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Sensory and physico-chemical quality attributes of jujube fruits as affected by crop load

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ABSTRACT

No information exists on the overall quality attributes of jujube fruits as influenced by crop load; besides, there are no studies describing the sensory profile of this fruit. For this reason, the aim of this study was to analyze the influence of the reduction of crop load (T1: one third of the crop load was removed; T2: two thirds of the crop load were removed) on the quality of jujube fruits. The quality parameters studied were: yield, fruit morphology, color, instrumental texture, minerals, volatile composition, and sensory profile. Results have demonstrated that reduction of crop load increased: (i) the intensity of characteristic sensory attributes of jujube fruits, such as sweetness, sourness, jujube-like, or fruity notes, and (ii) the contents of some volatile compounds, such as *trans*-2-hexenal, benzaldehyde, and 2-octenal, which are characterized by fruity notes. However, a reduction of crop load did not significantly affect any of the morphological parameters under study. Thus, the reduction of crop load increased the overall quality (intensity of key sensory attributes, and content of key volatile compounds) of jujube fruits.
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1. Introduction

Jujube tree (*Zizyphus jujuba* Mill), is native to temperate Asia, considered as a multipurpose plant (Bowe, 2006; Williams, 2006b) is able to withstand severe water deficits, while maintaining leaf turgor, which allows good gas exchange levels and, as a consequence, good leaf productivity (Cruz et al., 2012). Despite of being a minor crop, jujube is an integral part of the culture and way of life for millions of Asians and has also become so for large regions of Africa (Williams, 2006a). It is considered as a functional food, due to the epidemiological evidence that a high consumption of jujube, and of all its industrial products, is correlated with a reduced risk of some types of cancers (Gao, Wu, & Wang, 2013; Plastina et al., 2012).

Jujube is recommended for the treatment of some diseases, such as cardiovascular disease related to the production of radical species resulting from oxidative stress (Zhang et al., 2006). The actual growing interest on jujube fruit is due to the presence of health-promoting compounds, being considered a functional food (Collado-González et al., 2013; Heo et al., 2003; Huang et al., 2007; Li, Fan, Ding, & Ding, 2007; Mahajan & Chopda, 2009).

Quality of fruits and vegetables encompasses sensory properties (appearance, texture, and flavor), nutritive values, chemical constituents, mechanical properties, functional properties, and defects (Abbott, 1999). One added difficulty to define the quality is that fruits and vegetables are notoriously variable, and the quality of individual pieces may differ greatly from the average. Besides, the relative importance of different quality attributes changes from handling to purchase to consumption (Shewfelt, 1999). These difficulties are even more important for minor crops, such as jujube, which have received low attention; as a consequence, until now there is no scientific study describing the sensory quality of jujube fruits. Descriptive analysis will be used in this study because it is a valuable tool used to document sensory properties, allowing comparison of products.

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It is known that in most of fruits, the fruit size decreases with increasing crop load and several studies have showed that crop load can affect also fruit composition (Berman & DeJong, 2003; Buendía, Allende, Nicolás, Alracón, & Gil, 2008). Moreover, fruit size is a major criterion of marketable jujube fruit quality in Europe. For these reasons, the aim of this study was to increase the understanding on (i) the main sensory attributes controlling the quality of jujube fruits and (ii) the effect of crop load on the main physicochemical, volatile composition, and sensory quality of this fruit.

2. Materials and methods

2.1. Experimental conditions, plant material and treatments

The experiment was carried out in 2014 at a farm near Alhama de Murcia (Murcia, Spain) (37° 49′ N, 1° 26′ W). The plant material consisted of 12 year-old jujube trees (*Z. jujuba* Mill. cv. Grande de Albatera) planted at 4 m × 4 m. The soil of the orchard has a sandy loam texture, very low electrical conductivity, high lime content, low organic matter content, and low contents of potassium and phosphorus. The irrigation water had an electrical conductivity of 0.8–1.1 dS m^{-1}.

The climate of the area is strictly Mediterranean, with mild winters, low annual rainfall, and hot and dry summers. During the experimental period (204–248 DOY, day of the year), the average daily maximum and minimum air temperatures were 33 and 19 °C, respectively, while the mean daily air vapor pressure deficit (VPDm) (Allen, Pereira, Raes, & Smith, 1998) ranged from 1.1 to 2.7 kPa, and the reference crop evapotranspiration (ETo) (Allen et al., 1998) was 295 mm. The total rainfall was negligible, accounting on DOY 226 (2.1 mm) and on DOY 227 (1.1 mm).

Crop irrigation requirements (ETc) were determined according to daily ETo and a crop factor based on the time of the year (Sun et al., 2012) and the percentage of ground area shaded by the tree canopy (Fereres & Goldhamer, 1990). Jujube plants were drip-irrigated every night, using two lateral pipes parallels to the tree row and 2 emitters per tree, each delivering 8 L h^{-1}, applying 315 mm (124% ETc) during the measurement period in order to guarantee non-limiting soil water conditions. In-line water meters were used to measure the water supplied to each experimental unit. Fertilization practices consist only in the addition to the soil of shredded pruning rests and organic manure. Biological pest control was performed and weeds were mechanically controlled within the orchard.

On 24 July (DOY 205) jujubes were thinned in order to obtain three different crop load treatments. In the control treatment (T0) fruits were not thinned; in T1 and T2 fruitlets were hand-thinned in order to eliminate homogeneously around one third and two thirds of the crop load, respectively. At thinning, the fruitlets removed weighted in T1 and T2 treatments were 10.69 and 19.53 kg per tree, respectively.

2.2. Measurements

The water relations of the leaves were measured at midday (12 h solar time). Fully expanded leaves from the south facing side and middle third of the tree (4 trees per treatment) were selected for measurements. Leaf conductance (g_{lmd}) was measured with a porometer (Delta T AP4, Delta-T Devices, Cambridge, UK) on the abaxial surface of two leaves per tree. Leaf water potential (Ψ_{md}), and stem water potential (Ψ_{stem}) were measured in a similar number and type of leaves as used for g_{leaf} using a pressure chamber (PMS 600-EXP, PMS Instruments Company, Albany, USA). Leaves for Ψ_{stem} measurements were enclosed in a small black plastic bag covered with aluminum foil for at least 2 h before measurements.

Marketable jujube fruits were harvested on 3 September (DOY 246). The mean weight of jujube fruits was determined according to the weight and number of fruits per box in randomly selected boxes per replicate. Forty of this jujube fruits from each treatment were randomly selected and width and height of each one of this fruits were measured using a digital caliper Mitutoyo 500-197-20 150 mm (Illinois, United States of America).

2.3. Physicochemical analysis

Color determinations were conducted at room temperature using a Minolta Colorimeter CR-300 (Osaka, Japan). The references of this spectrophotometer are an illuminant D65 and a 10° observer. Color data are provided as CIE$L^*a^*b^*$ coordinates, where L^* indicates lightness (range 0–100), and a^* is the green-red coordinate (positives values for reddish colors and negatives for the greenish ones), while b^* is the blue-yellow coordinate (positive values for yellowish colors and negative values for bluish ones).

The moisture content of jujube fruits was determined by oven-drying fruits at 60 °C until constant weight was achieved. The moisture content of the fruit was calculated as loss of the fruit weight (g water kg^{-1} fresh weight, fw). The content of total soluble solids (TSS) was measured with refractometer (Hanna Instruments HI 96801, Eibar, Spain) in juice made from 40 fruits per treatment. Titratable acidity (TA) was determined by automatic titration (pH-Matic 23, Crison Instruments, S.A., Barcelona, Spain) with 0.1 mol L^{-1} NaOH up to pH 8.1 using 1 mL of diluted juice in 25 mL of distilled H_2O, and results were expressed as g malic acid equivalent per kg^{-1} fw.

Fruit firmness was measured using a flat steel plate coupled with a texturometer (TX-XT2i Texture Analyzer, Stable Microsystems, UK) interfaced to a personal computer. For each fruit, a force that achieved a 3% deformation of the fruit diameter was applied. Results were expressed as the force-deformation (N mm^{-1}). The test was performed in 40 replications.

2.4. Mineral analysis

Minerals were determined according to the methodology previously described by Carbonell-Barrachina, García, Sánchez-Soriano, Aracil, and Burló (2002). Basically, 0.5 g were digested using HNO_3 at temperature below 140 °C. Quantification was conducted in a Unicam Solaar 969 atomic absorption-emission spectrometer (Unicam Ltd., Cambridge, U.K.). A certified reference material (GBW07603) was used to ensure the goodness of the analytical protocol (Cano-Lamadrid et al., 2015). Analyses were run in triplicate.

2.5. Extraction procedure of volatile aroma compounds and chromatographic analysis

The volatile composition of the jujube fruits was studied by using headspace solid phase micro-extraction (HS-SPME), according to the methodology previously applied to tomatoes by Alonso, Vázquez-Araújo, García-Martínez, Ruiz, and Carbonell-Barrachina (2009), and to pomegranates by Melgarejo et al. (2011) and Vázquez-Araújo, Koppel, Chambers, Adhikari, and Carbonell-Barrachina (2011).

The identification and semi-quantification of the volatile compounds were performed on a gas chromatograph (GC–MS), Shimadzu GC-17A (Shimadzu Corporation, Kyoto, Japan), coupled with a Shimadzu mass spectrometer detector GC–MS QP-5050A. The GC–MS system was equipped with a TRACSIL Meta X5 column

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