2.1. Experimental conditions and plant material

The experiment was carried out in 2015 and 2016 at one farm located in San Isidro (38° 10′ 22.29″ N, 0° 51′ 36.138″ W, 19 masl; province of Alicante, Spain). All data are the average of the two years (similar results and trends were obtained), and the results were expressed as the mean values of both years. In this farm, two plots separated 500 m were taken, one plot of organic system and another plot of conventional system. Both plots consisted of 12-year-old jujube trees ('Grande de Albatera' cultivar) planted at 4 × 4 m. The soil of the farm had a sandy loam texture, very low electrical conductivity, high lime content, and low organic matter content. The irrigation water had an electrical conductivity of 0.8–1.1 dS m^{-1}. The water consumption was 4500 m^3 ha^{-1}. The nutritional conditions were the following in each plot:

- The organic plot relied only on organically certified fertilizers and pesticides and used no soil fumigation. This plot was biofertilized with 55 N fertilizer units (FU), based on Bombardier (certified product for organic farming by Sohiscert for European markets), 90 K FU based on Hortisul® (authorized according to CE regulations Nº 834/2007 and CE Nº 889/2008, to be used in organic farming), and 30 units of bactoneco®, a formulation based on specific strains of beneficial bacteria: *Pseudomonas* spp and *Bacillus* spp (suitable for organic farming and certified by Sohiscert).
- In the conventional plot inorganic fertilizers and synthetic pesticides were used. This plot was fertilized with 46 N FU, 25 P FU, 82 K FU, and 36 CaO FU.

For each farm, 200 fruits (50 fruits *per* tree) by year were hand-harvested, from the 4 central trees of the plot to avoid border trees, at physiological maturity, and immediately transported under ventilated conditions to the laboratory; avoiding border trees is essential to ensure in the case of the organic trees to avoid any pollution coming from adjacent plots. Thirty fruits from each farm were taken for the analyses of the physical parameters, while the other one hundred seventy fruits were used for the analyses of the chemical and sensory parameters, including the volatile composition each year.

The determination of the majority parameters (chlorophylls, carotenoids, total soluble solids, moisture, volatiles, proteins and minerals) was made in three samples that were quantified in duplicate (n = 6 each year). For each sample, three different whole fruits were used. The rest of parameters (antioxidant activity, total phenols, flavonoids and flavonols) were determined in similar samples but separating the peel and the pulp.

2.2. Market quality

Once in the laboratory, equatorial diameter and length (mm) of fruits and stones were measured with a digital caliper with 0.01 mm accuracy; fruits and stones weight (g) was measured using a digital balance, with an accuracy of 0.01 g; Color was assessed according to the *Commission Internationale de l'Eclairage* (CIE*Lab*) and expressed as L^*, a^*, b^* coordinates, chroma, and Hue angle, with a Minolta C-300 Chroma Meter (Minolta Corp., Osaka, Japan) coupled to a Minolta DP-301 data processor. Color measurements were made on the whole fruit on two opposite faces at the equatorial zone, according to Almansa et al. (2016). These parameters were measured in 30 fruits. The moisture content was determined by drying at 55 °C in a Binder oven until reaching constant weight and expressed as a percentage, and stored −80 °C until further analysis.

Chlorophylls *a and b* were extracted from whole fruit (mixing peel and pulp) using 85% acetone in a ratio 1:2 (w:v) (AOAC, 1990). The sample was crushed with sea sand and, then, centrifuged. Absorbance of the supernatant was read at 664 and 647 nm, using a Helios Gamma spectrophotometer (model, UVG 1002E; Helios, Cambridge, UK). Results were expressed as mg 100 g^{-1} fresh weight (fw). Total carotenoids were extracted with acetone and diethyl ether and quantified from whole fruit (peel and pulp) according to methodology previously described by Valero et al. (2011), with acetone and diethyl ether. The lipophilic phase was used to estimate the total carotenoids content, by reading the absorbance at 450 nm. Results were expressed as mg of β-carotene equivalent per 100 g^{-1} fw, taking into account the $\varepsilon_{cm}^{1\%} = 2560$.

2.3. Flavor and nutritional quality

The total soluble solids (TSS) were measured with a refractometer. The sugar and organic acid profile were quantified according to Hernández et al. (2016). Briefly, ∼5 g of jujube fruit were homogenized with 6 mL of 50 mM Tris-acetate buffer pH 6.0, 10 mM $CaCl_2$, and 6 mL of ethyl acetate. The aqueous phase was used for the identification and quantification of sugar and organic acid profiles, according to Almansa et al. (2016). 1 mL of the hydrophilic extract was used for high-performance liquid chromatography (HPLC) (Hewlett–Packard HPLC series 1100; Hewlett-Packard, Wilmington, DE, USA). The elution buffer consisted of 0.1% phosphoric acid with a flow rate of 0.5 mL min^{-1}. Organic acid was isolated using a Supelco column (Supelcogel TM C-610H column 30 cm × 7.8 mm) and a precolum Supelguard (5 cm × 4.6 mm; Supelco, Inc., Bellefonte, PA, USA). Sugars and acids were quantified using refractive index and diode-array detectors, respectively. Standards of organic acids (L-ascorbic, oxalic, citric, tartaric, malic, quinic, shikimic, succinic, and fumaric acids) and sugars (glucose, fructose, sucrose, and sorbitol) were obtained from Sigma (Poole, Dorset, UK). Calibration curves were used for the quantification of organic acids, showing good linearity ($R^2 = 0.999$). Results for both organic acids and sugars were expressed as g 100 g^{-1} fw.

The volatile composition of the jujube fruits was studied by using headspace solid phase micro-extraction (HS-SPME), according to the methodology previously described by Hernández et al. (2016). A gas chromatograph (GC-MS) Shimadzu GC-17A (Shimadzu Corporation, Kyoto, Japan) coupled with a Shimadzu mass spectrometer detector GC-MS QP-5050A was used in the identification and semi-quantification of the volatile compounds of jujube. A TRACSIL Meta X5 column (Telnolroma S. Co. Ltd., Barcelona, Spain) was used. Results were expressed as μg kg^{-1} fw.

The protein content was analyzed by Bradford (1976) method using the Bio-Rad reactive. A standard curve of pure bovine serum albumin (BSA) was used for quantification according to Almansa et al. (2016). Results were expressed as mg g^{-1} fw.

The mineral contents were analyzed using an atomic absorption-emission spectrometer (Solaar 969, Unicam Ltd, Cambridge, UK), according to Hernández et al. (2016). Macro-elements (Ca, Mg, K, and Na) were expressed as g kg^{-1} dry weight (dw) and micro-elements (Fe, Cu, Mn, and Zn) were expressed as mg kg^{-1} dw.

2.4. Nutraceutical compounds

Total antioxidant activity (TAA), phenols, flavonoids and flavonols were quantified in both pulp and peel of jujube fruit.

The extracts of jujube fruit (peel or pulp) for the analysis of H-TAA (hydrophilic-TAA) and L-TAA (lipophilic-TAA) were obtained with 50 mM tris-acetate buffer pH 6.0, and ethyl acetate to separate the aqueous and organic phases and used to quantify H-TAA and L-TAA, respectively. The reaction mixture contained 10 mM ABTS, 1 mM hydrogen peroxide, and 10 mM peroxidase in a total volume of 1 mL of 50 mM glycine-HCl buffer (pH 4.5) for H-TAA, or ethyl acetate for L-

TAA. The reaction was monitored at 730 nm until a stable absorbance was obtained using a UNICAM Helios spectrophotometer (Cambridge, UK). A calibration curve was performed with Trolox as antioxidant standard for both H-TAA and L-TAA (Arnao, Cano, & Acosta, 2001). The results were expressed as mmol Trolox kg^{-1} fw.

For the antioxidant activity determination by the $ABTS^{+}$, $DPPH^{\bullet}$ and FRAP methods, a methanolic extract was prepared described previously by Wojdyło et al. (2016). The free radical scavenging capacities were determined using the ABTS method described by Re et al. (1999), $DPPH^{\bullet}$ radical (2,2-diphenyl-1-picrylhydrazyl) method, as described by Brand-Williams, Cuvelier & Berst (1995) and FRAP (ferric reducing antioxidant power) method described by Benzie and Strain (1996). Calibration curves, in the range 0.5–5.0 mmol Trolox L^{-1} were used for the quantification of antioxidant activity by the three methods showing good linearity ($R^2 = 0.998$). The results were expressed as mmol Trolox kg^{-1} fw.

Total phenolic compounds were quantified in peel and pulp in the hydrophilic phase according to the method described by Singleton, Orthofer, and Lamuela-Raventos (1999), using the Folin–Ciocalteu reagent, and measuring absorbance at 760 nm. A calibration curve was performed with gallic acid and results were expressed as mg GAE 100 g^{-1} fw.

Flavonoids and flavonols were extracted from peel and pulp of jujube following the method of Zhuang (1992) with 80% methanol. The analysis of total flavonoids was performed by spectrophotometry following the method of Zhuang (1992) with 5% $NaNO_2$, 10% $AlCl_3$ and 1 M NaOH and the absorbance was measured at 512 nm. Results of total flavonoids were expressed in mg rutin equivalents 100 g^{-1} fw. For this, a rutin calibration line was performed whose equation was $y = 4.479x + 0.06773$ with a correlation of 99.88%. Quantification of total flavonols was performed by spectrophotometry following the method of Kumaran, Kutty, Chatterji, Subrayan, and Mishra (2007) with $AlCl_3$ (2 mg mL^{-1}) and sodium acetate (50 mg mL^{-1}) and the absorbance was measured at 440 nm. The results of total flavonols were expressed in mg rutin equivalents 100 g^{-1} fw. For this, a rutin calibration line was performed whose equation was $y = 3.408x + 0.0297$ with a correlation of 99.01%.

2.5. Statistical analysis

Statistical analyses were performed using the software package SPSS 18.0 for Windows (SPSS Science, Chicago, IL, USA). A basic descriptive statistical analysis was followed by an analysis of variance test (ANOVA) for mean comparisons. The method used to discriminate among the means (Multiple Range Test) was Fisher's LSD (Least Significant Difference) procedure at a 95.0% confidence level.

3. Results and discussion

3.1. Market quality

The experimental fruit weights were similar to those previously reported in Spanish (Hernández et al., 2016), Korean (Choi, Ahn, Kozukue, Levin, & Friedman, 2011), and Chinese jujube cultivars (Wang et al., 2012). Conventionally grown jujubes were significantly heavier than those cultivated under organic conditions (Table 1). This higher weight was due to larger size of the traditional jujubes and higher values of equatorial diameter and length. However, the stone of both types of jujubes were similar in weight and equatorial diameter. These experimental findings regarding fruit size and weight were predictable, because conventional farming provides easily available nutrients for plant uptake. The conventional system applied synthetic fertilizer, whereas the organic system only used certified organic products, which nutrient release was slow but sustainable. These differences between the farming types were in agreement with those previously reported in other species such as grapefruit (Lester, Manthey, & Buslig, 2007) and strawberry (Conti et al., 2014). In these two cases the fruit size, the fruit number per plant and the yield decreased under organic conditions, although the weight and longitudinal diameter of ripe passion fruit were statistically equivalent in both cropping systems (De Oliveira et al., 2017).

Significant differences in the dry matter content of jujubes were observed, with organic fruits having higher content (Table 1). This same trend was previously reported in tomatoes (Caris-Veyrat et al., 2004). Dry matter is often higher in organically grown plants than in conventionally grown ones, for leafy and root vegetables and tubers, although in vegetables and fruit the trend is not so clear (Woese et al., 1997).

The values of the CIE$L^*a^*b^*$ color coordinates were very similar to those described in other Spanish (Collado-González et al., 2014) and Chinese jujube cultivars (Wang et al., 2012). The fruits of both farming types were harvested on the same date; however, slight changes in the color values were observed (Table 2). The organic jujubes presented a slightly, but significant, more reddish color (higher a^* value) and more yellowish (higher b^* value) color. These differences in the basic color coordinates (a^* and b^*) led to a more color intensity (higher chroma values), although differences were below 2 units, which are not perceptible by the human eye (no significant differences in H^{o} parameter). These data agreed with those found by Lester et al. (2007), who found that organically grown grapefruits presented higher chroma index than the conventional ones; this trend was reported in both external color of the fruit and the fruit juices. Caris-Veyrat et al. (2004) they also found that more lycopene and carotene in organic tomatoes than in conventional tomatoes. However, López, Fenoll, Hellín, and Flores (2013) did not find differences in the color of organic and conventional peppers, but using the Hunter Lab System.

The organic jujubes presented significantly higher content of pigments, including both chlorophylls and carotenoids (Fig. 1), as compared to the conventional fruits, which agreed with a higher color intensity (higher chroma value; Table 2). Several authors (Caris-Veyrat et al., 2004; Conti et al., 2014; Juroszek, Lumpkin, Yan, Ledesma, & Ma, 2009) found more carotenoids in organic than conventional tomatoes and strawberries, too. However, the effects of the farming type were not significant in the β-carotene and anthocyanin contents in plums (Lombardi-Boccia, Lucarini, Lanzi, Aguzzi, & Cappelloni, 2004) and passion fruit (De Oliveira et al., 2017).

In general, the differences between organic and conventional products are justified by the different moisture content of the products, with lower moisture being expected for the organic ones. However, if this was the case, the differences in weight, total chlorophylls and total

Table 1
Physical parameters and moisture of jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Farming type	Fruit				Stone		
	Weight (g)	Equatorial diameter (mm)	Length (mm)	Moisture (%)	Weight (g)	Equatorial diameter (mm)	Length (mm)
Organic	23.4 ± 0.4 b†	37.5 ± 0.4 b	37.2 ± 0.4 b	73.35 ± 0.74 b	0.71 ± 0.02 a	9.7 ± 0.1 a	20.4 ± 0.2 b
Conventional	36.4 ± 1.3 a	42.8 ± 0.7 a	41.8 ± 0.5 a	79.43 ± 1.21 a	0.80 ± 0.06 a	9.8 ± 0.3 a	23.5 ± 0.4 a

†Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 30 per year; n = 60).

Table 2
External color of jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Farming type	L^* ‡	a^* ‡	b^* ‡	C‡	H^{o}‡
Organic	71.70 ± 0.64 a	1.84 ± 0.48 a	33.82 ± 0.41 a	33.97 ± 0.40 a	86.82 ± 0.82 a
Conventional	70.63 ± 0.46 a†	0.65 ± 0.36 b	32.07 ± 0.33 b	32.19 ± 0.33 b	88.79 ± 0.65 a

†Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level.
‡L*, lightness; a*, green/red coordinate; b*, blue/yellow coordinate; C, chroma; H°, hue angle (n = 60 per year; n = 120).

carotenoids in jujube fruits should have been only 7.7% (which was the moisture difference between both fruit types), and not 35.7, 45.9, and 30.4%, respectively. Thus, the differences reported here for these 3 parameters can be attributed to the farming type (organic or conventional). As a final conclusion, it can be stated that organic jujube fruits have an equivalent market quality to the conventional ones, because although they were smaller, they presented higher chlorophylls and carotenoids contents, and had a higher color intensity (*C* parameter).

3.2. Flavor and nutritional quality

The TSS were higher in the organic jujubes (Table 3), and this was supported by higher contents of sugars (sucrose, glucose, and fructose) and also organic acids (ascorbic and succinic).

These data seemed to indicate that organic jujubes should be sweeter than those in conventional grown. These data agreed with those obtained in other organic fruits, such strawberry (Conti et al., 2014), passion fruit (De Oliveira et al., 2017), and grapefruit (Lester et al., 2007). However, no significant effect of the farming type on these flavor parameters were reported in other studies, such as those conducted on tomatoes (Juroszek et al., 2009), apples (Roussos & Gasparatos, 2009), eggplant (Raigón et al., 2010), and black currant berries (Anttonen & Karjalainen, 2006).

The content of organic acids (Table 3) was also higher in organic grown jujubes, but with the predominant compounds (succinic and ascorbic) not presenting significant differences. Lester et al. (2007) also found more acidity in organically than conventionally grown grapefruit, with greater amounts of ascorbic acid. However, Juroszek et al. (2009) in tomatoes, Raigón et al. (2010) in eggplant fruit and Lombardi-Boccia et al. (2004) in yellow plums did not find significant differences in the total content of organic acids.

The volatile compounds found, by HS-SPME and GC-MS, were summarized in Table 5. Eighteen volatile compounds were found in jujube fruits 'Grande de Albatera' cultivar regardless of the farming technique. The low number of volatile compounds (18) seemed to indicate that the odor and aroma (perception of volatile compounds outside or inside the mouth, respectively) of these fruits is not one of the most relevant sensory attributes. The predominant compound was benzaldehyde (mean of 1333 μg kg^{-1} fw), followed by α-phellandrene, hexanoic acid, and *p*-cymene. The quantitative analysis showed that organic jujubes had higher total concentration of volatile compounds, which is it normally positively correlated with a higher odor and aroma intensities. Similarly, Picchi et al. (2012) found that the cauliflower 'Magnifico' cultivar had more than twice the content of volatile compounds when it was organically grown; however, the 'Emeraude' cultivar showed less volatiles in organic than in conventional products. A positive effect of organic farming on volatiles was also observed for other fruits and fruit-based products, such as mandarin organic juice (Pérez-López, López-Nicolás, & Carbonell-Barrachina, 2007).

The protein content of jujubes in both types of culture was within the normal concentration range (Almansa et al., 2016). However, the protein content was significantly lower in the organic jujubes, which could be linked to the different type of fertilizers used (Table 4). However, other authors did not find significant differences in the protein content of eggplant (Raigón et al., 2010) or yellow plum (Lombardi-Boccia et al., 2004) between conventional and organic

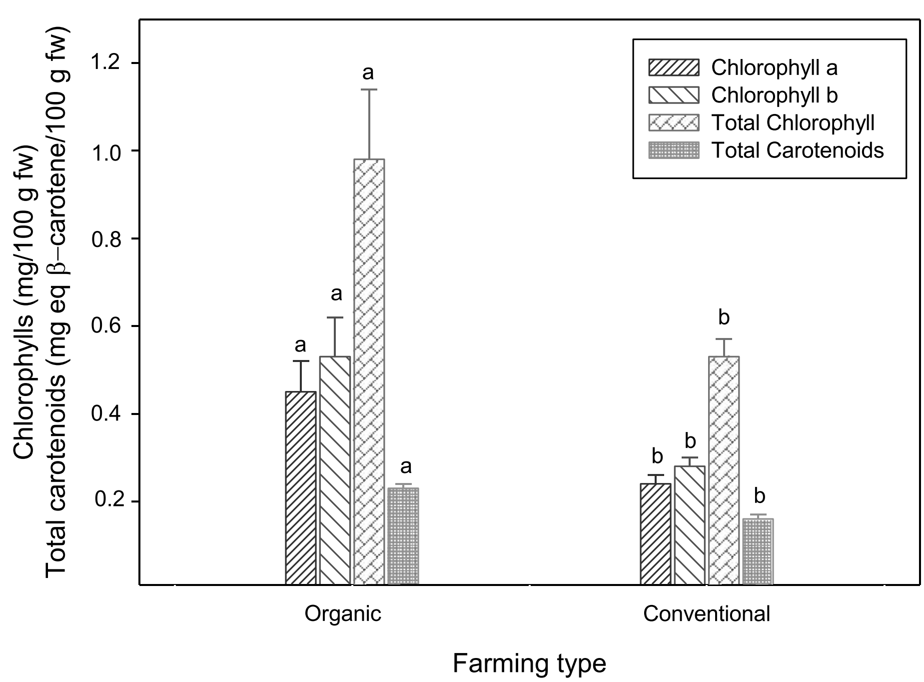

Fig. 1. Chlorophylls and carotenoids in jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming. Different letters on top of bars indicate significant differences according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 6 per year; n = 12).

Table 3
Total soluble solids (TSS), sugars and organic acids (g 100 g^{-1}) profiles of jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Farming type	TSS	Sucrose	Glucose	Fructose	Citric acid	Malic acid	Ascorbic acid	Succinic acid
	(ºBrix)	(g 100 g^{-1})						
Organic	24.00 ± 0.06 a†	8.82 ± 0.04 a	5.95 ± 0.06 a	7.43 ± 0.09 a	0.47 ± 0.01 a	0.25 ± 0.01 a	0.49 ± 0.01 a	1.02 ± 0.02 a
Conventional	23.41 ± 0.17 b	7.04 ± 0.44 b	4.61 ± 0.08 b	5.71 ± 0.09 b	0.42 ± 0.01 b	0.21 ± 0.01 b	0.50 ± 0.01 a	0.99 ± 0.11 a

†Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 6 per year; n = 12).

productions.

As for the minerals, no significant differences were found (Table 4). Other authors have reported a similar trend in yellow plums (Lombardi-Boccia et al., 2004), grapefruit (Lester et al., 2007), strawberry (Conti et al., 2014) or pepper (López et al., 2013). However, Raigón et al. (2010) found a higher mineral content in organic eggplant.

If it is considered that these differences in contents between organic and conventional products were only due to the moisture content, the differences in sugars, organic acids, minerals, proteins and volatile compounds, should around 7.7%; however, was not the case of sugars (21.8%), proteins (27.8%) and volatile compounds (31.2%).

Therefore, organic jujube fruits showed a good flavor potential/quality, because they had more sugars, organic acids, and volatile compounds, which is normally reflected in more intense odor, aroma and flavor.

3.3. Nutraceutical compounds

The total antioxidant activity (TAA) as described by the DPPH˙ test showed that the peel values were about 1.6–1.7 times higher than those of the pulp, in both organic and conventional jujube fruits (Table 6). These results agreed with those obtained by Xue, Feng, Cao, Cao, and Jiang (2009), who also found values of DPPH˙ between 1.5 and 1.8 times greater in peel than in jujube pulp of four Chinese varieties. These data were also in line with those obtained by other authors in the pulp of Chinese (Li, Ding, & Ding, 2005) and Korean (Choi et al., 2011) jujube varieties; however, the experimental DPPH˙ values were inferior to those obtained by Kamiloğlu, Ercisli, Şengül, Toplu, and Serçe (2009) in Turkish varieties. The variation of antioxidant capacity between peel and pulp extracts may be due to differences in antioxidant compounds and their effectiveness (Robards, Prenzler, Tucker, Swatsitang & Gloer, 1999).

In the same way, the FRAP test also demonstrated that the peel had higher TAA than the pulp of jujube fruits. Xue et al. (2009) also observed significantly higher FRAP in peel than in pulp but the differences were less clear in their antioxidant activity in four Chinese varieties.

The ABTS$^+$ assay, however, did not show significant differences between peel and pulp. However, Xue et al. (2009) did find differences between 1.3 and 2.0 times in peel and pulp of Chinese jujubes, respectively. They also found higher ABTS$^+$ values than in current the Spanish variety, which could be because they modified the reaction by changing the medium to an acidic pH. The TAA in the jujube peel was always greater than in the pulp, both in hydrophylic (H-TAA) and lipophylic (L-TAA) fractions. However, the differences were higher in the case of L-TAA (15.6 times greater in peel than in pulp) as compared to H-TAA (only 1.5 times). This could be due to the fact that the peel contains a greater part of lipids than the pulp which is mostly watery.

In general, no significant effects of the farming type were observed on the antioxidant activity with any of the methods used. Other researchers did not find differences in the TAA content of fruits grown in organic and conventional systems, such as apple (Valavanidis, Vlachogianni, Psomas, Zovoili, & Siatis, 2009), tomatoes (Juroszek et al., 2009) or passion fruit (De Oliveira et al., 2017). Similarly to what happened in the current study, Valavanidis et al. (2009) also quantified a higher concentration of TAA in apple peel than in pulp in both organic and conventional grown, but without finding differences between the two agricultural practices. In this case, these researchers studied five varieties of apples and found more important differences between the varieties than between the agricultural practices.

The contents of total phenols, flavonoids and flavonols were significantly higher in jujube peel than in pulp (Table 7), but the farming system only influenced the content of total flavonoids and flavonols, with conventional jujubes fruits having higher peel flavonoids and pulp flavonols while organic peel had higher total flavonols.

The content of total phenols was 1.6 times higher in the peel than in the pulp of jujube fruits, independently of the farming system. Xue et al. (2009) also found higher values in peel than pulp extracts in Chinese jujube varieties. Tomás-Barberán et al. (2001) also found that the peel of nectarines, peaches and plums had more total phenols than the pulp. Phenolic compounds tend to accumulate in the plant epidermal tissues because they have a potential role in the protection against ultraviolet rays, also because they act as attractants in the dispersion of fruits and as defensive chemicals against pathogens and predators (Xue et al., 2009).

Faller and Fialho (2010) also found similar contents of total phenols in organic and conventional banana, orange and apple pulp, although they found higher amounts in organic papaya and mandarin and smaller in organic mango. Similarly, no significant effect of the farming system was reported in eggplant fruits (Raigón et al., 2010), tomatoes (Anttonen & Karjalainen, 2006; Juroszek et al., 2009). However, Lombardi-Boccia et al. (2004) found higher total phenols in conventional than in organic yellow plums. Therefore, it was not clear whether the farming system has a significant and consistent effect on the total content of phenolic compounds accumulated in fruits and vegetables.

In general, the total flavonoids were 4.5–5.5 times higher in peel than in pulp. It was also unclear whether the cropping system influences the flavonoids content of the fruits. Thus, De Oliveira et al. (2017) found equivalent flavonoid concentrations in passion fruit under

Table 4
Protein and minerals content of jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Farming type	Macro-elements (g kg^{-1} dw)				Micro-elements (mg kg^{-1} dw)			Protein
	Potassium	Magnesium	Calcium	Zinc	Copper	Manganese	Iron	mg g^{-1} fw
Organic	3.37 ± 0.20 a	0.95 ± 0.06 a	2.22 ± 0.2 a	5.64 ± 1.39 a	0.98 ± 0.00 a	3.26 ± 0.29 a	5.85 ± 1.27 a	0.26 ± 0.03 b
Conventional	3.95 ± 0.16 a	0.79 ± 0.03 a	1.83 ± 0.2 a	4.89 ± 0.34 a	0.98 ± 0.00 a	2.54 ± 0.14 a	7.53 ± 2.37 a	0.36 ± 0.02 a

†Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 6 per year; n = 12).

Table 5
Volatile compounds in jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Compound	Retention time (min)	Retention Indexes		ANOVA[†]	Concentration (μg kg^{-1} fw)	
		Experimental	Literature		Organic	conventional
Hexanal	7.24	1071	1075	NS	15.7	21.6
α-Phellandrene	9.42	1148	1158	**	189 a [‡]	33.7 b
β-Myrcene	9.55	1152	1156	*	28.7 a	4.9 b
Heptanal	10.29	1177	1176	NS	5.3	4.3
Limonene	10.48	1183	1189	**	62.2 a	18.4 b
β-Phellandrene	10.76	1192	1196	*	106 a	18.7 b
trans-2-Hexenal	11.30	1210	1211	**	104 a	49.4 b
p-Cymene	12.80	1260	1268	**	175 a	49.1 b
Octanal	13.50	1284	1288	NS	9.4	9.0
1-Octen-3-one	13.84	1295	1300	NS	10.6	10.9
2-Heptenal	14.49	1317	1320	NS	36.6	21.0
6-Methyl-5-hepten-2-one	14.92	1331	1337	NS	22.8	5.1
Nonanal	16.58	1387	1389	NS	35.8	31.1
2-Octenal	17.63	1422	1416	NS	59.2	60.8
Benzaldehyde	20.39	1515	1508	***	1412 a	1253 b
6-Methyl-1-heptanol	20.84	1530	1520	NS	10.7	14.3
Hexanoic acid	30.05	1846	1843	*	177 a	91.6 b
Methyl hexadecanoate	39.54	2210	2217	NS	23.9	12.6
Total				**	2483 a	1709 b

[†]NS = not significant at $p < 0.05$; *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively.
[‡]Values (means ± standard error) followed by the same letter, within the same row, were not significantly different according to Fisher's least significant difference (LSD) (n = 6 *per* year; n = 12).

organic and conventional conditions, while Anttonen and Karjalainen (2006) found that the profile of flavonoids in black currant dependent more on where they have been grown than whether they were grown under organic or conventional farming conditions.

Total flavonols have been also higher in peel than in pulp and this difference was 2.7 and 3.8 times in conventional and organic jujubes, respectively, although total flavonols content was higher in the peel of organic jujubes and in the pulp of conventional jujubes. Mitchell et al. (2007) and Chassy, Bui, Renaud, Horn, and Mitchell (2006) found higher concentrations of flavonols in organic tomatoes than in conventional ones, while Lombardi-Boccia et al. (2004) found that organic yellow plums had less content of total flavonols than the conventional ones.

4. Conclusions

In general, organic farming led to higher contents of (i) chlorophylls, (ii) carotenoids, (iii) sugars, (iv) organic acids, (v) total volatile compounds; similar contents of (i) minerals, total phenols, and antioxidant activity; but lower contents of proteins. Considering that the difference on moisture content between organic and conventional jujube fruits was of only 7.7% (which is a low value as compared to those found in the rest of parameters studied), it can be concluded that the observed differences on weight, contents of chlorophylls, carotenoids, sugars, proteins, and volatile compounds were mainly due to the farming type, with organic farming leading to jujube fruits of higher quality and functionality. Besides, it is recommended to consume unpeeled jujubes because their peel has high contents of most of the nutraceutical compounds (total phenols, flavonoids, flavonols and antioxidant activity).

Table 7
Total content of phenols, flavonoids and flavonols of the jujube fruits, 'Grande de Albatera' cultivar, under organic and conventional farming.

Farming type		Total phenols (mg GAE 100 g^{-1} fw)	Total flavonoids (mg eq. rutin 100 g^{-1} fw)	Total flavonols (mg eq. rutin 100 g^{-1} fw)
Organic	Peel	452.2 ± 1.4 a[†]	83.1 ± 4.7 b	61.7 ± 3.1 a
	Pulp	269.3 ± 4.2 b	17.8 ± 1.6 c	0.83 ± 0.6 d
Conventional	Peel	433.7 ± 11.8 a	111.3 ± 3.2 a	54.6 ± 0.8 b
	Pulp	279.8 ± 8.5 b	20.1 ± 1.8 c	16.2 ± 0.2 c

[†]Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 6 per year; n = 12).

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Table 6
Antioxidant activity of the jujube fruits, 'Grande de Albatera' cultivar under organic and conventional farming.

Farming type		H-TAA	L-TAA	$ABTS^+$	FRAP	DPPH˙
		(mmol Trolox kg^{-1} fw)		(mmol Trolox kg^{-1} fw)		
Organic	Peel	23.27 ± 0.28 a[†]	24.21 ± 1.41 b	35.8 ± 11.0 a	312.2 ± 30.4 a	68.2 ± 0.9 a
	Pulp	5.87 ± 0.49 c	2.44 ± 0.06 c	31.4 ± 0.3 a	6.5 ± 1.2 b	41.2 ± 1.9 b
Conventional	Peel	24.75 ± 1.41 a	31.22 ± 1.78 a	35.5 ± 1.7 a	370.0 ± 34.8 a	67.9 ± 0.3 a
	Pulp	16.50 ± 0.58 b	2.00 ± 0.07 c	31.2 ± 0.4 a	14.7 ± 2.3 b	38.9 ± 0.5 b

[†]Values (means ± standard error) followed by the same letter, within the same column, were not significantly different according to Fisher's least significant difference (LSD) procedure at 95% confidence level (n = 6 per year; n = 12).

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