agronomy

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Tree-Ripe Mango Fruit: Physicochemical Characterization, Antioxidant Properties and Sensory Profile of Six Mediterranean-Grown Cultivars

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Received: 31 May 2020; Accepted: 18 June 2020; Published: 19 June 2020

Abstract: Some of the key components that contribute to the acceptance of high-quality fresh mangoes by consumers are its flavour, odour, texture and chemical constituents that depend mainly on level of maturity. In the European market, the demand for tree-ripened fruit has increased in recent decades. Nevertheless, the qualitative response and the marketable characteristics of tree-ripened mango fruit grown in the Mediterranean area are not yet studied. Tree-ripened fruits of cv *Keitt*, *Glenn*, *Osteen*, *Maya*, *Kensington Pride* and *Tommy Atkins* were submitted to analytical (fruit weight, transversal diameter, longitudinal diameter, flesh firmness, total soluble solid content, titratable acidity, seed weight, peel weight, percentage of flesh and fibre, ash content, fat content, carbohydrate content, riboflavin, niacin, thiamin, K, Na, Ca, Mg, Fe, Cu, Mn and Zn contents, ascorbic acid and vitamin A) and sensory evaluations. Significant differences were observed for sensory and physicochemical characteristics in a cultivar-dependent manner. The mango *Keitt*, in addition to its interesting physicochemical traits, content of protein and vitamin, has a higher sensory appeal. *Glenn* fruit showed more suitable weight, flesh firmness, soluble solids, vitamin content, total antioxidant activity and total polyphenolics content; *Maya* had the lowest titratable acidity and the highest soluble solid content, whereas *Tommy Atkins* revealed preferable ground colour, total antioxidant activity, and vitamin B2 and vitamin C contents. Tree-ripened fruits grown in the Mediterranean climate show interesting peculiarities in regard to fresh market requirements. The analytical-sensory approach established a qualitative characterization of the six observed cultivars.

Keywords: *Mangifera indica*; fruit quality; physicochemical analyses; sensory profile

1. Introduction

Mango is an evergreen tree belonging to the family *Anacardiaceae* and it is originated in the Indo-Burmese region. Mango is named the "king of fruits" due to its high palatability, its sweetness, richness of taste, flavour, huge variability, large production volume and exemplary nutritive value [1]. This fruit is disseminated in about 100 countries in the world with a production of over 42 Mt [2]. It is widely cultivated in many tropical and subtropical regions with the prominent production in

India, China, Thailand, Indonesia, Philippines, Brazil, Pakistan and Mexico [3]. Mangoes were not commonly known among the consumers outside the tropics before 1960s, and there was virtually no trade of fresh fruit while, today, they have become well established as products in the global market, particularly in Europe, North America, Asia and Africa [4]. Mango fruit traits such as size, colour, sugar and acidity depend on cultivar [5]. Generally, mango fruit contains a high percentage of starch [6] and it is an excellent source of minerals (calcium, phosphorus, potassium and iron) and essential vitamins (A, B and C) [7]. Moreover, mango flesh has a high nutraceutical value in a genotype dependent manner [8]. Mango is consumed and appreciated as fresh fruit, and is minimally processed [9] or dried [10]. The consumption of 100 g of raw mango will cover more than 50% of the recommended daily amount of each of the important vitamins [11].

Today, mango production is spread outside the traditional geographical regions to Central and South America, Australia, Southeast Asia, Hawaii, Egypt, Israel and South Africa [12,13]. In Italy, the fruit has been especially developed for export markets and it has gained a stable place among consumer preferences [5,14]. In Italy, mango fruit was originally only cultivated in Sicily when it started to be disseminated in the 80s, but in the last decade its cultivation has quickly expanded to several coastal areas characterized by a mild climate [15].

Some of the key components that contribute to the acceptance of high-quality fresh mango by consumers are its flavour, aroma, texture, chemical constituents [16] and antioxidant properties [17] that all depend mainly on the fruit's level of maturity [8,18]. In Europe, aroma and sweetness have always been important for consumption. Countries such as France, Spain and Switzerland offer interesting markets for airfreighted tree-ripened mango or ready-to-eat mango. In fact, generally this type of fruit reaches superior taste and aroma compared to those shipped by sea. Mangoes are usually collected at the stage of partial development when they are still hard and green, that is, before complete ripening during the mature-green stage. They are then allowed to ripen progressively post-harvest [8,14]. Moreover, tree-ripened mangoes are a specialty found in specialized shops and high-end retailers, but in large-scale retail trade too. For these reasons, the demand for tree-ripened fruit that is imported via air-shipping has increased in recent decades. Nevertheless, from an environmental point of view, locally grown (km 0) tree-ripened mangoes could reach markets in a fresher and more flavourful state, and their distribution through short supply chains could reduce food-miles and the associated transportation greenhouse gas emissions (carbon footprint) due to the shortened travel distances to refrigerated ships, airplanes or truck cargo [19]. Additionally, tree-ripened mangoes reach a more suitable pomological and sensory quality than those green-picked and post-harvested [8]. In this context, mangoes grown in Sicily (southern Italy) could be harvested as tree-ripened fruit capable of reaching neighbouring countries in 24–48 h. In this scenario, it is also necessary to evaluate the chemical-physical characteristics of this kind of harvested fruit in order to define their sensory attributes and the most important nutraceutical traits, such as antioxidant activities.

The use of analytical studies for mangoes is also significant to characterize the most important physicochemical parameters of fruit quality [20]. The developments in the field of sensory evaluation and instrumental analysis further accentuated the interface between humans (sensory science) and machines (instrumental analysis) [21] in evaluating fruit quality. Moreover, sensory profiles of the mangoes have an important commercial aspect, because colour, firmness and taste have a great impact on purchase decision [22,23]. The role of scientific methodologies on fruit quality perception by using both instrumental and sensory analyses has been affirmed and tested on many fruit tree species [24].

In the literature, to date, there is a lack of information on the physicochemical and sensory traits of tree-ripened fruit. The aim of this work is to evaluate the qualitative characteristics of tree-ripened fruit of several of the most important mango cultivars grown in Mediterranean climate. The physicochemical, antioxidant activities and sensory traits are expected to provide information about the fruit quality, as well as address all components of short supply chains to reduce food-miles in order to enhance sustainable production of European mangoes.

2. Materials and Methods

2.1. Experimental Site and Plant Material

The study was carried out in 2018 in a commercial orchard located in Acquedolci, province of Messina, Sicily, Italy (38°3′ N, 14°33′ E; 5 m a.s.l.). Temperatures average 17.9 °C and the mean rainfall is 691 mm over 77 rainy days) [25–27]. The station is referred to as the upper thermos-Mediterranean lower subhumid bioclimatic belt [27].

Fruits of the mango cv *Keitt*, *Glenn*, *Osteen*, *Maya*, *Kensington Pride* and *Tommy Atkins* were examined after harvest (Table 1).

Table 1. Harvest date of the six mango cultivars in trial.

CULTIVAR	Harvest Date	Origin	Season
Glenn	7 August	Florida	Early
Keitt	5 October	Florida	Late
Kensington Pride	4 September	Australia	Mid
Maya	6 September	Israel	Mid
Osteen	15 September	Florida	Mid
Tommy Atkins	20 August	Florida	Early–mid

Three uniform 11-year-old trees grafted on gomera-3 rootstock and trained to a globe shape were selected for each cultivar. Trees were planted in single rows (north-south oriented), spaced at 5 × 4 m, and submitted to routine cultural cares.

Fruiting of mango was continuously observed after full bloom (when more than 60% flowers had opened). Mango fruits were collected from using shape and colour as indexes of ripening [28]. Fruit harvest took place at full ripeness directly from the same tree, and fruit analysis was performed during one productive season. Fruits of uniform size, shape, and ripening stage were selected for analysis.

2.2. Physicochemical Analyses

A sample of 15 tree-ripened fruits (5 × tree × cultivar) were collected using colour as maturity index, and they were submitted for analytical and sensory evaluations. In particular, fruit fresh weight (FW), transversal diameter (TD), longitudinal diameter (DL), flesh firmness (FF), total soluble solids (TSS), titratable acidity (TA), seed weight (SW), peel weight (PW), percentage of flesh (PF) and presence/absence of fibre (FI) were recorded. FW, SW, PW (g) were determined by a digital scale (Gibertini EU-C 2002 RS, Novate Milanese, Italy); LD and TD (mm) by a digital caliper TR53307 (Turoni, Forlì, Italy); FF (N) by a digital penetrometer TR5325 with an 8-mm diameter tip (Turoni, Forlì, Italy); TSS (in Brix°) by a digital refractometer Atago Palette PR-32 (Atago Co., Ltd., Tokyo, Japan); TA (in % citric acid) and pH using a CrisonS compact titrator (Crison Instruments, SA, Barcelona, Spain). Flesh colour was determined by a digital image analysis of five photographs per cultivar each containing 6 fruits. Digital images were analyzed using an algorithm developed with MATLAB software (The MathWorks Inc., Natick, MA, USA) that converts images from RGB values to CIE 1976 L^*, a^*, b^* format (by lookup tables), extracts the fruit from the image (removing the image background), separates the total fruit area into two subregions—cover colour (closer to red) and ground colour (closer to green) according to an adjustable green-red threshold, and quantifies colour characteristics of each region as the weighed distance of each pixel in the image from pure green (ground colour) or pure red (cover colour) [29,30]. The output is an index for cover colour (CCI) ranging from 0 (no red) to 1 (red) and an index for the ground colour (GCI) ranging from 0 (no green) to 1 (green). Percentage of cover colour was calculated by dividing the number of pixels of the red region by the number of pixels of the entire fruit area.

2.3. Proximate Composition

Ash content was determined through the procedure described in AOAC [31–36], while the Kjeldal method was used for protein determination [37].

The fat content (FAT) was obtained through acid hydrolysis with a 1:4 HCl solution on the sample followed by filtration and dehydration in a heater (70 °C). After solvent evaporation, the extraction in Soxhlet with petroleum ether was determined through a gravimetric method of residual fat.

The carbohydrate content (TSG), either free of or present in polysaccharides, was obtained with the anthrone method reported in [38]. Carbohydrates are first hydrolysed into simple sugars using diluted hydrochloric acid. In hot acidic medium, glucose is dehydrated to hydroxymethyl furfural that with anthrone forms a green-coloured product with an absorption maximum at 630 nm.

The minerals K, Na, Ca, Mg, Fe, Cu, Mn and Zn were determined using atomic absorption spectroscopy following wet mineralization, while P was determined using colourimetry [39].

Riboflavin was extracted in an autoclave with a solution of diluted H_2SO_4 and later, after enzymatic treatment, was determined through HPLC (for the fluorescent spectra) [40]. Niacin was extracted from the sample in an acidic solution at 12–18 °C for 30 min and measured through a microbiological method. The titrator strain was *Lactobacillus plantatarum* ATCC8014. The test was carried out in a liquid culture medium with all the indispensable factors for the growth of *L. plantarum* present with the exclusion of the examined vitamin. The presence of niacin in the sample caused a proportional increase in growth of *L. plantarum* after 24 h of incubation at 37 °C. The growth was evaluated using a turbidimeter and was then compared with the values of a standard curve prepared in parallel to the test. The thiamine content was obtained through extraction in 0.1 N HCl and oxidation by thiochromium and analysis in HPLC using fluorometric detection.

The ascorbic acid (vitamin C) and the retinol (vitamin A) were determined according to procedures previously described by Barros et al. [41]. For this determination, the dried methanolic extract (100 mg) was extracted with 10 mL of 1% metaphosphoric acid for 45 min at room temperature and filtered through Whatman No. 4 filter paper. The filtrate (1 mL) was mixed with 9 mL of 2.6-dichlorophenolindophenol and the absorbance was measured within 30 min at 515 nm against a blank. Vitamin C and vitamin A were calculated on the basis of the calibration curve of authentic L-ascorbic acid (0.02–0.12 mg/100 g). Vitamin E was determined by HPLC after extraction of the lipophilic component from pulp samples. All measurements were completed in three replicates.

2.4. Antioxidant Properties

The total phenolic content (TPC) of ethanolic extracts was determined by the reduction of phosphotungstic-phosphomolybdic acid (Folin–Ciocalteu's reagent) to blue pigments, in an alkaline solution according to Folin and Denis [42]. Quantification was performed by gallic acid (GA) calibration curve, 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 decolourization assay [43]. $ABTS^{\cdot+}$ was prepared by reacting of ABTS with potassium persulfate [44]. Samples were analyzed at five different dilutions within the linearity range of the assay. TAA was expressed as μmol Trolox equivalent (TE) per 100 FW. All measurements were repeated three times.

2.5. Sensory Analyses

For the sensory characterization of mango fruits, a subsample of 10 fruits per cultivar was submitted to the sensory profile analysis according to the UNI 10957 [45] by a trained panel consisting of ten judges (five female and five male, 22–35 years old) qualified in different kinds of fruit evaluation [46–50]. The judges, in preliminary sessions, using both commercial and experimental mango samples, generated 20 sensory descriptors: two for appearance (flesh colour—FC; presence of filaments—FL), one for rheological (consistency to cut—C), six for odour (sea odour—SO; peach odour—PO; exotic fruit odour—EO; medicinal odour—MO; cheese odour—CO; burned oil odour—BO), two for touch in mouth (juicy—J; mellow—M), three for tastes (acid—A; sweet—SWE; bitter—B) and six for flavour (sea flavour—SF; peach flavour—PF; exotic fruits flavour—EF; medicinal flavour—MF; cheese flavour—CF; burned oil flavour—BF) [30,51]. The evaluations were carried out from 10.00 to 12.00 a.m. in individual booths with controlled illumination and temperature. In each session, judges evaluated the samples in triplicate using three different fruits from each cultivar. The sample order for each panellist was randomized and water was provided for rinsing between mango samples. The judges evaluated samples using a discontinuous scale, assigning to each descriptor a score from 1 (absence of sensation) to 9 (maximum intensity of the descriptor) [51]. Assessments were conducted at the laboratory of sensory analysis at University of Catania, built to UNI EN ISO 8589[52] with a specific software for sensory data acquisition (FIZZ, Software Solutions for Sensory Analysis and Consumer Tests, Biosystemes, Couternon, France). The study was carried out over three months (from August to October).

2.6. Statistical Analyses

The chemical and sensory data were tested for differences between the cultivars using the one-way analysis of variance (ANOVA; general linear model). The differences between cultivars were tested with Tukey's high significance difference (HSD) test at the 0.05 significant level using XlStat® statistical software version 9.0 (Addinsoft, Paris, France). Principal component analysis (PCA) was also applied to sensory and instrumental means data in order to interpret differences among mango cultivars using THE UNSCRAMBLER® statistical software package version 9.8 (Camo As, Trondheim, Norway).

3. Results and Discussion

3.1. Physicochemical Analyses

The examined mango cultivars showed a great variability in physicochemical traits in a cultivar-dependent manner (Tables 2 and 3). The fruits of cv *Keitt* and *Osteen* showed the greatest fresh weight (FW), followed by *Kensington Pride* and *Maya*, whereas the smallest fruits were observed for *Glenn* and *Tommy Atkins*. Diameter values confirmed the classification of fruit on the FW basis. Weight and diameter define fruit size and are important commercial characteristics. In the case of mangoes, the preferred size ranges 350–450 g due to packaging and logistics practices [53]. According to international marketing standards for mango [54], the studied cultivars fall under the B-size group class, ranging 351–550 g. (Table 2)

Table 2. Pomological aspects of the six mango cultivars in trial. Fruit weight (FW); longitudinal diameter (LD); transversal diameter (TD); seed weight (SW); peel weight (PW); ground colour index (GCI); flesh colour index (FCI); presence of fibre (FI); flesh percentage (FP).

Cultivars	FW (g)	LD (mm)	TD (mm)	SW (g)	PW (g)	GCI	FCI	FI	PF (%)
Glenn	372.10c [y]	109.61b	73.66c	30.82cd	65.08ab	0.861b	0.970a	N	74
Keitt	488.89a	111.93b	80.38b	38.78c	63.05b	0.878a	0.903c	N	79
Kensington Pride	432.12b	110.85b	84.63a	50.89b	68.70a	0.822d	0.942b	Y	72
Maya	456.51b	107.76b	82.54ab	41.01c	57.49bc	0.843c	0.952b	N	78
Osteen	462.12b	121.09a	74.43c	29.93d	52.26c	0.841c	0.909c	Y	82
Tommy Atkins	382.00c	112.77b	80.19b	52.39a	56.61bc	0.810e	0.949b	Y	71

[y] The values marked with different letters in the same column indicate significant differences according to Tukey's test ($p \leq 0.05$). Data are mean values ± SD 3 ($n = 30$).

The percentage of flesh (PF) indicates the edible part of a fruit. Our results for PF are partially in agreement with those reported by Rodríguez [55] in Spain, who recorded the highest percentage

(85.5%) for *Osteen* and the lowest value *for Kensington Pride* (74.6%). As expected, the highest values of seed weight (SW) were observed in the biggest fruits. In particular, *Kensington Pride* showed the highest value of peel weight (68.7 g). The incidence of seed and peel weight ranged from 71% for *Tommy Atkins* and *Kensington Pride* fruits to 82% for *Osteen* fruits and had no influence on the quantity of edible parts. Fibres (FI) were present only in *Kensington Pride*, *Osteen* and *Tommy Atkins* fruits. The absence of fibre is a characteristic which is liked by European mango consumers [56,57]. In fact, the consumers, especially in Western Europe, prefer fibre-free and easy-to-slice mangoes such as Kent, *Keitt* and *Palmer* fruits.

For mango, peel colour is one of the most important quality attributes and plays a dominant role in consumer acceptability [58]. Both colouration and fruit size are determinant traits of acceptance, but often consumers show a strong preference for peel colour [59]. It is the first characteristic of quality perceived by consumers who generally prefer a well and intensely coloured fruits; thus, in the case of mangoes, a colouration ranging from pink to red [60].

In this case, *Tommy Atkins* fruits exhibited the lowest values of GCI (less green) followed by *Kensington Pride* and *Maya*, while *Keitt* fruits had the lowest values (more green). On the other hands, *Glenn* fruits reached the highest value of CCI (more red), whereas *Keitt* fruits showed the lowest value, exhibiting a dark green ground colour and a very poor extension of cover colour. Despite this, consumer preference studies conducted in Europe indicated that *Tommy Atkins* mango was not the preferred mango according to recent tasting reports [61]. Despite the fact *Tommy Atkins* is inferior in taste to *Keitt* or Kent, it is by far the favourite of both retailers and consumers due to its transport resistance and long shelf life [61].

For mango flesh, firmness is an important quality factor that affects not only consumers' acceptance but also handling and transportation capability. Fruit firmness, in general, decreases as the fruits become more mature and decreases rapidly as they ripen. Overripe or injured fruit are relatively soft. Our data varied in a tight range and generally indicated a ready-to-eat fruit with a shelf-life compatible with a short supply chain.

Soluble solid content (SSC) is the most relevant quality attribute for assessing mango sweetness [62]. It is strictly linked with ripeness [63], also responsible for fruit taste and consequently for consumers' appreciation (Table 3). Significant differences were observed among the studied cultivars. In particular, SSC values were higher in *Maya*, *Keitt* and *Glenn* fruits, while *Osteen*, *Kensington Pride* and *Tommy Atkins* fruits showed similar lower values. According to Mukherjee [64], acidity is cultivar-related. Acidity values (TA) were higher in *Keitt* (0.40) and *Glenn* (0.37) fruits compared with those of *Tommy Atkins* (0.16).

Table 3. Physicochemical parameters of the six mango cultivars in trial. Flesh firmness (FF); total soluble solid content (SSC); titratable acidity (TA).

Cultivars	FF (N)	SSC (°Brix)	TA (%)	SSC/TA Ratio
Glenn	16.87a	17.80b	0.37a	48.10bc
Keitt	16.19ab	18.51ab	0.40a	46.27c
Kensington Pride	15.60b	15.22c	0.29b	52.48bc
Maya	15.70b	18.90a	0.21c	90.00a
Osteen	15.79b	15.30c	0.26b	58.84b
Tommy Atkins	15.40b	15.50c	0.16c	96.87a

Data are mean values ± SD of three replicates (n = 90).

Carvalho et al. [65] distinguished two groups in ripe mango cultivars, one with low acidity (0.20–0.29%) and the other with high acidity (0.35–0.48%). The values measured in *Tommy Atkins* fruits were lower than those reported by Carvalho et al. (2004) [65] for the same cultivar (0.20%), however grown in the tropics (Brazil). Consequently, the SST/TA ratio that we observed was balanced in *Keitt Keitt* and *Glenn* mangoes, whereas *Maya* and *Tommy Atkins* fruits showed higher values, followed by *Osteen* fruits.

3.2. Mineral Composition

Potassium (K) was the predominant element of the mineral elements in the examined mango fruit. The highest K contents were observed in *Osteen* (242.15 mg 100 g^{-1}) and *Maya* fruits (250.25 mg 100 g^{-1}), and the lowest values in *Tommy Atkins* fruits (190.34 mg 100 g^{-1}). Potassium, in fact, is the major mineral of mango fruit, and contributes to the major fraction of the ash [16].

Phosphorus (P) was the second element most present in the observed mango fruits, with levels that ranged from 18.44 mg 100 g^{-1} in *Keitt* to 10.05 mg 100 g^{-1} in *Kensington Pride* (Table 4). Similar trends (5.5–18.1 mg 100 g^{-1}) have been reported [16,66]. Our results showed that mango pulp is a good source of phosphorus, with similar content to that of papaya (15.0–20.5 mg 100 g^{-1}) or rambutan (8.8–18.8) [67], but lower values compared to that of litchi (23.7–31.1 mg 100 g^{-1}) and longan (30.1–35.7 mg 100 g^{-1}) [68] among tropical fruits (Table 4). Mango is a good source of calcium (Ca). Its amount in fruit ranged from 12.40 mg 100 g^{-1} in *Keitt* to 9.16 mg 100 g^{-1} in *Tommy Atkins*. This range is comparable to previous reports (14.4–6.1 mg 100 g^{-1}) in mango fruits from Cuba, Central America, Africa and India [69], from Spain [55]; and lower to *Dodo* [16] and *Viringe* mangoes from Tanzania (20.6–23.7 mg 100 g^{-1}) [70]. Factors that influence Ca fruit content include nutrient balance and fruit size [71,72].

Table 4. Flesh mineral composition (mg 100 g^{-1}) of the 6 mango cultivars in trial. Potassium (K); sodium (Na); calcium (Ca); magnesium (Mg); phosphorus (P); iron (Fe); copper (Cu); manganese (Mn); zinc (Zn).

Cultivars	K	Na	Ca	Mg	P	Fe	Cu	Mn	Zn
Glenn	199.63cd [y]	7.42bc	11.30bc	0.84b	13.79c	0.40b	0.02b	0.03ns	0.30b
Keitt	221.77b	8.09a	11.87b	0.81b	18.44a	0.41b	0.03ab	0.03ns	0.29b
Kensington Pride	210.85c	7.65bc	9.68d	0.66c	10.05d	0.26d	0.05a	0.03ns	0.27b
Maya	250.25a	8.01ab	12.40a	0.88a	15.71b	0.47a	0.03ab	0.03ns	0.38a
Osteen	242.15ab	8.55a	10.85c	0.81b	17.01ab	0.36bc	0.04ab	0.03ns	0.31b
Tommy Atkins	190.34d	7.11c	9.16e	0.90a	13.95c	0.30cd	0.04ab	0.02ns	0.28b

[y] The values marked with different letters in the same column indicate significant differences according to Tukey's test ($p \leq 0.05$); ns: not significant. Data are mean values (n = 30). The values marked with different letters in the same column indicate significant differences ($p \leq 0.05$) according to Tukey's test (ns = not significative).

The sodium (Na) content in mango fruit varied from 8.55 mg 100 g^{-1} in *Keitt* to 7.11 mg 100 g^{-1} in *Tommy Atkins*. The observed levels were higher than values (2.0–4.0 mg 100 g^{-1}) reported by Othman and Mbogo [70], and lower than those (30.51 mg 100 g^{-1}) reported by Mamiro et al. [16], probably due to different varieties and soil characteristics.

Among the nine mineral elements studied, manganese (Mn) and copper (Cu) were the lowest in all the analyzed fruits. The contents ranged from 0.02 to 0.05 mg 100 g^{-1} of CU and from 0.02 to 0.03 mg 100 g^{-1} of Mn. Our analyses ranged lower amounts of Mn (0.97–1.19 mg 100 g^{-1}) and Cu (0.16–0.21 mg 100 g^{-1}) compared with those of African mangoes [70].

3.3. Biochemical Composition

Fruit of the studied mango varieties showed high moisture contents that ranged from 82.65 to 85.40%. This moisture content is slightly higher than in cv. *Dodo* (79.06%), a local Tanzanian cultivar [70], and similar to the range (82.9–84.9%) reported by Mahattanatawee et al. [73] in cv. *Keitt*. Values are in line with other fresh fruit that contain more than 80% water, such as apples, bananas and guavas, [74].

The content of proteins ranged from 0.359 to 0.803%. The lowest values, measured for *Kensington Pride* and *Maya* fruits, are similar to those (0.36–0.40%) reported by Morton [69]. Mid-range values (0.49–0.62%) observed in *Osteen* and *Tommy Atkins* fruits, are comparable to the protein content recorded by Srivastava [75]. The highest protein values were found in *Glenn* (0.701%) and *Keitt* fruits (0.803%).

Crude fibre content ranged from 0.788 to 0.924%, in line with contents (0.70%) reported by Ramulu [74]. The content of fats ranged from 0.314 and 0.326 g 100 g^{-1} and were lower values than those recorded by Mamiro et al. [16], but higher than those for crude fat of *Dodo* and *Viringe* mangoes [68]. The fruit total sugar content of the six cultivars was within 12.93–13.55%. The ash content of mangoes was 0.257–0.453% (Table 5).

Table 5. Mango chemistry composition (g 100 g^{-1}) of the six mango cultivars in trial. Moisture (MST); proteins (PRO); fats (FAT), crude fibre (CRF); total sugars (TSG); ash (ASH).

Cultivars	MST	PRO	FAT	CRF	TSG	ASH
Glenn	83.54ns	0.701b	0.314ns	0.842b	12.93ns	0.313bc
Keitt	84.81ns	0.803a	0.325ns	0.807bc	13.44ns	0.453a
Kensington Pride	83.69ns	0.359e	0.322ns	0.924a	12.98ns	0.320b
Maya	82.65ns	0.365e	0.314ns	0.865b	13.07ns	0.313bc
Osteen	85.40ns	0.621c	0.326ns	0.788c	12.99ns	0.443a
Tommy Atkins	84.56ns	0.491d	0.317s	0.821bc	13.55ns	0.257c

The values marked with different letters in the same column indicate significant differences according to Tukey's test ($p \leq 0.05$); ns: not significant. Data are mean values ($n = 30$).

Among tropical fruits, mango is one the best sources of carotenoids and provides high vitamin A content [76,77]. In this study vitamin A content ranged from 0.866 mg 100 g^{-1} in *Tommy Atkins* to 1.082 mg 100 g^{-1} in *Keitt* fruits (Table 6). This range is comparable to the range (0.135–1.872 mg 100 g^{-1}) reported by Morton (1987) [69] with fruits grown in the tropics. Vitamin C content was higher in *Tommy Atkins* and *Maya* fruits (12.99 and 12.69 mg 100 g^{-1}) than in *Keitt* fruits (10.97 mg 100 g^{-1}) (Table 6). Mango fruit is a rich source of ascorbic acid, although the content has been reported to decrease during ripening [78,79]. Mango varieties are used to show significant differences in ascorbic acid content, with the highest contents (up to 25.2 mg 100 g^{-1}) in indigenous accessions [70].

Table 6. Vitamin (mg 100 g^{-1}) of the six mango cultivars in trial. Vitamin A (Vit. A); riboflavin (Vit. B_2); ascorbic acid (Vit. C); niacin (Vit. B_3); thiamin (Vit. B_1).

Cultivars	Vit. A	Vit. B_2	Vit. C	Vit. B_3	Vit. B_1
Glenn	0.971ab ^{y}	0.035a	11.86b	0.573c	0.061ab
Keitt	1.089a	0.029b	10.97e	0.785b	0.054b
Kensington Pride	0.789d	0.034a	11.12d	0.534cd	0.060ab
Maya	0.896b	0.031b	12.69a	0.841a	0.067a
Osteen	0.903b	0.032b	10.96c	0.375d	0.046c
Tommy Atkins	0.854c	0.037a	12.99a	0.360d	0.053b

^{y} The values marked with different letters in the same column indicate significant differences according to Tukey's test ($p \leq 0.05$). Data are mean values ($n = 30$).

Niacin content in the six examined cultivars ranged from 0.360 to 0.841 mg 100 g^{-1} in *Tommy Atkins* and *Maya* fruits, respectively. Riboflavin content was 0.028–0.036 mg 100 g^{-1}. In this case, vitamin B_2 levels are lower than those reported by Quinones et al. [80]. Vitamin B_1 content ranged from 0.046 mg 100 g^{-1} in *Osteen* fruits to 0.067 mg 100 g^{-1} in *Maya* fruits, in accordance with values recorded by Quinones et al. [80]. Mangoes are definitely considered an excellent source of vitamins B_1 and B_2 [60].

3.4. Antioxidant Properties

Bioactivity of plant chemicals has been related especially to their antioxidant properties, which are not only useful to prevent oxidative stress phenomena but also influence intracellular redox status by modulating a number of important redox-dependent cell functions [81]. Our results showed a significant variability in radical-scavenging potential of the studied genotypes (Table 7). Regardless, high values of TAA were recorded for *Glenn*, *Tommy Atkins*, *Maya* and *Kensington Pride*. Similar results were observed in mango fruits collected at the mature-ripe stage [8].

Table 7. Bioactive compounds of the six mango cultivars in trial. Total antioxidant activity (TAA) and total polyphenolic content (TPC).

Cultivars	TAA	TPC
Glenn	432.76a [y]	48.57a
Keitt	139.16e	16.24d
Kensington Pride	246.81c	31.27bc
Maya	295.44bc	36.17b
Osteen	189.16d	27.98c
Tommy Atkins	303.72b	18.94b

[y] The values marked with different letters in the same column indicate significant differences according to Tukey's test ($p \le 0.05$). Data are mean values ($n = 30$).

However, TAA is positively correlated with TPC ($p = 0.78$), which is instead comparable to what is reported in literature for other mango cv [82], and is correlated less with vitamin C ($p = 0.57$). These results indicate that the presence of significant amounts of phenolic compounds is a major contribution to the antioxidant activity of these fruits.

3.5. Sensory Analyses

The sensory traits recorded were significantly different between the various cultivars under sensory assessment. The twelve descriptors were used to construct the sensory profile of each mango variety (Figure 1): peel colour, presence of filaments, consistency to cut, sea odour and flavour, exotic fruit odour and flavour, medicinal odour, cheese odour, burned oil odour, acidity and sweetness.

As highlighted by other authors [83,84], the *Tommy Atkins* fruit had an attractive red colour, but despite this, it is of declining interest because of the bland flavour when compared with green-skin mangoes such as *Keitt*.

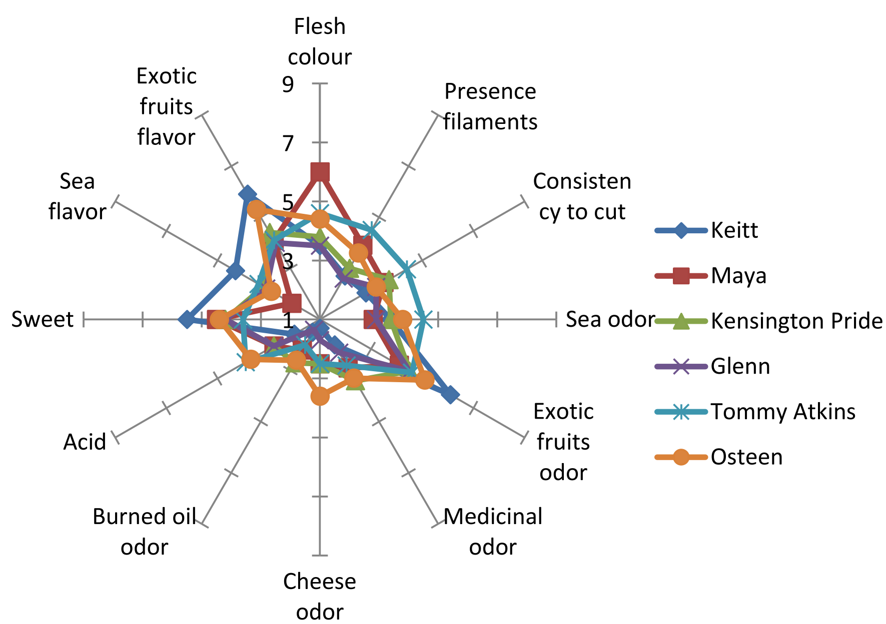

Figure 1. Sensory profiles of the six observed mango cultivars as evaluated by a trained panel. Data are mean values ± SD (n = 30).

In fact, panellists rated mangoes of cv. *Keitt* to be the worst for colour. Moreover, this cultivar presented the highest values for exotic fruit odour and flavour, as well as for sweetness at par with *Osteen*. *Maya* fruit was highly acceptable for flesh colour in visual examination. However, this cultivar rated lower for all other flavour attributes.

The principal component analysis applied to the significant sensory descriptors could discriminate among the samples in a multidimensional space (Figure 2).

The variance explained by the first two principal components was 69%. Fruits of the cv *Kensington Pride*, *Osteen* and *Tommy Atkins* (in the first quadrant) were characterized by the presence of filaments, consistency to cut, acidity, and sea, medicinal, burned oil and cheese odours. The cv. *Keitt* (in the second quadrant) was characterized by a sea flavour and exotic fruit odour and flavour. The cv. *Glenn* (in the third quadrant) was characterized only by the sweetness, while *Maya* (in the fourth quadrant) was characterized by the presence of filaments, consistency to cut, acidity, and medicinal, burned oil and cheese odours.

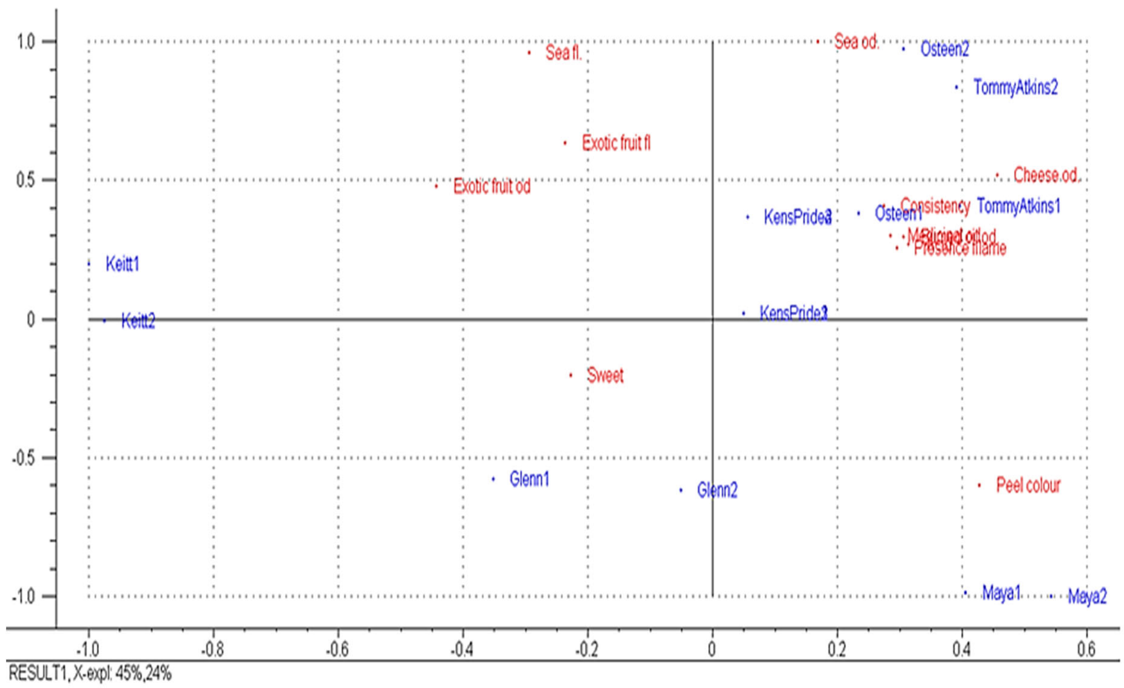

Figure 2. Bi-plot of six mango fruit varieties from sensory descriptors during the first and the second year of study.

4. Conclusions

Mangoes produced in the Mediterranean environment exhibited a high marketable value as tree-ripened fruit, but with a great variability in physicochemical traits according to the cultivar. Generally, all the analyzed cultivars of mango were transport sensitive and a good source of ascorbic acid and vitamin A, which are natural antioxidants valued by consumers . Proximate analyses of these mango fruits revealed that they are a good source of carbohydrates and proteins, which is a trait shared with tropical mangoes. *Keitt* fruit, in addition to its interesting FW, FP, FF, SSC, and contents of PRO, vitamin A, vitamin B3 and vitamin B2, had a higher sensory appeal. *Glenn* fruit had good results in terms of FW, FF, SSC, vitamin content, total antioxidant activity and total polyphenolics content, confirming the success already achieved in European markets. Other cultivars showed specific interesting fruit characteristics; for example, *Maya* had a low acidity and a high SSC, while *Tommy Atkins* had high GCI, vitamin B2, vitamin C contents and total antioxidant activity. Tree-ripened fruit of these cultivars have great commercial potential as high-quality fresh fruit in the EU and neighbouring countries' short supply chains, and their commercial implementation would allow for a reduction in food-miles and enhance sustainable production.

Author Contributions: Conceptualization, V.F., A.M. and G.S.; methodology V.F., G.S., E.P. and C.G.; validation, V.F., A.M. and C.G.; formal analysis E.P., G.S., C.G., G.G. and V.F.; investigation, C.G., G.S., and V.F.; resources, C.G., V.F., G.S. and A.M.; software, A.M., G.G., and V.F.; data curation, A.M., G.G., C.G. and V.F.; writing—original draft preparation, A.M., G.S., G.G., C.G. and V.F.; writing—review and editing, G.S., A.M., C.G. and V.F.; visualization G.G., G.S. A.M. and V.F. Supervision V.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would like to acknowledge MedicAir Industry and Orved S.p.A. for its collaboration in the research activity and for the availability of the instrumentation needed to carry out the research. The authors would like to thank Giuseppe Marinaro for the supply of plant material.

Conflicts of Interest: The authors declare no conflict of interest.

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