

Comparative study of mango cultivars at the ready-to-eat stage: The case of Western Crete, Greece, a cool subtropic region of the Mediterranean

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Abstract

With the expansion of the mango consumer market, exports of the product have increased. The harvest time effects quality characteristics, which identify the quality and consequently the price of the product. Greece is very close to the European markets, so mango fruits can be transferred at a ready-to-eat stage and minimize the distance between harvest maturity and edibility. On this research we studied the characteristics of twelve mango cultivars ('Carrie', 'Keitt', 'Kensington', 'Kent', 'Lippens', 'Osteen', 'Palmer', 'Sabre', 'Sensation', 'Tommy Atkins', 'Van Dyke' and 'Zill') in Greece. The parameters measured were the harvest time, fruit weight and size, fruit firmness, juice pH, soluble solid components, dry matter, ascorbic acid, total sugars and acidity. The first fruits were harvested ready-to-eat, at the first days of August. Fruit firmness was from 4.28 K/cm² ('Sensation'), to 1.55 ('Lippens'). The pH level ranged from 3.64 ('Van Dyke') to 4.52 ('Osteen'). Total soluble solids were 19.84% Brix in 'Kent', different from 'Osteen' (16.33%). 'Kent' had the highest dry matter concentration (25.3%). The higher amount of ascorbic acid (Vit C) was measured in 'Palmer' (82.79 mg/100 g juice). Total sugar was the highest in 'Tommy Atkins' (24.82 g glucose/100 g juice) and the lowest in 'Palmer' (6.51 g glucose/100 g juice). The lowest acidity was observed in 'Lippens' (0.16%). Our results indicate that Greece can offer fruit production of high quality, at the ready-to-eat stage. Our results are the first data of mango cultivation in Greece, a region of Europe where mango crop is gaining ground on the market.

Keywords: fruit characteristics; fruit quality; *Mangifera indica*; Mediterranean; quality characteristics

Introduction

Mango (*Mangifera indica* L.) fruit constitutes one of the most grown crops in tropical and subtropical regions. Its pleasant aroma and unique flavour made it popular among the consumers (Ke *et al.*, 2022). It belongs to Anacardiaceae family (Tharanathan *et al.*, 2006) and is an evergreen and long living tree, which originates from Asia (Wauthoz *et al.*, 2007).

It is a typical climacteric fruit with a rapid synthesis of ethylene that leads to a clear climacteric peak (Feng *et al.*, 2013). After the synthesis of ethylene, there are several changes taking place to the fruit, that

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determine fruit quality and taste, such as tissue softening, epidermis colour, organic acid and soluble sugar concentration. During ripening, degradation of pectin and starch lead to the softening of the pulp tissue (Prasanna *et al.*, 2006). Epidermis colour, anthocyanins and carotenoids can be used to estimate the maturity of mangoes, as they are the main indicators of fruit appearance and quality. Nambi *et al.* (2015) reported that the epidermis of mature mangoes takes olive, orange, yellowish, dark red, purplish red, and yellow-red hues in different varieties. Mango flavour is significantly based on the content of organic acids. In ripe mangoes these are mainly citric, malic and tartaric acid, with pH level from 3.40 to 6.00. Green mangoes are more acidic than ripe ones, while ripe mangoes would be less acidic with a pH reading of 5-6. During climacteric change, the organic acid content of mangoes is degraded during the postharvest ripening process, leading to the gradual loss of the edibility and flavour of the fruit (Nordey *et al.*, 2014). Accumulation of soluble sugars provides sweetness to the fruit and enhances its commercial value. Soluble sugars in ripe fruit include mainly glucose, fructose, sucrose, xylose and maltose. These changes during fruit ripening occur when non-reducing sugars breakdown to reducing sugars (Liu *et al.*, 2019).

Characteristics of mature mango fruit depend on the cultivated variety, time of harvesting and postharvest technics. For example, dry matter (DM) classification, when harvest at physiological maturity, affects fruit quality during cold storage, as fruit with higher DM (15%) presents better quality than fruit with lower DM (11%) (Santos Neto *et al.*, 2018). The time of harvesting effects quality characteristics, which identify the quality and consequently the price of the product.

Varieties' growth and production depends on the climatic conditions among other parameters (Tharanathan *et al.*, 2006; Normand *et al.*, 2015; Laxman *et al.*, 2016; Tiyagi *et al.*, 2017), including temperature and rainfall. In the case of temperature, differences between day and night affect the skin colour, acidity, and sweetness (Lobo and Sidhu, 2017). Regions with high temperatures and humidity are the appropriate production areas of mango (FAO, 2023). However, high rainfall decreases the fruit firmness involved in shelf-life (Tiyagi *et al.*, 2017). With the interaction of these climatic conditions, the fruit quality of mango is also affected by geographical regions from tropic to subtropic and temperate regions (Hofman *et al.*, 1997). There are some cultivars that could produce better in different places and climates. There are places in Southern Greece with favourable climatic conditions for the mango crop, where harvest time is expanded from August to January, as long as different varieties are combined in the same orchard.

Over the past years mango consumption is following an upwards trend, which creates the requirement to increase mango yield, in order to cover the global annual needs. The leading exporters for mango export quantities are Mexico, Thailand, Brazil, Peru and India (FAO, 2023). Except the forementioned ones, there are many other mango producing countries, possibly more than 87 all over the world (Tharanathan *et al.*, 2006). Recently, mango cultivation has expanded to temperate regions (Han *et al.*, 2016), due to climate change. Considering that there are also countries that only the last few years have started organized cultivation, like Greece, which belongs to a cool subtropic region of the Mediterranean basin, mango is becoming favourite in new markets and consumers. In addition, the absence of serious pests and diseases in Greek mango crops, gives to producers the opportunity of an easy handling organic cultivation system, that adds extra value to the final product.

With the expansion of the mango consumer market, exports of the product have increased. Normally, mangos are air-freighted to other countries after the initial application of heat treatment. This pre-storage heat treatment has a positive impact on fruit quality, with improved colour and slow fruit weight loss. However, the post-shipment quarantine heat treatment is only desirable in case of refrigerated shipments by sea or by road because it deteriorates fruit quality and firmness (Javed *et al.*, 2022). In each case, cold-chain transportation for an extended period with postharvest ripening and aging during storage and transportation, results in the deterioration in the mango quality and in high economic losses (Liu *et al.*, 2023). Greece is very close to the European markets, so mango fruits can be transferred quickly and with low cost from the fields to the markets. This allows the harvesting of a ripe fruit (ready-to-eat) and minimize the distance between harvest maturity

and edibility. In addition, market demand shifts towards smaller sized fruits, with the characteristics that a heavier fruit can offer (Kulkarni *et al.*, 2019). In any case, better fruit quality characteristics can increase the economic and consumption values of the fruit (Liu *et al.*, 2023), as well-ripened mangos have a distinctive flavour, a mix of sweet and sour, are soft and juicy, and accompanied by a pleasant aroma (Tao *et al.*, 2022). So, it is important to know the postharvest characteristics of outstanding mango genotypes from Greece in order to diversify the market supply.

Since mango tree is vulnerable to winter rainfall, specifically in the Mediterranean basin, and admittedly in cold, it should be grown under cover or alternatively in a greenhouse to prevent chilling injury during the winter (Han *et al.*, 2016; Lim *et al.*, 2020). Meanwhile, since the ripening of mango fruit is mainly studied openly grown in typical subtropical or tropical regions (Ramírez *et al.*, 2014; Gentile *et al.*, 2019; Liguori *et al.*, 2020), little is known about greenhouse cultivation (Han *et al.*, 2016; Farina *et al.*, 2020), especially in cool subtropic areas (Chung *et al.*, 2021). In this research we studied the fruit characteristics of 12 mango cultivars ('Carrie', 'Keitt', 'Kensington', 'Kent', 'Lippens', 'Osteen', 'Palmer', 'Sabre', 'Sensation', 'Tommy Atkins', 'Van Dyke', 'Zill') at the ready-to-eat stage, growing in a greenhouse located in Chania, a city in Western Crete. The parameters measured were those related to organoleptic and maturation characteristics of mango fruit (beginning of the harvest time of each variety, fruit weight and size, fruit firmness, juice pH, soluble solid components, percentage of dry matter in fruit, ascorbic acid, total sugars and acidity), aiming on fruit quality. Our results are the first data of mango cultivation in Greece, a region of Europe where mango crop is gaining ground on the market.

Materials and Methods

Plant material

Crete is an island in the North-East of the Mediterranean Sea, adequate for mango cultivation. However, Western Crete belongs to a unique climatic zone where, in the north part there is high rainfall and cool temperatures during winter, while in the south part winter is warmer and less rainy. The mango orchard that we studied was located in the north of Western Crete (Chania). Under these climatic conditions, 5-year-old trees were in a greenhouse, to be protected mainly from the winter rain. Planting distances were 3*3.5 m and the trees were pruned once a year. Irrigation was minimum during winter and twice a week during the summer period. Nutrients were applied through fertigation system. Pests and diseases were not an important problem and they were controlled only when necessary. Measurements were taken in a two-year period, from the beginning until the end of the harvest period. Each treatment (variety) consisted of five to fifteen (5-15) mango fruits, harvested from three mango trees. The results were the mean of two-year measurements.

Initial measurements

Measurements

Each fruit was harvested total ripen and it was immediately transferred to the lab. A photo was taken and fruit weight was recorded. Length, width and the length/width ratio were also measured.

Chemicals

All chemicals used were of the appropriate purity. Potassium iodide ($\geq 99.5\%$), potassium iodate ($\geq 99.7-100.4\%$) and phenol (99.0-100.5%) were purchased from Sigma-Aldrich (Steinheim, Germany). Sodium hydroxide 0,1N standard and soluble starch (analytical grade) were obtained from Chem-Lab (Zedelgem, Belgium). Phenolphthalein solution (1% w/v in ethanol), sulfuric acid (95.0-97.0%) and glucose anhydrous D(+)- (analytical grade) were from Fluka Chemie GmbH (Buchs, Switzerland), Honeywell (Seelze, Germany) and VWR (Leuven, Belgium), respectively.

Fruit firmness measurement

Fruit firmness was estimated using a digital handheld fruit penetrometer (FR-5120, Lutron Electronics Enterprises, Taipei City, Taiwan) with an 8 mm tip, by measuring the force required to penetrate the pulp in whole fruit. Values were expressed in $K\ cm^{-2}$.

Determination of total soluble solids (TSS)

Juice drops of the middle section of the fruit pulp were set on the optical sensor of a digital refractometer (PAL-1, Atago, Tokyo, Japan); TSS were expressed in % Brix.

Determination of dry matter (DM)

Fruit was cut into slices and the initial weight of the fresh sample was taken. Samples were then placed in the oven at $103.5\ ^\circ C$ overnight to dry. The final weight of the dried sample was measured, and the dry matter was calculated according to the following equation: $DM\ (\%) = [1 - ((FW - DW) / FW)] * 100$, where: DM is Dry Matter, FW is Fresh Weight, and DW is Dry Weight.

Mango juice preparation

After removing their pericarp and core, mango fruits were sliced and processed in a juicer. 10 g of the pulp extracted were mixed with distilled water to a final volume of 100 mL (pulp solution).

pH measurement

pH of pulp solution was measured in a pH meter (Starter 3100 OHAUS Corporation, NJ, USA).

Determination of total carbohydrate content (TCC)

0.5 mL of pulp solution were diluted with water to 100 mL. Total carbohydrate content (total sugars) of the diluted extracts was determined according to the phenol-sulfuric acid method, as described by Albalasmeh *et al.* (2013). Reference aqueous glucose solutions of $0.01\text{-}0.16\ g\ L^{-1}$ were used. TCC was expressed as g glucose per 100 g of mango juice.

Determination of % titratable acidity (TA)

10 mL of pulp solution were titrated with 0.01N NaOH solution using phenolphthalein as indicator, according to slightly modified method of Khairul Islam *et al.* (2013). TA was expressed as g citric acid per 100 g of mango pulp (%).

Determination of ascorbic acid content (AA)

AA was determined by a redox titration with iodine formed by the reaction of iodate and iodide ions, based on a method described by Helmenstine (2019). 30 ml of pulp solution were titrated with an iodine solution of 0.005 M in the presence of ten drops of 1% starch solution, until a dark blue-black complex was formed. The iodine solution was previously prepared by dissolving potassium iodate (0.178 g) and potassium iodide (3.328 g) in water, adding 20 mL of 3M sulfuric acid and diluting the mixture to 500 mL. AA, expressed as mg ascorbic acid per 100 g of mango juice, was calculated using the following equation:

$$\left(\frac{\mu \times 3 \times 1000}{M_{KIO_3} \times 500}\right) \times \left(\frac{\alpha}{1000}\right) \times \left(\frac{M_{asc} \times V_1}{V_2}\right) \times \left(\frac{100}{m}\right) \times 1000$$

where m is the mass of mango pulp, μ the weighed mass of KIO_3 , α the volume (mL) of iodine solution used for the titration, V_1 the final volume (mL) of diluted pulp, V_2 the volume of pulp solution A used, M_{asc} and M_{KIO_3} the relative molecular mass of ascorbic acid and potassium iodate, respectively.

Statistical analysis

Each cultivar included four mango trees. Each number presented in the results is the mean values of 5 (minimum) to 15 (maximum) fruits, harvested from the four-tree cultivar. Differences were analysed using SPSS 21 (SPSS Inc., Chicago, IL, USA). Mean values were compared using Duncan's post-hoc test for $p \leq 0.05$.

Results*Harvest date*

Mango flowering of trees cultivated in greenhouse in the North - Western Crete (Chania), begins in late winter and the first fruits are harvested ready-to-eat, at the first days of August for the early varieties (Table 1). The harvesting period is expanded until January, with 'Keitt' variety (data not shown). At this stage of maturation, fruits have the colour of the variety (Figure 1), maximum fruit weight and dimensions, and the peak quality characteristics, such as juice pH, total soluble solids, dry matter, vitamin C, high total sugar and low acidity.

Table 1. Harvest period of 12 mango cultivars at the ready-to-eat stage, cultivated in Chania, Greece

Variety	Harvest period	
	From	To
Van Dyke	6-Aug	28-Sep
Tommy Atkins	10-Aug	16-Oct
Zill	18-Aug	28-Sep
Kensington	24-Aug	23-Sep
Osteen	4-Sep	16-Oct
Lippens	7-Sep	16-Oct
Kent	11-Sep	17-Oct
Carrie	14-Sep	28-Sep
Sensation	18-Sep	27-Oct
Palmer	21-Sep	6-Oct
Sabre	25-Sep	27-Oct
Keitt	12-Nov	17-Oct

Results are the means of a two-year period



Figure 1. Mango fruits of 12 cultivars at the ready-to-eat stage, cultivated in Western Crete, Greece

Fruit weight

The statistical higher fruit weight was measured in 'Kent' variety at 625.6 g, with recorded weight between 512.4-765 g, while 'Carrie' fruit (139.4-307.6 g) were lighter than 'Tommy Atkins' (307.2-559.4 g), 'Kensington' (221-548.4 g), 'Osteen' (317.1-484.2 g), 'Sensation' (283.4-438.6 g) and 'Sabre' (179.4-459.6 g). However, the lower fruit weights were observed in 'Lippens' (241.4 g), 'Van Dyke' (275.5 g), 'Carrie' (307.6 g), 'Zill' (313.3 g) and 'Palmer' (339.9 g) (Figure 2a).

Fruit size

'Kent' (12.6 cm), 'Osteen' (12.2 cm) and 'Keitt' (12.2 cm) had the higher fruit length, statistically different from 'Lippens' (9.1 cm), 'Sabre' (9.4 cm), 'Zill' (10.1 cm) and 'Van Dyke' (10.2 cm), which had the lower ones (Figure 2b).

The fruit width had also significant differences among the varieties, with the lower values measured in 'Lippens' (7.1 cm) and 'Carrie' (7.5 cm) varieties, and the higher width observed in 'Kent' fruits (10.0 cm). 'Kensington' (9 cm) and 'Keitt' (9 cm) had statistically higher fruit width than 'Carrie' and 'Lippens', but statistically lower than 'Kent' (Figure 2c).

Fruits of the most mango varieties have an oval shape, but dimensions indicate differences in fruit shape. So, the ratio fruit length/width statistically differed among the varieties, with 'Carrie' (1.98) having the highest value of length/width (most oval shape), 'Palmer' (1.56) having statistically lower value, while 'Kensington' (1.21), 'Sabre' (1.23), 'Kent' (1.26), 'Lippens' (1.31), 'Sensation' (1.31) and 'Tommy Atkins' (1.32) had the lower ratio, which translates into a rather spherical shape (Figure 2d).

Fruit firmness

Fruit is hard at the beginning of maturation, and fruit firmness decreases as maturation continues. Thus, fruit is important not to be too soft for consumption. In our study, at the ready-to-eat stage of harvest, 'Sabre', 'Tommy Atkins', 'Lippens', 'Kent' and 'Kensington' varieties had statistically lower fruit firmness values than 'Keitt', 'Osteen', 'Palmer', 'Sensation' and 'Van Dyke'. The hardest fruits were 'Sensation' (4.28 K cm⁻²), 'Palmer' (3.90 K cm⁻²), 'Van Dyke' (3.80 K cm⁻²), 'Osteen' (3.46 K cm⁻²), 'Keitt' (3.45 K cm⁻²) and 'Zill' (3.14 K cm⁻²); the softest were 'Sabre' (1.46 K cm⁻²), 'Lippens' (1.55 K cm⁻²), 'Kent' (2.00 K cm⁻²) and 'Tommy Atkins' (2.01 K cm⁻²) (Figure 2e).

Juice pH

As mango is used for juice, pH level is an important parameter of fruit quality characteristics. The pH level of 'Van Dyke' (3.64), 'Zill' (3.86), 'Kent' (3.77) and 'Carrie' (4.37), was statistically lower than 'Osteen' (4.52), 'Lippens' (4.45), 'Sensation' (4.3), 'Palmer' (4.38), 'Sabre' (4.33) and 'Keitt' (4.32) (Figure 2f).

Total soluble solids (TSS)

Total soluble solids were abundant in 'Kent' variety (19.84% Brix), significant different from 'Lippens' (16.09% Brix) and 'Osteen' (16.33% Brix), which had the lowest value (Figure 2g). No significant differences were observed among the other varieties.

Dry matter (DM)

'Kent' variety also had the highest DM concentration (25.3%), while 'Osteen' (18.9%), 'Lippens' (20.2%), 'Van Dyke' (20.3%) and 'Palmer' (20.4%) had the lowest. No significant differences were observed among the rest of the varieties (Figure 2h).

Ascorbic acid content (AA)

The highest ascorbic acid (Vit C) content was measured in 'Palmer' (82.79 mg per 100 g juice) and it differed significantly from all the other varieties (Figure 2i). 'Osteen' (57.96 mg per 100 g juice), 'Sensation' (45.08 mg per 100 g juice), 'Sabre' (45.42 mg per 100 g juice) and 'Keitt' (43.81 mg per 100 g juice) were the second higher cultivars in ascorbic acid concentration, statistically higher than 'Tommy Atkins' (16.48 mg per 100 g juice), 'Zill' (19.14 mg per 100 g juice), 'Lippens' (17.50 mg per 100 g juice), 'Kensington' (22.40 mg per 100 g juice) and 'Carrie' (21.76 mg per 100 g juice), where the lowest Vit C was observed.

Total sugars (Total carbohydrate content, TCC)

'Tommy Atkins' fruits had the highest total sugar concentration (24.82 g glucose per 100 g juice), with statistical differences towards Keitt (22.73 g glucose per 100 g juice), and all the other varieties. The lowest total sugar concentration was measured in 'Kensington' (7.50 g glucose per 100 g juice), 'Palmer' (6.51 g glucose per 100 g juice) and 'Sabre' (6.66 g glucose per 100 g juice) cultivars (Figure 2j).

Acidity (Titratable acidity, TA)

The lowest acidity was observed in 'Lippens' (0.16%) and 'Sensation' (0.18%) varieties, statistically lower than 'Van Dyke' (0.48%), 'Zill' (0.48%), 'Kent' (0.42%), 'Kensington' (0.35%), 'Sabre' (0.34%) and 'Carrie' (0.26%) which had the highest acidity (Figure 2k).

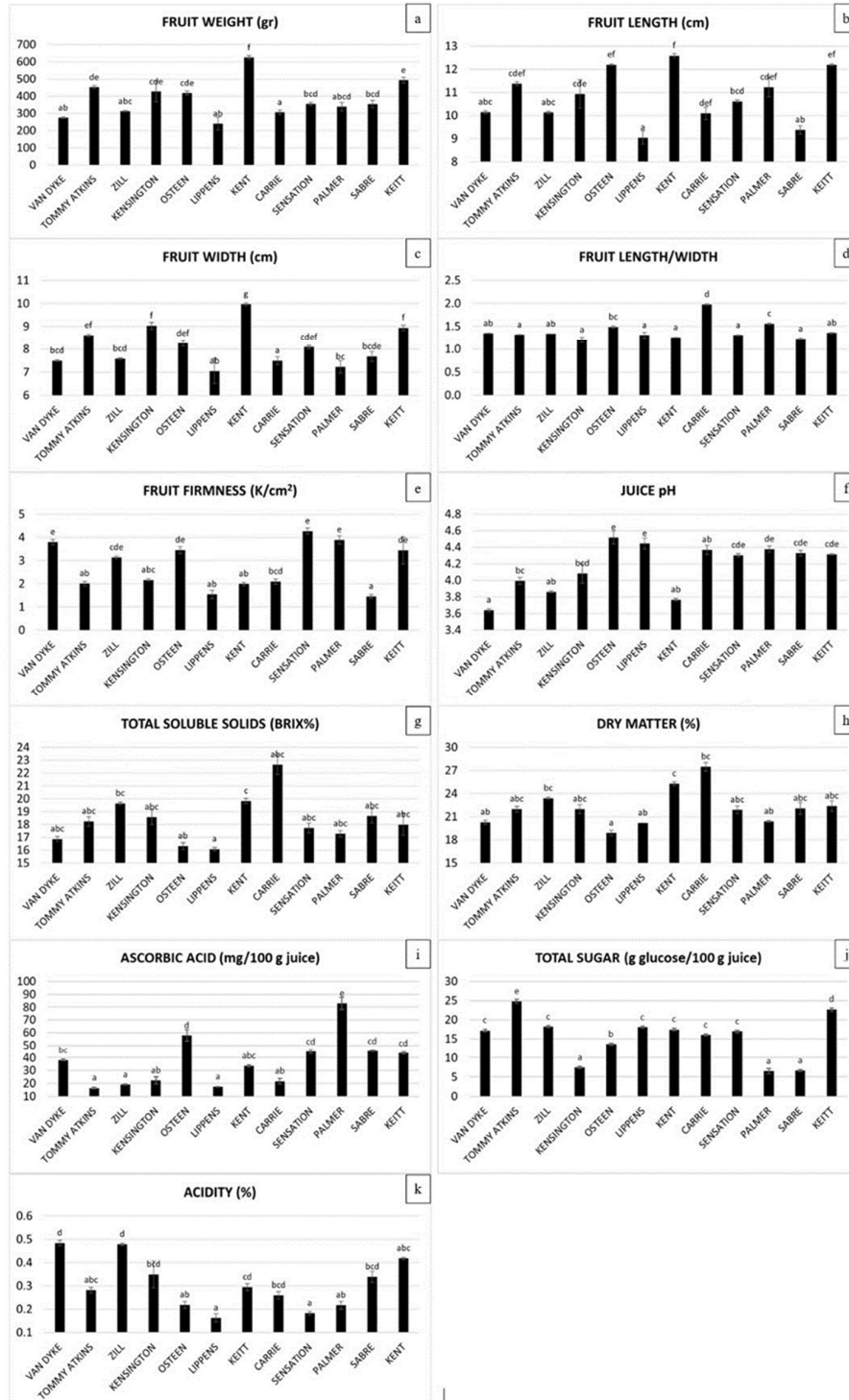


Figure 2. Quality characteristics of mango fruits at ready-to-eat harvest stage, cultivated in Western Crete, Greece

Fruit Weight (a), Fruit Length (b), Fruit Width (c), Fruit Length/Width (d), Fruit Firmness (e), Juice pH (f), Soluble Solid Components (g), Dry Matter % (h), Ascorbic Acid (i), Total Sugar (j) and Acidity (k)

Data represent average values. Different letters in columns (cultivars) of each figure denote significant differences (Duncan test, $p \leq 0.05$)

Discussion

Harvesting of the mango cultivars began on 6th August and ended in early January (data not shown), with harvesting of the last cultivar beginning on 12th November. We can conclude that by using the appropriate varieties, mangoes can be produced from August throughout January in Chania region. To achieve this, early, middle and late varieties should be included simultaneously in the orchard. Therefore, it is necessary that one of these varieties is 'Van Dyke' or 'Tommy Atkins', as according to our results they are the first for harvest. Mango orchard should also include 'Keitt' variety, which begins to be harvested in late autumn and lasts up to January. Additional varieties will have to be cultivated as well, to fill the gap between harvesting of 'Tommy Atkins' and 'Keitt'.

According to data from Florida, mango season runs from May to September, but the main fruit-bearing period varies with the cultivar. For example, the 'Keitt' cultivar is harvested from August through September (Crane *et al.*, 2006). On the other hand, in Sicily - Italy, 'Tommy Atkins' was harvested on 20th August, 'Kensington Pride' on 4th September, 'Osteen' on 15th September and 'Keitt' on 5th October (Farina *et al.*, 2020). The above results indicate the differences between Chania and Florida, and the similarities between Crete and Sicily, with the geographical indication, environmental and climatic conditions being of great importance on harvest time.

Although market demands smaller sized fruits, with the characteristics that a heavier fruit can offer (Kulkarni *et al.*, 2019), size is not a restrictive factor in a good fruit quality. According to our results, fruit weight in 'Kent' variety was statistically higher than the other, with recorded weight between 512.4-765 g. 'Carrie' fruit (139.4-307.6) were lighter than 'Tommy Atkins' (307.2-559.4), 'Kensington' (221-548.4), 'Osteen' (317.1-484.2), 'Sensation' (283.4-438.6) and 'Sabre' (179.4-459.6). Size and weight are mainly matter of cultivar, along with fertilization and cultivation techniques. In an experiment in Florida, in 'Haden' and 'Tommy Atkins', weights from 400 to 600 g were recorded (Vega-Vega *et al.*, 2013). Comparing the two surveys, fruit weight may differ when growing in Florida and in Chania. With losses up to 3% per day, weight loss is an important factor in mango harvested fruit, that affects other parameters as well (Flores-Hernández *et al.*, 2023).

Knowing fruit size is an important factor when packing fruit in trays. Prediction of fruit size at harvest based on measurements made five and four or four and three weeks prior to harvest (Amaral and Walsh, 2023). In our experiment, measurements were taken at ready-to-eat stage, with fruit having their final size. 'Kent' produced the biggest fruits (length and width), with 'Carrie' having the most oval shape.

Firmness is one of the main quality attributes of mango fruits. According to our findings, 'Sabre', 'Tommy Atkins', 'Lippens', 'Kent' and 'Kensington' had significantly lower fruit firmness than 'Keitt', 'Osteen', 'Palmer', 'Sensation' and 'Van Dyke'. According to research in Sicily-Italy, 'Keitt' fruit firmness was 16.9 N (1.65 kg), 'Kensington' 15.6 N (1.59 kg), 'Osteen' 15.79 N (1.61 kg) and 'Tommy Atkins' 15.4 N (1.57 kg). However, no statistical differences were recorded (Farina *et al.*, 2020). Sicily has climatic conditions similar to Crete and the results are more comparable to our findings.

Although mango fruits in our experiment were at the ready-to-eat stage, firmness values were higher than others' researchers. It is possible that epidermis, that was kept on the sample, affected the results. Additionally, when fruits are subjected to hydrothermal treatment, loss of firmness is inevitably a factor of deterioration (Luna-Esquivel *et al.*, 2006). Some genotypes show higher firmness values than others, which is an advantage in packing and logistics practices (Luna-Esquivel *et al.*, 2006). Luna-Esquivel *et al.* (2006) report that this treatment causes a 50% loss in fruit firmness of the 'Ataúlfo' cultivar.

Changes in juice pH caused by changes in citric, malic, and ascorbic acid. Mango is acidic as its pH level ranges from 3.40 to 6.00 (Nordey *et al.*, 2014). Comparing the twelve varieties in Chania, 'Van Dyke', 'Zill', 'Kent' and 'Carrie' had the lower pH level and they differed statistically from 'Osteen', 'Lippens', 'Sensation', 'Palmer', 'Sabre' and 'Keitt'.

In our experiment, 'Palmer' pH level was 4.38 and the minimum pH value recorded in all the varieties was 4.00. Santos Neto *et al.* (2018) found pH of 'Palmer' variety being 3.25 at harvest time. As ripe mangoes are less acidic than green ones, our findings demonstrate the change in pH level during ripening on the tree and harvest at the ready-to-eat stage. Similarly, Javed *et al.* (2022) also reported that advancement in fruit maturity increased the juice pH by converting more organic acids into other metabolites.

NMX-FF-058-SCFI-2006 8/20 for mango quality standard about human consumption, mentions a minimum acceptable value of 2.9% Brix at physiological maturity. Fruits of all genotypes had a soluble solid (SS) value of 7.7% Brix at harvest in the (Flores-Hernández *et al.*, 2023) study, but fruits had an increase of 58-67% in total SS during storage. According to our results, lower SS were recorded in 'Lippens' (16.09%) and 'Osteen' (16.33%), statistically lower than 'Kent' (19.84%).

In the experiment in Sicily-Italy, 'Keitt' variety had 18.51% Brix, 'Kensington' 15.22% Brix, 'Osteen' 15.3% Brix and 'Tommy Atkins' 15.5% Brix. 'Keitt' SS were statistically different from 'Kensington', 'Tommy Atkins' and 'Osteen' (Farina *et al.*, 2020). Additionally, Nambi *et al.* (2015) reported 19.3 and 16.5% Brix for Indian cultivars 'Alphonso' and 'Banganapalli', respectively. Comparing the results, all studies agreed that SS values at consumption maturity should be 10-20% Brix for ripe mangoes.

Most of the fruit characteristics during harvest effect each other and the quality in total; for example, fruits with high DM content have higher specific weight and may have higher sugar and organic acid content, which is another quality indicator (Famiani *et al.*, 2012). Although 'Palmer' mango fruits DM was recorded at 12.42% by Santos Neto *et al.* (2018), many mango genotypes have an average DM content of 17-19%, when they reach eating maturity with the development of all organoleptic characteristics (Flores-Hernández *et al.*, 2023).

According to our findings, DM content was higher than results of other researchers, in most of the genotypes. Lower values were observed in 'Osteen' (18.9%), 'Lippens' (20.2%), 'Van Dyke' (20.3%) and 'Palmer' (20.4%) varieties, having no statistical differences among them, but they had significant lower DM than 'Kent' (25.3%). Having in mind that epidermis was part of the drying sample in our experiment, that dry matter increases during maturity, and that we harvested mango at the ready-to-eat stage, this is compatible with our results.

Vitamin C (Ascorbic acid, AA) has a variety of beneficial biological properties for human health. It is one of the non-nutritive, however important, bioactive phytochemicals contained in a variety of horticultural crops (Vicente *et al.*, 2022). Although mango fruits have a remarkable amount of vitamin C, its concentration varies among cultivars, as indicated by our results (82.79 - 21.76 mg per 100 g juice) and the research of Farina *et al.* (2020). In addition, as vitamin C is a water-soluble and temperature-sensitive vitamin (Igwemmar *et al.*, 2013), it seems that postharvest treatments decrease its content. According to Javed *et al.* (2022), vitamin C was decreased during ambient and cold storage conditions, and it might be possible that high temperature during heat treatments and room temperature under ambient conditions decreased the vitamin C content. In our research, mango fruits were not subjected to any postharvest treatment, so, vitamin C was at its greatest concentration.

Total sugars (Total carbohydrate content, TCC) increased as mango fruit ripened (Barua and Mondal, 2004). According to our findings, in ready-to-eat mango fruits, high concentration of total sugars was recorded in most of the cultivars, higher than that reported by Farina *et al.* (2020). Since ripening is in progress, the organoleptic characteristics are affected as well, with sweet taste being one of the most important.

Total acidity (TA) is also responsible for these organoleptic characteristics, so it is a reliable parameter of fruit quality (Anthon *et al.*, 2011). The increased rate of metabolic activities during maturation process lead to the conversion of organic compounds into sugars and reduces the acid content (Barua and Mondal, 2004). Our results indicated that the lowest acidity was almost 0.16% ('Lippens') and the highest was 0.48% ('Van Dyke' and 'Zill'). Although total sugar concentrations were lower in Farina *et al.* (2020) research, compared to our results, our findings about acidity were in accordance with their experiment.

Conclusions

Cool subtropical regions prove to be suitable for mango cultivation in greenhouse, presenting a long harvest period. Under these conditions, ready-to-eat stage of mango fruit presents interesting values of fruit characteristics, indicating the optimal time to consume a mango fruit. Further study is required to determine the conditions under which mango performs best and to understand how environmental conditions affect fruit ripening in the cool subtropics.

Authors' Contributions

Conceptualization: TTT and KG; Data curation: FS and TTT; Formal analysis: FS, TTT and KG; Investigation: TTT, KG and FS; Methodology: TTT and KG; Project administration: TTT; Supervision: TTT and KG; Validation: FS and TTT; Writing - original draft: FS and TTT; Writing - review and editing: TTT. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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