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Research article

Yield, pomological characteristics, bioactive compounds and antioxidant activity of *Annona cherimola* Mill. grown in mediterranean climate

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Abstract: The agronomic and qualitative responses of the cherimoya (*Annona cherimola* Mill.) fruit grown in Mediterranean climate are not properly studied. Fruits of *Fino de Jete*, the most diffused worldwide cultivar of cherimoya, and *Torre 1* a new genotype obtained by breeding program in Sicily, Italy, were collected at commercial ripening and subjected to productive (yield efficiency, number of fruits, crop load), analytical (fruit weight, transversal diameter, longitudinal diameter, total soluble solid content, titratable acidity, seed weight, seed number, peel and pulp weight, pulp/seed ratio and colorimetric analysis), bioactive compound content (total antioxidant activity, Phenolic and Carotenoid) and sensory evaluations by a semi-trained panel, recorded over two productive seasons. Even if the climatic conditions prevailing in Sicily differ from those of most cherimoya-growing regions, the two observed cultivars generally showed yields and fruit qualitative characteristics comparable with those harvested in other Mediterranean and Tropical areas. *Fino de Jete* confirmed its quality standard thanks to its yields performance and fruit weight. Despite of this, *Torre 1* showed interesting physico-chemical, sensory properties and bioactive compounds, suitable for the consumer needs: less number of seeds and better pulp/seed ratio, better total solid soluble content/tritratable acidity ratio, higher phenolic content and antioxidant activity. These results suggest that cherimoya can be cropped for fresh production in Mediterranean environment with promising yields and good standards of fruit quality.

Keywords: *Annona cherimola*; local production; yield components; physico-chemical properties; bioactive compounds; sensory analysis

1. Introduction

1.1. Origin and diffusion

Cherimoya (*Annona cherimola* Mill.) originates in the Andean regions of Ecuador and Peru and more generally in the American intertropical band where is found in the spontaneous and fruiting state [1]. It gradually spread to Venezuela, Colombia, Brazil, Mexico and California, becoming a characteristic species of these regions, where is still cultivated. In fact, cherimoya is cultivated in tropical countries characterized by short, mild, dry winters and hot, wet, long summers. There are only five areas in the world characterized by a Mediterranean climate [2] including the European Mediterranean Basin, were cherimoya is mainly cultivated.

Genus *Annona* (family *Annonaceae*) includes more than 100 species of tropical and subtropical origins [1]. Among these, only five are of fruit bearing importance: *Annona cherimola* Mill. (cherimoya), *Annona muricata* L. (soursop), *Annona reticulata* L. (custard apple), *Annona senegalensis* Pers. (wild soursop) and *Annona squamosa* L. (conde fruit). For this reason, these are the only species being currently studied. Cherimoya is the only cultivated species whose fruit is widely marketed and is considered one of the most appreciated tropical fruits within the genus Annona spp. [3].

1.2. Production and world distribution

Spain is the world's largest producer, with around 3000 ha of plantations [4]. In several places, production is destined for the national market due to the low resistance of the fruit to handling and transport. Its expansion is very limited due to the limited number of commercial varieties available [2]. The latest useful data indicate that there are only few specialized cherimoya orchards in southern Italy, characterized by specific pedoclimatic conditions with mild and wet winters but hot and dry summers, who differ from those of most cherimoya growing regions [5]. For years now, in the Italian markets the cultivation of fruits coming from tropical and subtropical countries has become a consolidated reality [6]. In this context cherimoya does not play such a significant role despite its organoleptic properties and health potential [7–12]. It is mainly cultivated only in several coastal areas of Sicily and Calabria and intended just for local consumption [13]. Production is primarily aimed at the fresh market, for this reason the fruits must have uniform shape and low number of seeds. At present *Fino de Jete* is the prevailing cultivar in European markets. It was originated from Spain, and commercially established worldwide. Recently, particular attention has also been paid to the selection of new cultivars that can enhance the positive characteristics of the existing ones like fewer seed content and more regular shape of the fruits.

1.4. Characteristics of the fruit and health importance

Cherimoya fruit is climacteric and ethylene plays a primary role in fruit ripening; however, ethylene production is preceded by increased respiration and decreased pulp hardness.

Physicochemical changes are induced, such as an increase in titratable acidity by malic acid accumulation and total free sugar, with a consequent decrease in starch and pH.

Fruit ripes quickly after harvesting at temperatures between 15 and 20 °C with a postharvest life no longer than 5 days [14]. However, Sicily is suited for tropical fruit cultivation [15] and in comparison with other common fruits there is a gap of knowledge. Furthermore Sicily is relatively closer to the large absorption market located in Europe, so could be supposed an increment of cultivated areas due to their role in human health [16]. In fact, consumption of cherimoya can contribute to the prevention of diseases associated with oxidative stress and digestive disorders due to the presence of bioactive compounds in the fruit pulp [5,17–21].

1.5. Aim of the study

The purpose of this investigation is to evaluate yields, pomological charateristics, bioactive compounds and antioxidant activity of *Fino de Jete*, the commercial cultivar of cherimoya, and a new genotype obtained by breeding program in Sicily called *Torre 1*, in order to focus on possible prospects that cultivation of cherimoya can offer in Mediterranean climate.

2. Materials and methods

2.1. Experimental site

The trial was carried out in an experimental orchard located at Vivai Torre in Milazzo province of Messina (Sicily, Italy; 38 °19’N, 15 °24’E; 20 m a.s.l.) during two productive seasons (2016–2017). In this area the average temperatures is between 17–18 °C and the average rainfalls are close to 690.8 mm along 77 rainy days [22–24]. The station is referred to the upper thermos-Mediterranean lower sub-humid bioclimatic belt [24].

2.2. Plant material

The examined fruits belonged to the following varieties: *Fino de Jete* (international affirmed cv) and *Torre 1* (local cv). *Torre 1* was obtained by a breeding program conducted at Vivai Torre using seed reproduction and visual selection of the best genotypes. Trees were grafted on their own rootstock and planted in North-South direction with an inter-trees spacing of 6 m and 6 m between rows. Ten years trees were submitted to the organic farming techniques. Fruits were harvested in late October when not fully mature and the color is changing from dark to light green or greenish-yellow [25,26], then kept to ripen under storage conditions (20 °C).

2.3. Yield components

Weighing and counting the total number of fruits per tree was measured to express the yield per tree. After fruit harvest, trunk circumference was measured at ~15 cm above the soil. Yield efficiency and crop load were expressed as kilogram on number of fruits per trunk cross-sectional area (TCSA) or leaf area.

2.4. Physico-chemical analyses

A sample of eighteen fruits per CV (three fruits per tree) were handpicked and analysed for physical and chemical properties and for sensory evaluation. In particular, each fruit was submitted to the determination of fruit weight (FW), longitudinal diameter (LD), transversal diameter (TD), flesh weight (FLW), peel weight (PW), seed weight (SW), total soluble solids content (TSSC), titratable acidity (TA), TSSC/TA ratio and color index (CI). TTSC (as °Brix) was determined by digital refractometer (Palette PR-32, Atago Co., Ltd), titratable acidity (TA) was measured by titration of 10 mL juice with 0.1 N NaOH to pH 8.1 and expressed as % malic acid (mod. S compact titrator, Crison Instruments, Barcelona, Spain). Peel and flesh color was measured using a portable spectrophotometer (CM 700d, Konica Minolta, Tokyo, Japan) with a D65 illuminant, previously calibrated with a white ceramic tile. Chroma value was calculated as [(a*2 + b*2)1/2] and represents the hypotenuse of a right triangle created by joining points (0,0), (a*, b*) and (a*, 0); °Hue value was calculated as [(arctan (b*/a*)]; it is defined as the angle between the hypotenuse and 0° on the *axis [27,28].

2.5. Bioactive compounds analyses

Three different samples of a 15 fruits homogenate were analysed for each cultivar. The fruits were thawed, peeled and the seed was removed. The pulp was finely chopped and weighed. Then 5 g of flesh homogenate was extracted for two times with 5 mL ethanol. After a clean-up step via centrifugation (10 min at 10.000 g, 4 °C) and filtration through a Millex HV 0.45 μm filter (Millipore, Billerica, MA), the supernatants were recovered, combined and used for the determination of the total antioxidant activity, the ferric reducing activity power, the total phenolic content, the proianthocyanidin content, and the cellular antioxidant activity. Phenolic content of ethanolic extracts was determined by the reduction of phosphotungstic-phosphomolybdic acid (Folin-Ciocalteu's reagent) to blue pigments, in alkaline solution according to Folin and Denis [29]. Quantitation was by reference to a curve constructed with GA, and the results were expressed as mg GA equivalents (GAE) per 100 g FW. All measurements were done in three replicates. The total antioxidant activity (TAA) of ethanol extracts was evaluated using the ABTS radical cation decolorization assay [30,31]. ABTS• + was prepared by reacting of ABTS with potassium persulfate. Samples were analysed at five different dilutions, within the linearity range of the assay, as previous described [32,33]. TAA was expressed as mol Trolox equivalent (TE)/100 g fresh weight (FW).

2.6. Sensory analyses

A subsample of 5 fruits per tree per cultivar was submitted to the sensory profile analysis immediately after picking by a semi-trained panel consisting of ten judges (5 females and 5 males, 22–35 years old) [34]. Effects of rapid refrigeration and map on litchi. All panellists were experienced in sensory evaluation of fruits [35,36]. The judges, in preliminary sessions, using both commercial and experimental cherimoya samples, generated 24 sensory descriptors: appearance (A); skin colour (SC), flesh colour (FC), consistency (C), fruity odour (FO), exotic fruits odour (EFO), off-odour (OFF), cherimoya odour (CO), medicinal odour (OM), grass odour (GO), sweet (S), acid (A), juicy (J), astringent (AST), pungent/fermented (PF), cherimoya flavour (CF), mellowness (M), fruity flavour (FRF) exotic fruits flavor (EXF), fermented flavour (FEF); flavour alcohol (ALF), off flavour (OF); floury (F) and overall evaluation (OVE) [37] The evaluations were carried out from 10.00 to 12.00 a.m.. In each session, judges evaluated the samples in triplicate. The sample order for each panellist was randomized and water was provided for rinsing between cherimoya samples. The judges evaluated samples, using a hedonic scale, assigning to each descriptor a score from 1 to 9 according to other author [38,39]: 9—Excellent (fully characteristic cherimoya); 7—Very good (pleasantly mild cherimoya); 5—Good (blandly faint cherimoya; limit of marketability); 3—Fair (faint off-odor, brown, limit of unacceptability); and 1—Poor (distinct off-odor, brown, no marketability).

2.7. Data analysis

All data were submitted to statistical validation using analysis of variance (ANOVA) followed by Tukey's multiple range test for $P \leq 0.05$ using XLStat® software (XLStat version 2011.1.02, Addinsoft, Paris, France).

3. Results and discussion

3.1. Yield components

The two cultivars showed a different behaviour during the two seasons. *Fino de Jete* was the more productive tree reaching 30.4 kg tree^{-1} and a yield of 8.4 t ha^{-1}. These results are comparable with varieties grown in Californian Mediterranean environment [40] and in Calabria, Italy [41] where you get respectively productions of 7.5 and 7 t ha^{-1}. *Torre 1* reached a production of 17.15 kg tree^{-1} and a yield of 4.8 t ha^{-1}. Yield efficiency were consequently higher for *Fino de Jete* (0.06), whose production in terms of number of fruits was 80 tree^{-1}, against 45 fruits tree^{-1} of *Torre 1* whose yield efficiency was 0.04 (Table 1). This marked difference is due to genetic characteristics of the two cultivars.

Table 1. Yield components of the two observed cherimoya cultivars during two cropping seasons. Data are mean values ± SD. The values marked with different letters in the same column indicate significant differences ($P < 0.05$).

Cultivar	Yield (kg)	Yield Efficency	Trunk Circumference (cm)	Trunk Radius (cm)	Area (cm)	Area (m)	Average Weight (g)	Fruits Number	Crop Load
Fino de Jete	30.4 ± 5.8 a	0.06 ± 0.01 a	80.0 ± 7.3 a	12.74 ± 2.3 a	509.5 ± 11.4 a	0.509 ± 0.03 a	380.0 ± 15.0 a	80.0 ± 9.0 a	0.16 ± 0.07 a
Torre 1	17.1 ± 3.7 b	0.04 ± 0.01 a	72.0 ± 6.5 a	11.46 ± 1.8 a	412.7 ± 12.3 a	0.413 ± 0.05 a	381.0 ± 13.0 a	45.0 ± 7.0 b	0.11 ± 0.05 a

3.2. Pysicho-chemical analysis

The examined cherimoya cultivar showed some significative differences in pomological aspects and physicochemical characteristics. In particular, *Fino de Jete* fruits showed during the two seasons an average weight of 608 g against 454 g of *Torre 1* in accordance with average weight evaluated by other authors in Ecuador [42] where fruits characterized by the same irregular shape reached between 180 and 590 g. On the other hand, *Torre 1* showed a better pulp/seed ratio. It has a lower weight in terms of flesh (341 g vs 528 g) but higher in term of peel (80.4 g against 93.3 g) and seeds (13.9 g vs 25.6 g). This is matched with less number of seeds (Figure 1). Both longitudinal and transversal diameters (LD and TD) confirmed the values of FW in accordance to other authors [42]. This could make *Torre 1* a more adaptable genotype for the consumers need because of less number of seed related to the inconvenience of removing them. Peel colour is an important characteristic of cherimoya quality because it changes with the proximity of physiological maturity from dark to light green or yellowish green [25]. After the colorimetric analysis (Table 2), *Fino de Jete* showed a higher L* value in respect to *Torre 1*, indicating a greater brightness. The values of Chroma calculated for skin were almost the same (31.89 for *Fino de Jete* vs 33.14 of *Torre 1*), indicating a yellowish green tint. This means an appropriate ripening stage for commercialization [43,44]. About flesh color no substantial differences were found. Two genotypes showed similar L* and Chroma values (13.1 vs 12). Flesh firmness was higher in *Fino de Jete* (7.45 N vs 5.88 N) but, according to Paull [45], both could be considered appropriate values for commercial ripe. The total soluble solid content (TSSC) is responsible for fruit taste, affecting sweetness and consequently consumer appreciation. Chemical analysis (Figure 2) results are in favor of the new selected genotype *Torre 1*. It showed a better TSSC (21.6 ° Brix) compared to *Fino de Jete* (17 ° Brix). TSSC values are confirmed by other authors from Ecuador who reported values between 15.8 and 21.0 [42]. Considering the almost coinciding TA values (4.61 gL^{-1} of malic acid for *Fino de Jete* and 4.64 gL^{-1} of malic acid for *Torre 1*), Torre 1 had a better TSSC/TA ratio (3.68 vs 4.65). It can be assumed that the fruits of genotype *Torre 1*, according to instrumental analysis, are sweeter, characteristic typically appreciated by the consumer.

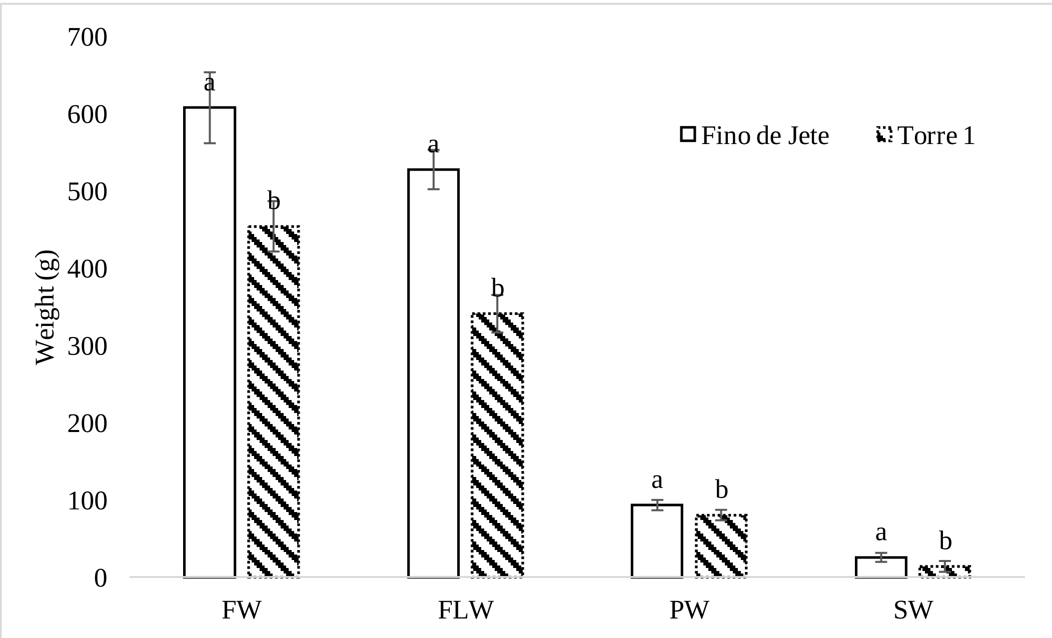

Figure 1. Pomological traits of the two cherimoya cultivars measured over two cropping seasons: Fruit weight (FW); Flesh weight (FLW); Peel weight (PW); Seed weight (SW). Data are mean values ± SD. The values marked with different letters in the same column indicate significant differences (P < 0.05).

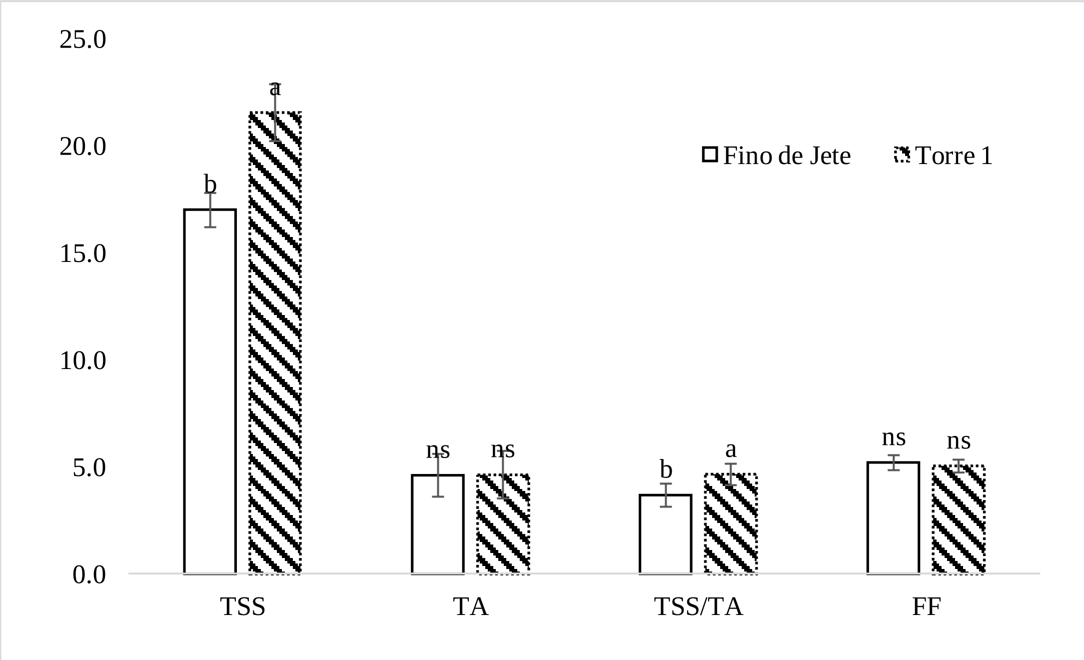

Figure 2. Chemical traits of the two cherimoya cultivars measured over two cropping seasons: Total Soluble solids content (TSSC), expressed in °Brix; Titratable acidity (TA) expressed in gl-1 of malic acid; the soluble solids content/titratable acidity ratio (SSC/TA); Flesh Firmness (FF). For last, measurements made with a penetrometer on the pulp of the fruits expressed in kg/cm2. Data are mean values ± SD. The values marked with different letters in the same column indicate significant differences (P < 0.05).

Table 2. CieLab coordinates (L∗, a∗, b∗) of Annona cherimola from the two studied varieties {L [1–100 light: a (−100 green to +100 red): b (−100 blue to +100 yellow)]}. Data are mean values ± SD. The values marked with different letters in the same column indicate significant differences (P < 0.05).

	Skin Colour			Flesh Colour		
	L*	a*	b*	L*	a*	b*
Fino de Jete	69.7 ±3.5 a	−8.7 ±1.9 a	30.6 ±3.3 a	83.5 ±4.9 a	−1.1 ±0.5 a	13.1 ±1.8 a
Torre 1	63.2 ±2.4 b	−11.5 ±2.1 a	31.1 ±2.7 a	82.0 ±3.6 a	−1.5 ±0.6 a	12.0 ±1.2 a

3.3. Bioactive compounds

Bioactive compounds analysis shows that the new genotype has a higher phenolic content compared to *Fino de Jete* according to the colorimetric analysis carried out on the skin (Figure 3): 80.4 mg GAE/100 g FW vs 64.6 of *Fino de Jete*, concentration comparable to that found on *Annona muricata* by other authors in Brazil (54.8 mg GAE/100 g FW) and Fiji (42 mg GAE/100 g FW) [46, 47], higher than that found by Albuquerque in Portugal [48] (12 mg GAE/100 g FW) but lower than that found by Hassimotto (2005) in Brazil [49] (120 mg GAE/100 g FW). Therefore, it has a high antioxidant activity: 379.2 μmol Trolox eq/100 g FW vs 231.1 of *Fino de Jete*, higher than that found on *Annona cherimola* (230 μmol Trolox eq/100 g FW) and other tropical fruits harvested in Ecuador [42]. On the other hand, the analysis showed a higher carotenoid content in *Fino de Jete*: 5.5 µg β-carotene eq/100 g FW vs 2.7 of *Torre 1*, according to the colorimetric analysis carried out on the flesh.

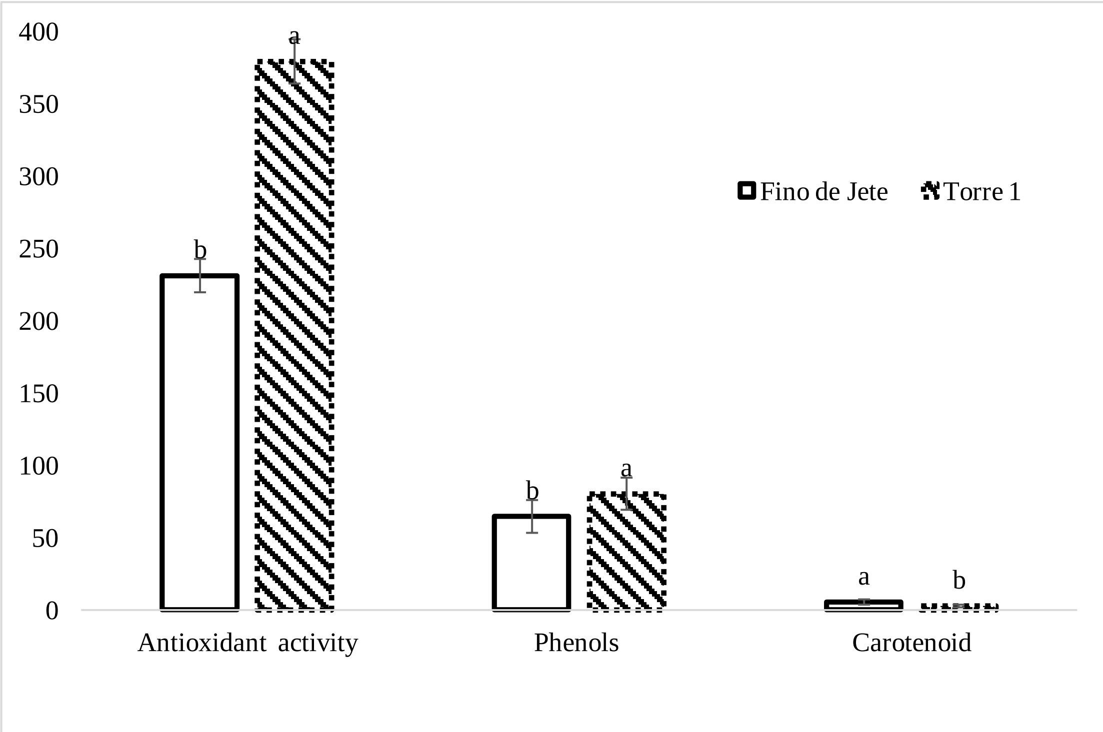

Figure 3. Biochemical compounds of the two cherimoya cultivars measured over two cropping seasons: Antioxidant activity expressed in µmol Trolox eq/100g FW. Total phenolic concentration expressed in mg gallic acid eq/100g FW. Carotenoid content expressed in g β-carotene eq/100g FW. Data are mean values ± SD. The values marked with different letters in the same column indicate significant differences ($P < 0.05$).

3.4. Sensory analysis

Sensory analysis (Figure 4) showed significant differences only for the descriptors compactness, fruity odor, exotic odor, color of the pulp, off-odor, acidity, fermented flavor and off-flavor, juiciness. For the genotype *Torre 1*, the panelists expressed the best values in terms of compactness. This fact disagree with the analytical value of firmness. Probably, this is due to the difference between the instrumental measurement and the judge impression that is obtained by several consistence components (texture, structure and fibers). Both fruity odor and exotic fruit odor were more appreciated by judges in *Torre 1*; the same behavior was observed for flesh color, the difference of which was not so obvious after the colorimetric analysis; off-odor, acidity, fermented flavor and off-flavor, whose lowlights show that *Torre 1* does not have such unpleasant features. *Fino de Jete*, however, proved to be far superior in terms of juiciness. It should be emphasized that the best relationship between total soluble solids and titratable acidity that *Torre 1* highlighted by chemical analysis was not fully perceived by panel judges, who considered the fruits of both genotypes comparable under this parameter. This is probably due to an interaction between the various chemical and aromatic-taste components of cherimoya fruits.

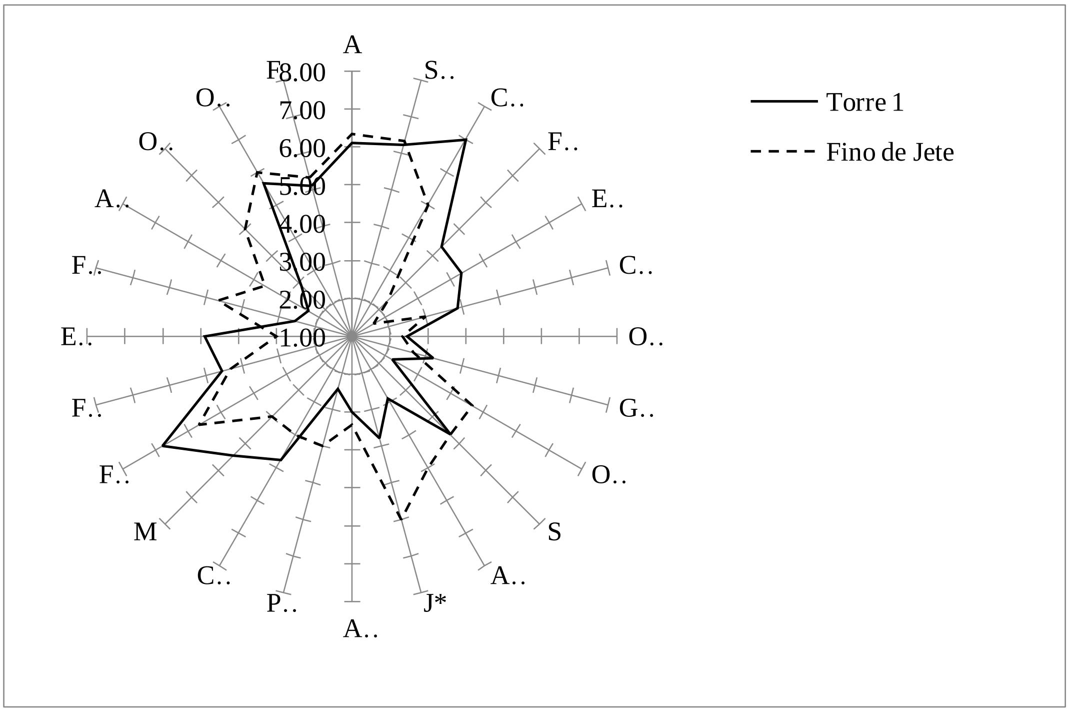

Figure 4. Sensory profiles of the two cherimoya cultivars analyses. The symbol (*) indicates the descriptors for which significant differences were found.

4. Conclusions

The new cherimoya genotype *Torre 1* was found to be better in terms of pulp/seed ratio, small number of seed, TSSC/TA ratio and panel acceptance, together with a greater concentration of bioactive compounds, comparable to that found in fruits grown in tropical areas. Instead, *Fino de Jete* showed a higher production per tree and a better average weight and shape in fruits. Therefore, it is possible to confirm the leader position *Fino de Jete* already had in European market due to his yield efficiency. However, it should be noted that the new cultivar showed interesting characteristics in terms of health properties and sensory profile and may be considered suitable for the consumers. The obtained results suggest it is possible to cultivate cherimoya in the Mediterranean climate with promising yields and a good standard of fruit quality. This show how the potential of a marginal crop like cherimoya is untapped today. It is therefore possible to speculate that a careful breeding program and further studies on cultivation techniques can lead to obtain new most suitable cultivars for the European market.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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