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Original article

Chemical-physical and nutritional characteristics of mature-green and mature-ripe 'Kensington Pride' mango fruit cultivated in Mediterranean area during cold storage

V. Farina[1,a], A. D'Asaro[1], A. Mazzaglia[2], G. Gianguzzi[1] and E. Palazzolo[1]

[1] Department of Agricultural, Food and Forest Sciences, Università degli Studi di Palermo, Italy

[2] Department of Agricultural, Food and Environmental, Università degli Studi di Catania, Italy

Summary

Introduction – **Mango is a very short postharvest life climacteric fruit. Mangoes are usually harvested firm and green because they are often assigned to long transportation before reaching the market, or they are collected after color break for local markets. In both cases, temperature control is the most critical factor in fruit ripening management. The aim of this study was to investigate the quality evolution of mature-green and mature-ripe mango fruit submitted to 8 °C and 90 ± 5% of relative humidity to assess the possibility to prolong its postharvest life.** *Materials and methods* – **The fruit of mango (*Mangifera indica* L. cv. Kensington Pride) grown in a Mediterranean environment was submitted to the determination of fresh weight, color index, cover color percentage, flesh firmness, total soluble solid content (TSS), titratable acidity (TA), total TSS/TA ratio, ash, fats, crude fibers, carbohydrates, mineral composition (K, P, Ca, Na, Mg, Fe, Zn, Mn, Cu), ascorbic acid, vitamin A, niacin, riboflavin, thiamine and sensory analysis during cold storage.** *Results and discussion* – **A significant effect of storage was observed for weight loss, color, flesh firmness, total soluble solid, titratable acidity, ash, fat, crude fiber, carbohydrates, mineral composition and vitamins.** *Conclusion* – **A cold storage (8 °C) prolongs the life of mango produced in Mediterranean climate, maintaining a good level of physico-chemical and sensory quality of the fruit.**

Keywords

Mediterranean region, mango, *Mangifera indica*, fruit quality, postharvest management, organoleptic traits

Significance of this study

What is already known on this subject?

- Mango is a climacteric fruit that possesses a very short postharvest life. Temperature is the most critical factor in fruit ripening management in mature-green and mature-ripe fruit.

What are the new findings?

- A storage temperature of 8 °C applied to mature-green and mature-ripe mango slowed down the ripening and prolonged postharvest life, maintaining fruit quality.

What is the expected impact on horticulture?

- Both mature-green and mature-ripe mango fruit could be commercialized, stored or transported using low temperature to enlarge their postharvest life and shelf life.

Résumé

Caractéristiques physico-chimiques et physiques des mangues 'Kensington Pride' mures vertes ou mures à point cultivées en zone méditerranéenne pendant le stockage frigorifique.

Introduction – **La mangue est un fruit climactérique dont la durée de vie après récolte est très courte. Les mangues sont habituellement récoltées vertes et fermes parce qu'elles sont souvent soumises à un long transport avant d'atteindre le marché; ou bien elles sont collectées après avoir viré de couleur, pour les marchés locaux. Dans les deux cas, le contrôle de la température est le facteur le plus important dans la gestion de la maturation des fruits. L'objectif de cette étude était d'étudier l'évolution de la qualité des fruits murs encore verts ou murs à point soumis à 8 °C et à 90 ± 5% d'humidité relative pour évaluer la possibilité de prolonger leur vie post-récolte.** *Matériel et méthodes* – **Les caractéristiques des fruits du manguier (*Mangifera indica* L. cv. Kensington Pride) cultivés dans un environnement méditerranéen ont été déterminées au cours du stockage au froid: poids frais, indice de couleur, pourcentage de coloration de la peau, fermeté de la chair, teneur totale en matières solubles (TSS), acidité titratable (TA), ratio TSS:TA, teneurs en cendres, graisses, fibres brutes, hydrates de carbone, composition minérale (K, P, Ca, Na, Mg, Fe, Zn, Mn, Cu), teneurs en acide ascorbique, vitamine A, niacine, riboflavine, thiamine et analyse sensorielle.** *Résultats et discussion* – **Un effet significatif du stockage a été observé sur la perte de poids, la couleur, la fermeté de la chair, la teneur en matières solubles totales, l'acidité titratable, les teneurs en cendres, graisses, fibres brutes, glucides, sur la composition minérale et en vitamines.** *Conclusion* – **Le stockage au froid (8 °C) prolonge la vie des mangues produites sous climat méditerranéen en maintenant un bon niveau de qualité physico-chimique et sensorielle.**

[a] Corresponding author: vittorio.farina@unipa.it.

Mots-clés
région méditerranéenne, mangue, *Mangifera indica*, qualité du fruit, gestion post-récolte, traits organoleptiques

Introduction

Mango (*Mangifera indica* L., family *Anacardiaceae*) is the most diffused fruit crop in the tropical and subtropical areas of the world originating in South Asia (Candolle, 1884). Mango is an evergreen tree with simple and alternate leaves. The inflorescence produces hundreds of small flowers, which are 5–10 mm in diameter, that develop into large fleshy drupes containing an edible mesocarp. In the last decade mango production has increased and in 2013 there were harvested globally 42 Mt (FAOSTAT, 2013). The mango currently ranks fifth in total production among major fruit crops worldwide, after banana (*Musa* spp.), citrus (*Citrus* spp.), grapes and apples, and its production is reported in more than 87 countries. The predominant mango production is concentrated in India, China, Thailand, Indonesia, Philippines, Pakistan and Mexico, but recently its cultivation has spread outside the traditional geographical regions to Australia, Central and South America, South-east Asia, Hawaii, Egypt, Israel, South Africa, and Europe, especially for export markets (Tharanathan *et al*., 2006). The favorable climate of the Mediterranean basin areas is promoting the mango cultivation, particularly in Egypt, Israel, Spain, and in Italy, especially in Sicily (Homsky, 1977; Calabrese *et al*., 2005; Galán and Farré, 2005; Mossad *et al*., 2016). The climatic conditions prevailing in Sicily differ greatly from those of most mango-growing regions: the winter is mild and wet and the summer is hot and dry. As a result, the harvest window was enlarged to six months (June – November) (Galán and Farré, 2005). From its introduction in Sicily, several varieties were observed for vegetative and productive behavior in Mediterranean climate and the results of these studies indicated the possibility to cultivate a few cultivars of mango in several coastal areas characterized by a mild climate (Calabrese *et al*., 2005). Among these cultivars, 'Kensington Pride' registered a good adaptation to climate conditions and to frost incidence. Originally from Australia, this cultivar produces a round ovate fruit with a flattened base and it weighs 350–750 g, it is characterized by a soft and juicy flesh, it has moderate to little fiber, it is sweet with a characteristic flavor that makes it the most popular cultivar in Australian markets (Galán, 2009). The seed is polyembryonic and moderately thick and woody. 'Kensington Pride' is a midseason ripening variety and when the fruit approaches maturation, as most of mango cultivars, it changes color from green to yellow, often showing an orange blush. Skin ground color is used as maturity index and fruits are collected before reaching complete ripening to maintain a market-compatible firmness (Galán, 2009). Uniform weight, external appearance, skin color and cover color, firmness, flavor and aroma are probably the most important characteristics persuading the consumer to purchase mango fruit (Singh, 2011). Moreover, consumer acceptance is higher for mango which do not have external damages. Internal quality attributes include uniform flesh color, acidity and total soluble solid content, depending on the cultivar, stage of maturity and post-harvest techniques (Dick *et al*., 2009). The mango is rich in nutrients (Ajila and Rao, 2008): the pulp of the fruit is rich in fiber, vitamin A, C and E, polyphenols and carotenoids. Vitamin B6, vitamin K, other B vitamins and other nutrients such as potassium, copper, and 17 amino acids are also all present in the flesh, depending on the cultivar (Ribeiro *et al*., 2007).

Generally, fruit intended for local markets or shipment by air are harvested after color break at mature-ripe stage. Fruit assigned to longer transportation markets or for storage are in general harvested firm (mature-green). Mango, as a climacteric fruit, possesses a very short postharvest life (Pesis *et al*., 2000) and a limited shelf-life (7–28 days at 20–25 °C, depending on the ripening stage. After harvest the ripening process in mature-green mangoes usually takes between 9–14 days (Herianus *et al*., 2003) at ambient conditions at 25 °C. Temperature control greatly influenced post-harvest life in mature-green mangoes. Mature-green mangoes can be preserved at 10–13 °C for 14–28 days (Paull and Chen, 2004) or for 20–25 days at 8 °C (Galán, 2009) whereas mature-ripe mangoes can be preserved at 10–13 °C for up to one week. In India, Singh (1960) showed that 19–21 °C was the optimum temperature range for ripening as mangoes developed better quality characteristics when compared with those ripened at ambient temperatures (28–30 °C); whereas Hatton *et al*. (1965) recommended 21–24 °C as the optimum ripening temperatures for Florida mangoes with 15.5–18.5 °C also being satisfactory. However, Thomas and Rahalkar (1975) found that temperatures below 25 °C adversely affected the development of a typical aroma, flavor and carotenoid formation during the ripening of 'Alphonso' mango. Similarly, with the same variety, Vazquez-Salinas and Lakshminarayana (1985) showed that fruits stored at a temperature below 25 °C did not ripen satisfactorily, even though the critical temperature for the development of chilling injury was found to be at about 10 °C. After two weeks at 17 °C fruit firmness, color and sugar:acid ratio declined (Medlicott *et al*., 1986). Temperatures below 13 °C may delay ripening and promote chilling injuries (Mitra and Baldwin, 1997) including skin browning and pulp discoloration (Phakawatmongkol *et al*., 2004).

In this study, the behavior of the mango cv. Kensington Pride produced in Sicily was investigated through physico-chemical trait analysis of its fruit using the lowest possible temperature (8 °C and 90 ± 5% RH) at two different stages of maturation (mature-green and mature-ripe) to assess the possibility to prolong its postharvest life.

Materials and methods

Experimental site

The research was carried out in Balestrate (38.01°N, 13.01°E, 50 m a.s.l.) close to Palermo in 2011. For the climatic characterization of the area, reference was made to the closer thermo-pluviometric station. In this area the presumable average temperatures hover around 19.6 °C, while the average rainfalls are close to 647 mm with 78 rainy days (Duro *et al*., 1996; Drago, 2005; Gianguzzi *et al*., 2015). Under the bioclimatic aspect, the station is referred to the upper infra-Mediterranean lower subhumid bioclimatic belt (Gianguzzi *et al*., 2015).

Plant material

Four 6 year-old trees of mango cv. Kensington Pride spaced 5 × 5 m, trained to vase shape and grafted on Gomera 3 rootstock were studied.

Table 1. Pomological characteristics of mature-green (GRN) and mature-ripe (MAT) mango fresh fruits cv. Kensington Pride. FW: Fresh weight; LD: Longitudinal diameter; TD: Transversal diameter; SW: Seed weight; LDS: Longitudinal diameter of seed; TDS: Transversal diameter of seed. Mean values of 6 fruits, 4 replicates.

Pomological characteristics	Harvesting stages	
	GRN (15 Sept.)	MAT (26 Sept.)
FW (kg)	0.407 ns	0.405 ns
LD (mm)	110.6 ns	109.6 ns
TD (mm)	82.4 ns	79.5 ns
SW (kg)	0.050 a	0.046 b
LDS (mm)	85.4 ns	83.1 ns
TDS (mm)	44.8 a	41.6 b

Means followed with different letters within a row indicate significant differences with the F-test ($P < 0.05$). ns: not significant.

Experimental design

Fruit were harvested at two maturity stages: 24 fruits (6 per 4 trees) were picked at mature-green (GRN) stage (Galán, 2009) and 24 fruits (6 per 4 trees) were picked at mature-ripe (MAT) stage (Cheema and Dani, 1934) (Table 1). For each maturity stage, a sample of 6 fruits was immediately submitted to biometrical, physicochemical and sensory analyses**;** another sample of 6 fruits were stored at a temperature of 8 °C and 90 ± 5% relative humidity (RH); a further sample of 6 fruits was placed at the same temperature of 8 °C and 90 ± 5% RH and subjected to weight measurement with intervals of 3–5 days to monitor the weight loss and color evolution; the last group was stored at 25 °C as control (CTR). At the end of the cold storage period (30 days for GRN and 10 days for MAT), fruit were submitted to physicochemical, chemical composition and sensory analyses.

Physico-chemical analyses

Fruit weight (FW) and seed weight (SW) were determined by a digital scale. Transversal diameter (TD) and longitudinal diameter (TD) were determined by a digital caliper TR53307 (Turoni, Forlì, Italy). Fruit was peeled and flesh firmness (FF) was measured at the equator of the fruit using a digital penetrometer TR5325 fitted with a 7.9 mm diameter head (Turoni, Forlì, Italy) and expressed in newton. Total soluble solid content (TSS) was measured by digital refractometer Atago Palette PR-32 (Atago Co., Ltd., Tokyo, Japan) and expressed in percentage. Titratable acidity (TA) was determined by titration with 0.1 N NaOH to pH 8.2 and calculated as citric acid equivalent and expressed as g L^{-1} of citric acid in juice using a Crison compact titrator (Crison Instruments, SA, Barcelona, Spain). We also determined TSS/TA ratio and flesh/seed (FS) ratio. Each fruit was photographed with a digital camera and digital images were used to determine percentage and intensity of cover peel color. Specifically, we used an algorithm that converts images from RGB (Red, Green, Blue) to CIE (Commission Internationale de l'Eclairage) L*a*b* format, extracts the fruit from the image (removing the image background), and quantifies color characteristics as the weighed distance of each pixel in the image from a reference sample (best colored area interactively chosen from a well-colored fruit). The output is an index (ground cover color index – CI) ranging from 0 to 1 (identical to the reference sample) (Lo Bianco *et al.*, 2010). For cover color determination, a green-red threshold algorithm was added to the previous procedure to obtain a separation of the total fruit area (in number of pixels) into two sub-regions, cover color (closer to red) and ground color (closer to green). The pixel ratio between red-colored area and total fruit area was used to quantify the percentage of cover color (CC).

Chemical composition

Ash (AS) content was determined in 5 g of dried fruit by the procedure described in AOAC (1985a, 1985d). The Kjeldahl method was used for protein determination. In particular, a sample rate was subjected to acid-catalyzed mineralization to turn the organic nitrogen into ammoniacal nitrogen. The ammoniacal nitrogen was then distilled in an alkaline pH. The ammonia formed during this distillation was collected in a boric acid solution and determined through titrimetric dosage. The value of ammoniacal nitrogen was multiplied by 6.25 (Palazzolo *et al.*, 2012).

The fat content 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 was obtained with the anthrone method reported in Loews (1952). The anthrone reaction is the basis of a rapid and convenient method for the determination of carbohydrates, either free or present in polysaccharides Carbohydrates are first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium, glucose is dehydrated to hydroxymethyl furfural. This compound with anthrone forms a green-colored product with an absorption maximum at 630 nm (Palazzolo *et al.*, 2012).

The mineral constituents Ca, Mg, Na, K, Fe, Mn, Z and Cu were determined using atomic absorption spectroscopy following wet mineralization. Phosphorus levels were determined using colorimetry (Loews, 1952).

The riboflavin was extracted in an autoclave with a solution of diluted H_2SO_4. After enzymatic treatment, the riboflavin was determined through HPLC (for the fluorescent spectra) (Morard and Gullo, 1970). The 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 plantarum* 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 of growth of *L. plantarum* after 24 h of incubation at 37.8 °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 (Palazzolo *et al.*, 2012).

The thiamine content was obtained through extraction in 0.1N HCl and oxidation by thiochromium and analysis in HPLC using fluorometric detection (AOAC, 1985c). The ascorbic acid was determined according to procedures previously described by Barros (2007). Vitamin A was determined by AOAC (1985e).

For ascorbic acid 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. Content of ascorbic acid was calculated on the basis of

the calibration curve of authentic L-ascorbic acid (0.02–0.12 mg mL^{-1}; $Y = 3.4127X - 0.0072$; $R^2 = 0.9905$) and the results were expressed as mg ascorbic acid g^{-1} extract (Palazzolo *et al.*, 2012).

Sensory profile

The sensory profile (ISO, 2003) was defined by a panel of 10 judges (4 male and 6 female, aged between 25 and 37 years). The judges were experienced in the sensory analysis of fruits and fruits products over 5 years (Liguori *et al.*, 2014, 2017). Panel members were trained (3 sessions of 90 min), using different samples of mango to recognize the qualitative characteristics to be assessed and to generate the attributes, on the basis of frequency of citation (>60%). Besides, the judges were trained on aroma, flavor, textural and mouth feel attributes during the training session, using product and ingredient references. The samples were evaluated, in duplicate, using 21 attributes sorted by groups: 2 for appearance (flesh color and presence of filaments), 1 for rheological (consistency to cut), 6 for odor (sea, peach, exotic fruits, medicinal, cheese, burned oil), 3 for taste (sour, sweet, bitter), 2 for touch in mouth (juicy and mellow), 6 for flavor (sea, peach, exotic fruits, medicinal, cheese, burned oil) and finally an overall assessment. About 50 g sample were dispensed into a small plastic plate with a 3-digit code on the side and served to judges. The judges evaluated the intensity of each attribute by assigning a score between 1 (absence of the sensation) and 9 (extremely intense). The order of presentation was randomized for each judge and water at room temperature was provided for rinsing between fruit samples. The evaluations were carried out from 10.00 to 12.00 am in individual booths illuminated by white light, at the laboratory of sensory analysis of University of Catania, built to UNI EN ISO 8589 (UNI EN ISO, 2014). A computerized data collection program was used (FIZZ, Software Solutions for Sensory Analysis and Consumer Tests, Biosystèmes, Couternon, France).

Data analysis

The physicochemical and sensory data were subjected to statistical validation using analysis of variance (ANOVA) through software SYSTAT, while data concerning the evolution of the weight in the fridge and color were subjected to analysis of the regression using the SigmaPlot software (SPSS).

Results and discussion

Physico-chemical analyses

The cold storage at 8 °C and 90 ± 5% RH allowed to prolong the postharvest life of fruit in respect to the control ones (CTR). Green-mature fruits (GRN) were stored for 30 days and mature-ripe fruits (MAT) for 10 days in respect to CTR fruits that reached 12 and 4 days respectively.

The fruit weight (FW) of GRN during storage decreased following a polynomial trend ($y = -0.0285\ x^2 - 0.2136\ x + 406.59$; $R^2 = 0.95$). In 30 days the fruit lost 7% of its weight due to respiration and other biological changes taking place in the fruit (Rathore *et al.*, 2007). The FW of MAT showed a decrease following a polynomial behavior ($y = 0.04\ x^2 - 0.8272\ x + 402.67$; $R^2 = 0.97$). In 10 days, the fruit lost an amount of weight of 1%. The experimental storage conditions limited weight losses, even for long periods of storage, as observed by Nunes *et al.* (2007), Rathore *et al.* (2007), and Doreyappa Gowda and Huddar (2001). In both cases, in fact, the weight losses caused by cold storage can be considered irrelevant for commercialization.

Color changed gradually during the evaluation as a function of ripening. For GRN the color index (CI) first increased and then stabilized following a polynomial trend. The same behavior was observed for the cover color (CC) that increased following a polynomial trend (Figure 1). Both CI and CC indicated that the red color gradually increases in percentage and darkens and the fruit under cold storage reached a high uniformity of peel color. Fruit ripening continued in low

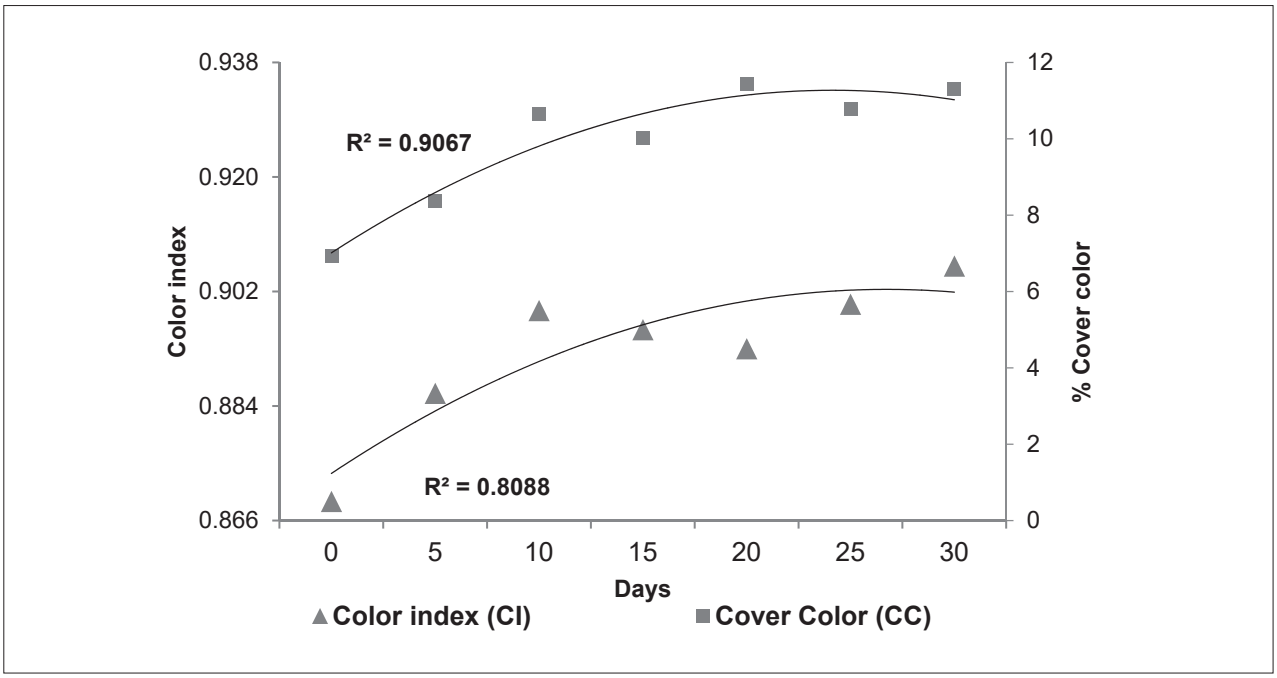

Figure 1. Color index (CI) and cover color (CC) evolution of mature-green (GRN) mango fruit cv. Kensington Pride during 30 days of cold storage at 8 °C at 90 ± 5% RH.

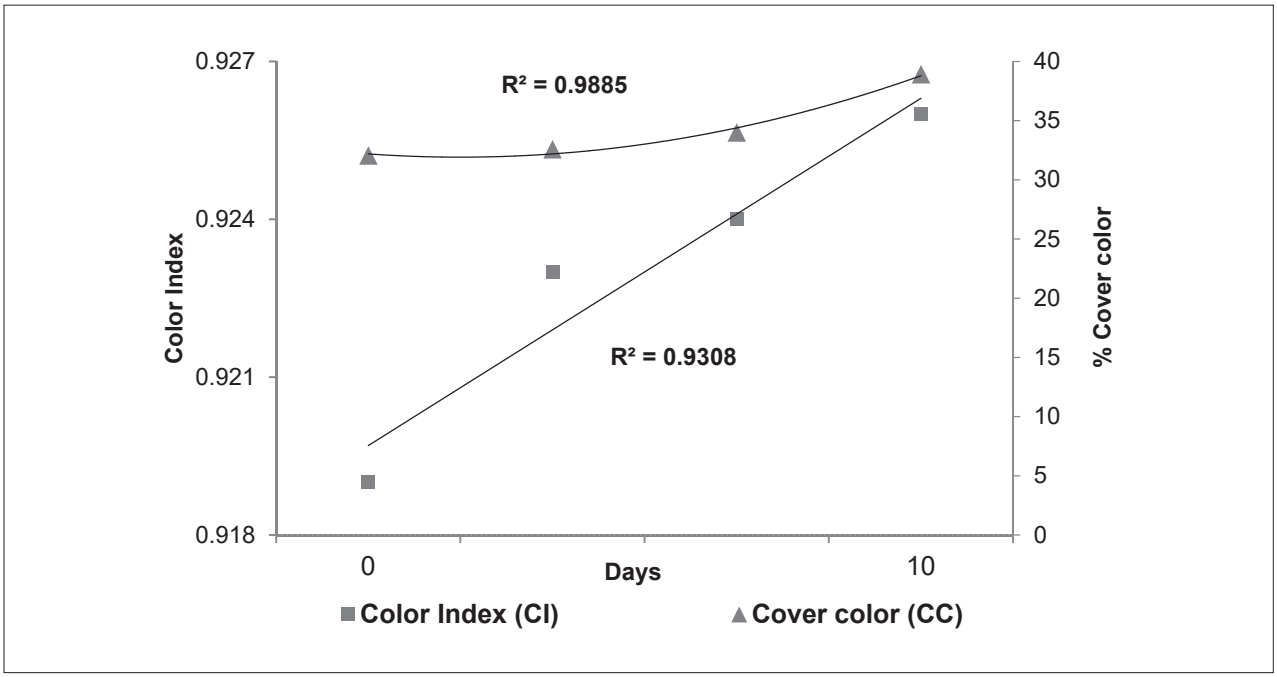

Figure 2. Color index (CI) and cover color (CC) evolution of mature-ripe (MAT) mango fruit cv. Kensington Pride during 10 days of cold storage at 8 °C at 90 ± 5% RH.

storage temperature. In fact, a color change was detected from green to red (Medlicott *et al.*, 1986). The fruit reached the final colorimetric characteristics after circa 10 days. The colorimetric evolution is strictly correlated to the final quality of fruit and, in particular, to the development of cover color which could positively affect consumer appreciation.

As for the MAT, CI increased following a linear model whereas the percentage of CC increased following a polynomial trend (Figure 2). The storage conditions seemed to slow down the fruit ripening in the early days for CC; after a week, instead, there was a sudden recovery and the fruit reached after 10 days a very high value, probably due to the breakdown of chlorophyll and the increase in carotenoid pigments (Rathore *et al.*, 2007). Even if color development was not completely stopped by cold storage, MAT fruit at the end of storage reached higher values of CI and CC in respect to GRN fruit, confirming the best color quality of a tree ripe fruit.

Regarding flesh firmness (FF), significant differences were observed between GRN and MAT fruits at ripening time and at the end of storage. An important decrease during storage was noted (Table 2): GRN fruit was harvested at an elevate grade of FF, compatible with fruit postharvest manipulation (60.1 N) (Galán, 2009), and reached, after 30 days of storage, a ready-to-eat fruit value (17.16 N) (Mitcham and McDonald, 1992). MAT fruit started from a ready-to-eat value (20.69 N) and reached 14.10 N after 10 days of storage. Both final values of FF are compatible with the marketability of the fruits (Siller-Cepeda *et al.*, 2009) but with a very short shelf life. These results are further in line with Rathore *et al.* (2007), Rodríguez Pleguezuelo *et al.* (2011) and Nunes *et al.* (2007), who reported a significant decrease of flesh firmness during cold storage at 2–5 °C.

The total soluble solids expressed also significant differences between GRN and MAT fruits before and after storage. During storage, the TSS increased from 9.95% to 13.40% in GRN fruits after 30 days and from 13.26% to 15.95% in MAT fruits after 10 days (Table 2). Storage conditions did not influence TSS evolution. Similar patterns were reported in mature-green fruits stored at 18 °C (Doreyappa Gowda and Huddar, 2001) due to the hydrolysis of complex carbohydrates into simple sugars (Kittur *et al.*, 2001). This significant increase in TSS certainly makes the fruit more palatable improving its sensory characteristics (Rajwana *et al.*, 2010).

On the contrary, the titratable acidity (TA) decreased during cold storage in both GRN and MAT fruits, showing significant differences after storage. At the end of the cold storage, GRN fruits reached a higher value (5.66 g L^{-1}) in comparison with MAT (4.52 g L^{-1}) fruits. It could be due to the higher value of GRN at harvest. Temperature conditions did not influence negatively fruit ripening that continued its evolution: similar behavior of TA has been reported by Doreyappa Gowda and Huddar (2001) at 18 °C and attributed to the degradation of citric acid by an increased activity of citric acid glyoxylase (Rathore *et al.*, 2007).

At last, the fruit, especially in the case of MAT, reached a balanced SSC/TA ratio (Table 2). GRN started from 0.56, and then reached 2.71. MAT started from 1.75 to reach 3.52.

Table 2. Physico-chemical characteristics of mature-green (GRN) and mature-ripe (MAT) mango fruits cv. Kensington Pride at harvest (Fresh), after 30 or 10 days, respectively, of cold storage (Stored) at 8 °C at 90 ± 5% RH. FF: Fresh firmness; TSS: Total solid soluble content; TA: Titratable acidity. Mean values of 6 fruits, 4 replicates.

Chemical-physical characteristics	Harvesting stages			
	GRN		MAT	
	Fresh	Stored	Fresh	Stored
FF (N)	60.01 a	17.16 c	20.69 b	14.10 d
TSS (%)	9.95 c	13.40 b	13.20 b	15.95 a
TA (g L^{-1})	17.70 a	5.66 c	7.56 b	4.52 d
TSS/AT ratio	0.56 d	2.71 b	1.75 c	3.52 a

Means followed with different letters within a row indicate significant differences with the F-test ($P < 0.05$).

These results are further in line with Rathore *et al.* (2007) and Malundo *et al.* (2001) in fruit stored at 12 °C.

Chemical composition

The AS content is connected to the mineral salt content. The average ash content of the GRN fruit after 30 days of cold storage showed a 27.5% decrease while in the MAT fruit a 15.15% increase (Table 3). In both maturity stages there were significant differences between fresh and stored fruit. These levels are similar to the values reported by Mamiro *et al.* (2007).

FT values of the GRN fruit after 30 days of storage (Table 3) showed a 21.43% decrease; in this case there were significant differences only in GRN fruit, whereas in MAT fruit the content after storage did not change significantly. The levels are lower than the FT values reported by Mamiro *et al.* (2007).

CF values of the GRN fruit after 30 days of storage (Table 3) showed a 87.86% decrease. Also in this case, there were significant differences only in GRN fruit whereas MAT fruit, after 10 days of storage, showed a non-significant loss of content. Even in this case the CF levels are lower than the values reported by Mamiro *et al.* (2007), but consistent with West *et al.* (1988) for ready-to-eat fruit.

The CR in GRN fruit during cold storage showed an 27.42% increase but did not reach the levels of CR in MAT, whereas in MAT fruit it did not vary after storage (Table 3). Also in this case, there were significant differences both in GRN and MAT fruits at the end of storage depending on a MAT fruit tree-ripe harvest. Probably, for this reason, fruit did not increase during storage as GRN fruit did. Similar values of carbohydrates were also observed by Zaied *et al.* (2007).

The mineral composition of mango fruit expressed significant differences between fresh and stored fruits in GRN and MAT for all elements (Table 4). As expected, K is the most abundant element in mango fruit, followed by P and Ca. K is associated with the translocation of photosynthates to fruit (Shear, 1980) and plays an important role in ion balance to maintain cell organization and permeability (Liu and Luh, 1979), and influences the activity of some enzymes. The other elements, in descending order by quantity, were Na, Mg, Zn, Fe, Cu and Mn.

Potassium (K) exhibited a marked decrease in concentration after the storage period in GRN fruit whereas in MAT fruit it showed an opposite trend. This, as mentioned previously, was directly related to changes in TSS. K could also affect TA of these fruits and hence the intensity of the sour taste (Koo and Reese, 1977). In GRN fruit evolution, the content of K and TA follows an inversely proportional trend; in the MAT fruit the opposite trend was observed. P was the second most abundant mineral component in mango fruit increasing during storage due to the rapid synthesis of sucrose (Pratt, 1970). Others chemical elements decreased during storage in GRN fruit but increased or remained unchanged in MAT fruit.

Elevated concentrations of calcium (Ca) extended postharvest storage and shelf-life in avocado (Witney *et al.*, 1999) and mango fruits (Singh *et al.*, 1987), influencing fruit quality (Vuthapanich *et al.*, 1997). Although the relationship between Ca and ripening is not always obvious (Hofman *et al.*, 1997), it may limit chilling injury in mango fruit cv. Kensington Pride (Simmons *et al.*, 1995).

The magnesium (Mg) ion content generally showed a steady decrease during storage in GRN fruit whereas it increased in MAT fruit. Shear (1980) believed that the activity of this element in fruits was related to that of Ca because the maintenance of an adequate supply of Mg is an important factor in ensuring efficient Ca uptake. A weak negative correspondence between the changes in these two elements was observed.

There were significant differences in ascorbic acid content before and after the storage period in both GRN and MAT fruits (Table 5). During the storage period, ascorbic acid content decreased significantly in MAT fruit whereas, as expected, it increased in GRN fruit during ripening. According to Hernández *et al.* (2006), ascorbic acid is one of the most important vitamins for human nutrition. Its content decreases significantly during fruit ripening (Hernández *et al.*, 2006) and declines when fruits become overripe (Tavarini

Table 3. Chemical composition of mature-green (GRN) and mature-ripe (MAT) mango fruits cv. Kensington Pride at harvest (Fresh), after 30 or 10 days, respectively, of cold storage (Stored) at 8 °C at 90 ± 5% RH. AS: Ash; FT: Fat; CF: Crude fiber; CR: Carbohydrate contents. Mean values of 6 fruits, 4 replicates.

Chemical composition (g kg^{-1})	Harvesting stages			
	GRN		MAT	
	Fresh	Stored	Fresh	Stored
AS	5.00 a	3.90 b	3.30 c	3.80 b
FT	4.20 a	3.30 b	3.20 b	3.10 b
CF	76.60 a	9.30 b	7.30 b	6.90 b
CR	87.90 c	112.00 b	133.60 a	136.00 a

Means followed with different letters within a row indicate significant differences with the F-test ($P < 0.05$).

Table 4. Mineral composition of mature-green (GRN) and mature-ripe (MAT) mango fruits cv. Kensington Pride at harvest (Fresh), after 30 or 10 days, respectively, of cold storage (Stored) at 8 °C at 90 ± 5% RH. K: Potassium; P: Phosphorus; Ca: Calcium; Na: Sodium; Mg: Magnesium; Fe: Iron; Zn: Zinc; Mn: Manganese; Cu: Copper. Mean values of 6 fruits, 4 replicates.

Elements (mg kg^{-1})	Harvesting stages			
	GRN		MAT	
	Fresh	Stored	Fresh	Stored
K	401.60 a	218.20 d	241.50 c	333.40 b
P	153.30 c	178.00 b	99.50 d	241.90 a
Ca	187.50 a	109.50 c	97.20 d	124.00 b
Na	151.40 a	82.00 c	75.50 d	103.90 b
Mg	17.00 a	7.60 b	6.30 d	8.20 c
Fe	6.50 a	3.60 b	2.50 c	3.50 b
Zn	5.20 a	2.90 b	2.80 b	2.80 b
Mn	0.50 a	0.30 b	0.30 b	0.30 b
Cu	0.60 a	0.30 b	0.30 b	0.30 b

Means followed with different letters within a row indicate significant differences with the F-test ($P < 0.05$).

Table 5. Vitamin contents of mature-green (GRN) and mature-ripe (MAT) mango fruits cv. Kensington Pride at harvest (Fresh), after 30 or 10 days, respectively, of cold storage (Stored) at 8 °C at 90 ± 5% RH. Mean values of 6 fruits, 4 replicates.

Vitamins (mg %)	Harvesting stages			
	GRN		MAT	
	Fresh	Stored	Fresh	Stored
Ascorbic acid	45.24 d	77.01 c	110.09 a	99.95 b
Vitamin A	0.02 c	0.76 b	0.88 a	0.78 b
Niacin	0.13 c	0.33 b	0.53 a	0.54 a
Riboflavin	0.02 b	0.02 b	0.04 a	0.04 a
Thiamine	0.01 d	0.03 c	0.06 a	0.05 b

Means followed with different letters within a row indicate significant differences with the F-test ($P < 0.05$).

et al., 2008) due to the degradation of fruit tissues losing firmness (FF) and higher soluble solid content in the fruit. GRN and MAT mangoes were found to be rich in ascorbic acid content at the end of storage (Table 5).

Vitamin A increased in GRN fruit during storage and decreased in MAT fruit, but values were similar for both maturities at the end of storage (Table 5). Vitamin A has antioxidant and anti-inflammatory properties; in particular it is very useful in protecting from stress and diseases fighting free radicals. In general, the ß-carotene levels raise as the intensity of color increases during mango growth (Abdul Aziz *et al.*, 2012).

Sensory analysis

Significant differences were observed between GRN and MAT fruits before and after cold storage for the following attributes: flesh color, consistency to cut, medicinal odor and flavor, cheese odor, sour, sweet and juicy (Table 6). As skin color, even flesh color intensity depends on carotenoid content and chlorophyll degradation during maturation. In the GRN fruit this value increased after storage in agreement with the results of the physico-chemical study, showing a continuous ripening of fruit during cold storage. This value did not change in MAT fruit since harvesting took place when the color reached a definitive grade of intensity. The consistency to cut, as expected, decreased in both GRN and MAT fruits (Table 6) as observed for the fresh firmness (FF) in the physico-chemical study (Table 2).

A noticeable medicinal odor increased during the conservation of GRN fruit and reached the same value as for MAT fruit, which did not vary during storage (Table 6). On the contrary, cheese odor did not vary in GRN fruit whereas it decreased in MAT fruit. Sourness decreased and sweetness increased only in GRN fruit whereas in MAT fruit it did not vary. The same trend was observed for the juicy descriptor that, as expected, increased only in GRN fruit (Table 6).

Conclusion

The GRN and MAT ripening stages of mango fruit produced in Mediterranean climate was significantly influenced by storage at 8 °C and 90 ± 5% RH. The most significant changes occurred in all investigated quality traits indicating that ripening was only slowed down. GRN fruit under such storage conditions had a postharvest life of 30

Table 6. Sensory analysis of mature-green (GRN) and mature-ripe (MAT) mango fruits cv. Kensington Pride at harvest (Fresh), after 30 or 10 days, respectively, of cold storage (Stored) at 8 °C at 90 ± 5% RH. Analysis of Variance of sensory attributes scores of the sensory attributes (F values). Mean scores of the twenty-one sensory attributes for the four samples ($n = 6$).

Sensory attributes	F values	GRN		MAT	
		Fresh	Stored	Fresh	Stored
	3.29*	4.18 b	5.45 a	5.10 a	4.72 ab
Presence of filaments	0.87 ns	3.72	2.63	3.10	3.72
Consistency to cut	4.37**	3.73 ab	2.81 b	4.81 a	3.45 b
Sea odor	0.66 ns	3.54	4.00	4.45	3.54
Peach odor	0.94 ns	3.81	3.63	4.36	3.10
Exotic fruits odor	0.75 ns	5.36	5.54	6.18	5.18
Medicinal odor	2.54*	1.27 b	2.90 a	2.36 ab	2.00 ab
Cheese odor	2.27*	1.10 b	1.36 ab	1.90 a	1.18 b
Burned oil odor	0.50 ns	1.27	1.81	1.45	1.54
Sour	2.25*	3.54 a	2.18 b	3.45 a	2.81 ab
Sweet	2.25*	3.81 b	5.45 a	4.90 ab	4.90 ab
Bitter	1.86 ns	2.54	1.72	1.54	1.36
Juicy	2.52*	4.36 b	5.81 a	5.54 a	5.54 a
Mellow	0.12 ns	3.81	3.54	3.81	3.45
Sea flavor	0.05 ns	3.27	3.36	3.54	3.54
Peach flavor	0.64 ns	4.63	4.54	4.36	3.63
Exotic fruits flavor	0.03 ns	5.63	5.45	5.45	5.45
Medicinal flavor	2.46*	1.36 b	2.72 a	2.36 ab	1.54 ab
Cheese flavor	0.20 ns	1.27	1.36	1.36	1.18
Burned oil flavor	0.22 ns	1.27	1.36	1.36	1.54

Values marked with different letters in the same row are significantly different ($P \leq 0.05$) according to the LSD multiple comparison test;
*: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$; ns: not significant.

days and MAT fruit reached 10 days whereas the control fruit stored at room temperature hardly reached 12 and 4 days, respectively. At the end of these periods both GRN and MAT fruits were in line with the market and ready-to-eat needs.

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