

Fruit Physicochemical and Antioxidant Analysis of Mango Cultivars under Subtropical Conditions of Brazil

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ABSTRACT

The study of mango (*Mangifera indica* L.) cultivars in different regions is of great importance, due to the enormous diversity of cultivars and hybrids, as well as different soil and climatic conditions. The aim of this study was to evaluate the physicochemical characteristics and bioactive compounds of mango fruits under subtropical conditions. The experiment was conducted at the São Manuel Experimental Farm, School of Agriculture, Botucatu, São Paulo State University (UNESP), Brazil. Espada Vermelha, Keitt and Palmer cultivars were evaluated. For physical analysis, weight, longitudinal and transverse diameters, fruit shape, pulp yield, peel, seed, peel color and pulp color were evaluated. Regarding chemical characteristics and bioactive compounds, titratable acidity, soluble solids, SS/TA ratio (relationship between soluble solids and titratable acidity), reducing sugars, non-reducer, total ascorbic acid, carotenoids, flavonoids, polyphenols and antioxidant activity were determined. The results showed that Palmer and Keitt cultivars had higher physical quality, such as higher pulp yield, analyzed under subtropical conditions of Brazil. However, Palmer cultivar had higher chemical quality, which was observed in the values of SS/TA ratio, high antioxidant capacity, high ascorbic acid content, greater amount of total polyphenols, and suitable quantities of flavonoids and sugars.

Keywords: Bioactive compounds, *Mangifera indica* L., Fruit quality, Phenolic compounds.

INTRODUCTION

According to the center of origin of cultivated plants (Vavilov, 1951), mango tree (*Mangifera indica* L.) comes from the Indian sub-center and Indo-Malay, which is the second major center. Mango is one of the most popular tropical fruits in the world, due to its characteristic flavor and aroma, attractive color, and excellent nutritional quality (Nunes *et al.*, 2007). In 2014, Brazil produced 1.13 million tons of mango in an area of approximately 70,317 hectares (FAO, 2017).

Brazil mainly produces a cultivar of mango called 'Tommy Atkins' (Sabato *et al.*, 2009). Mango trading market is expanding as the demand for traditional

varieties in Western markets is increasing. There is a huge variety of mango cultivars and their potential should be studied (Jha *et al.*, 2010). Thus, it seems promising to introduce mango cultivars in new areas that present suitable soil and climatic characteristics for their development.

Due to the growing demand, the fruit quality should be seriously considered. Then, choosing the right cultivar is of great importance, since there are several requirements related to fruit quality, such as appearance (color, size, and shape), flavor (soluble solids and titratable acidity), aroma and nutritional value (vitamin C and carotenoids), besides ensuring safe and nutritious food for the consumers (Brecht and Yahia, 2009).

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According to Melo *et al.* (2006), when it comes to consumer health, mango fruit is an important source of antioxidants, especially polyphenols, carotenoids and vitamin C, although polyphenols concentration depends on the cultivar, cultivation conditions, and maturity of fruit (Reynerston *et al.*, 2008).

Some other researches have also evaluated and analyzed mango cultivars over different producing regions (Ribeiro *et al.*, 2008; Jilani *et al.*, 2010; Ma *et al.*, 2011; Feng *et al.*, 2013; Das *et al.*, 2013; Kaur *et al.*, 2014). Although mango originates from tropical areas, it is also successfully cultivated under subtropical climate, e.g. in Southeast of Brazil, Northwest of India, and some parts of South Africa, as described by Mitra (2016). However, fruit quality is directly and indirectly related to many intrinsic (genetic diversity and cultivar type) and extrinsic (soil type, temperature, precipitation, and relative humidity) factors that affect all stages of development. Thus, the final quality is influenced by the result of these factors throughout the production process (Pantastico, 1975).

Under the subtropical conditions of Atari that is located in the village of Amritsar district in the Punjab state of India, Kaur *et al.* (2014) evaluated fruits of two local mango selections and the following cultivars: Dasherari, Gola, Langra Banarasi, Langra, Kala Gola, Dharbhanga, Alphonso, Hundel, Malda, Amarpali, Rettaul, and Chausa. These authors observed variation of total sugar content from 8.26 to 19.00% and acidity from 0.20 to 7.86%. While Feng *et al.* (2013), in Sanya (Hainan Province, China), showed a variation of total sugars from 8.44 to 15.35% in Tainung N°1, Irwin, JinHwang and Keitt cultivars.

As discussed, the quality of the mango varies according to the cultivar and its growing area; thus, the objective of this study was to evaluate the fruit physicochemical and antioxidant analysis of mango cultivars under subtropical conditions of Brazil.

MATERIALS AND METHODS

Characterization of Materials and Experimental Area

The current study took place at São Manuel Experimental Farm, located in the homonymous city. The farm belonged to the School of Agriculture, Botucatu campus, Sao Paulo State University (UNESP), with the geographic coordinates of 22° 44' 28" S, 48° 34' 37" W and an altitude of 740 m. In São Manuel, the climate is classified to be Cwa according to Köppen, i.e. subtropical; warm temperate climate with rainfall concentrated from November to April (Summer); annual average rainfall of 1,376.70 mm, and the warmest month above 22°C (Cunha and Martins, 2009).

The orchard was established on January 5, 2008, and mango cultivars (i.e. 'Espada Vermelha', 'Keitt' and 'Palmer') were planted at the space of 6 meters between rows and 4 meters between trees. All species of *M. indica*. Were grafted on 'Espada' rootstock. Technical guideline recommendations for the crop were followed in rainfed agriculture and plants flowered spontaneously. On the 2012/2013 crop season, 100 fruits of each variety were picked, only if they had reached commercial maturity, i.e. beginning of fruit softening. After harvesting, fruits were transported to the Fruticulture Laboratory at School of Agriculture, in the city of Botucatu, State of Sao Paulo, Brazil.

Fruit Physical Characteristics

The fruit was weighed individually. The weight (g) was obtained in semi-analytical balance. Digital caliper was used for measuring the longitudinal and transverse diameters (mm). The relation between longitudinal and transverse diameters was also assessed, which revealed the fruits shape, i.e. values less than 1 means that fruits are flat, those with averages close to 1 are rounded and values greater than 1 mean that are elongated.

The percentages of pulp, peel, and seed were individually obtained by weighing each party in semi-analytical balance. The values, expressed in grams, of each part were divided into fruit total weight, then multiplied by 100 to obtain the percentage (i.e. percentage = respective weight [in grams] / fruit total weight X 100).

Peel color and pulp evaluation were obtained using the Minolta colorimeter CR-400, in reflectance mode with diffuse lighting illuminant C and angles of 0° and 2°. The results were expressed in color coordinate space L^* (Lightness) C^* (Chroma) $^{\circ}h$ (Hue angle). In hue angle where 0° refers to red color, 90° to yellow, 180° to green, 270° to blue and 360° to red-purple color (Chunthaworn *et al.*, 2012).

Fruit Chemical Characteristics

The Titratable Acidity (TA) of the fruits followed the procedures described by Adolfo Lutz Institute (2008), i.e. by using Five grams of homogenized pulp, diluted in 95 mL of distilled water, followed by titration with 0.1N NaOH standard solution. The indicator used for the turning point was the phenolphthalein and the results were expressed in percentage of citric acid (Famiani *et al.*, 2015).

Evaluation of Soluble Solids (SS) was carried out for direct reading in the digital refractometer with results expressed in °Brix. The SS/TA was also calculated.

Reducing sugars, non-reducing sugars, and total sugars, which were found in the pulp of the fruit, were also evaluated. For reading the samples, Micronal 382 B spectrophotometer was used at a wavelength of 535 nm. The methodology used was described by Somogy, adapted by Nelson (1944), and the results were expressed as a percentage.

Fruit Antioxidant Characteristics

For quantification of ascorbic acid, 10 mL of the standard solution of ascorbic acid was pipetted in Erlenmeyer flask containing 50

mL of 1% oxalic acid solution. Then, to determine the pattern, this solution was titrated with 2,6-DiChlorophenol-Indophenol (DCFI) until pink color persisted for 15 seconds. Subsequently, the samples were prepared with 10 g of pulp and 50 mL of 1% oxalic acid solution in the flasks. Then, the solution was titrated with standard 2.6 DCFI until pink color persisted for 15 seconds. The results were expressed in mg of ascorbic acid per 100 g of pulp (AOAC, 2010).

Determination of total polyphenol content followed the procedure described by Singleton *et al.* (1999). Samples of 2.5 g were homogenized with 4 mL of 50% acetone and taken to the ultrasonic bath for 20 minutes and centrifuged. Then, the supernatant was collected and added to precipitate more than 4 mL of 50% acetone, then, the tubes were taken back to the centrifuged ultrasonic bath. Both supernatants were blended and 0.1 mL of this extract was used to react with 0.9 mL of deionized water, 0.5 mL of Folin-Ciocalteu reagent and 2.5 mL of sodium carbonate. Readings were taken using a spectrophotometer at wavelength of 725 nm and the results were expressed in mg of gallic acid per 100 g of pulp.

The total flavonoids were obtained by using the methodology of Funari and Ferro (2006), in which 1 g of pulp was homogenized in 4 mL of acidified MeOH. Subsequently, the samples were subjected to ultrasonic bath for 30 minutes, then, centrifuged. One mL of the aluminum chloride solution was added to the supernatants. After 30 minutes in the dark, reading was taken at 425 nm wavelength. The results were expressed in mg per 100 g of pulp.

The carotenoid content was quantified by using the methodology of Sims and Gamon (2002). Samples of 0.5 g of pulp were homogenized with 80% buffered acetone, subsequently, centrifuged. After centrifugation, the supernatant was collected and the analysis proceeded in a spectrophotometer at 470 nm length waves.



The results were expressed in mg per 100 g of pulp.

The antioxidant activity was determined according to the methodology of Rufino *et al.* (2007). Samples of 2.5 g of pulp were homogenized with 4 mL of 50% methanol. Then, they were centrifuged and the supernatant was collected and stored in containers in the refrigerator. The extraction procedure was repeated with precipitation by adding 4 mL of methanol. Again, after the break, the samples passed through centrifuging. Then, mixed the two supernatants. Later, 0.1 ml of the extract was used to react with 3.9 mL of 2,2-DiPhenyl-1-PicrylHydrazyl (DPPH) solution (0.06 mM). Readings were performed in a spectrophotometer at a wavelength of 515 nm, the results were expressed in mg of DPPH degraded per 100 g of pulp.

Statistical Analysis

Using randomized block design, the three cultivars ('Espada Vermelha', 'Keitt' and 'Palmer') were considered as treatment. Each cultivar was divided into ten repetitions with one tree. Ten fruits per repetition were evaluated, i.e. 100 fruits per cultivar; in totality, 300 fruits were evaluated. The data were submitted to variance analysis test at probability levels of 1 and 5%. When there was significant variance, the means were compared by Tukey's test at 5% using the statistical program Sisvar[®] (Ferreira, 2011).

RESULTS AND DISCUSSION

Physical Characteristics

Table 1 shows mangoes physical characteristics. The highest average fruit weight (659.05 g) was observed in 'Keitt', followed by 'Palmer' (519.84 g); while the lowest average fruit weight was found in 'Espada Vermelha' (227.55 g), which is similar to that found by Jilani *et al.* (2010) in several mango cultivars of Pakistan. However, the averages of weight observed by these authors were lower than the averages of 'Keitt' and 'Palmer'. Likewise, Iqbal *et al.* (2012), Das (2013), and Kaur *et al.* (2014) observed lower averages than those of 'Keitt' and 'Palmer' in other cultivars.

The lowest averages found in the literature are related to the genetic factors of each cultivar. 'Keitt' and 'Palmer' are cultivars from a genetic improvement program in Florida (USA), which is characterized by producing large fruits, i.e. weigh up to 510 g (Schnell *et al.*, 2006). Fruit weight is directly affected by climatic factors, especially precipitation. During fruit development, water supply is of prime importance, as growth is the result of cell elongation that depends on the water content within the cell (Taiz and Zeiger, 2010).

'Palmer' and 'Keitt' presented higher average of longitudinal and transverse diameter than 'Espada Vermelha', i.e. an average of 132.60 and 131.74 mm in longitudinal diameter and 89.09 and 111.15

Table 1. The results of fruit characteristics of the studied mango cultivars.

Cultivar	Weight (g)	LD ^a (mm)	TD ^a (mm)	LD/TD ^c	Pulp (%)	Pell (%)	Seed (%)
Espada Vermelha	227.55 c	110.55 b	66.31 b	1.67 a	67.64 b	15.13 a	17.24 a
Keitt	659.05 a	131.74 a	111.15 a	1.25 c	80.54 a	11.35 b	8.10 b
Palmer	519.84 b	132.60 a	89.09 a	1.49 b	82.85 a	8.03 c	9.12 b
Average	468.81	124.96	86.84	1.47	77.01	11.50	11.49
CV (%)	14.02	5.86	4.69	4.83	4.04	14.12	22.91
DMS	75.06	8.36	4.65	0.08	3.55	1.85	3.00

^a Longitudinal Diameter, ^b Transverse Diameter, ^c Shape (LD/TD). Different letters in columns differ by Tukey test at 5% probability.

mm in transverse diameter, respectively (Table 1). Kaur *et al.* (2014) observed considerably lower longitudinal and transverse diameter than the current study.

The relationship between longitudinal and transverse diameters shows the shape of the fruits. It was found that the three cultivars presented elongated shape of fruits, i.e. the relation between longitudinal and transverse diameters was greater than 1. 'Espada Vermelha' fruits were more elongated, followed by 'Palmer' and, at last, 'Keitt' (Table 1). It is worth mentioning that this characteristic is defined specifically by genetic factors, regardless of climate.

It is more interesting for industry to have mangoes with lower peel percentage to result in higher pulp percentage (Benevides *et al.*, 2007). Furthermore, 'Palmer' presented the lowest peel percentage of all evaluated cultivars. However, 'Palmer' and 'Keitt' presented the highest pulp percentages [(82.85 and 80.54(%), respectively)] like Jilani *et al.* (2010). In India, fourteen mangoes genotypes were evaluated from a germplasm bank by Kaur *et al.* (2014), who found average percentage of pulp between 41.73 and 89.78%. By evaluating Haden, Palmer, Parwin, and Tommy Atkins cultivars under subtropical conditions of São Paulo State, Brazil. Modesto *et al.* (2016) also obtained slightly lower average percentage of pulp than the current study, i.e. 71.41 and 73.98%.

'Espada Vermelha' had the highest peel percentage, in addition to the highest seed percentage, therefore, the lowest pulp percentage (Table 1). It is noteworthy that the highest seed percentage is an important feature when rootstock is applied. This result is common, because mango fruits have various forms not only the size, but also the shape, color, presence of fibers and other characteristics, according to the species and cultivar (Mukherjee and Litz, 2009).

Regarding peel coloring of the three cultivars, it has been found that 'Espada

Vermelha' has the highest luminance and chroma values (63.19 and 50.59) in comparison with 'Keitt' and 'Palmer' (Table 2). This indicates that the outer surface of 'Espada Vermelha' has a greater color intensity than the other two. Similar values to lightness and chroma of 'Palmer' cultivar was reported by Nunes *et al.* (2007). Ribeiro *et al.* (2008) found 54.9 for peel lightness in 'Palmer' ripe fruit, which is higher than the present work.

Temperature and solar radiation can affect fruit peel colour, since light is directly involved in the production of pigments (Taiz and Zeiger, 2010). Moreover, water availability also affects fruit color. According to Taiz and Zeiger (2010), during water scarcity, plant increases the production of abscisic acid and ethylene, the latter promotes the action of enzymes responsible to produce carotenoids and anthocyanins, which are responsible for yellow, orange, red and purple colours in vegetables.

However, the cultivar should also be considered for the differences in coloration between fruits, since each one carries a certain genetic load responsible for this characteristic.

Regarding Hue angle ($^{\circ}\text{H}$), 'Keitt' presented the highest average (74.60), followed by 'Espada Vermelha' and 'Palmer' (63.21 and 56.79, respectively) (Table 2). Nunes *et al.* (2007) observed higher hue angle value for Palmer cultivar. The angle of 0° indicates red and 90° yellow color. In this case, the values found for the three cultivars are between these two groups, indicating that their peel showed yellow and red color, though 'Palmer' and 'Espada Vermelha' fruits presented peel color closer to redness than 'Keitt' (Table 2).

Analyzing the color of the fruits is of great importance, since this determines commercial use, as consumer appreciates more often red mangos, which can be sold at higher price, sometimes (Saks *et al.*, 1999).

**Table 2.** The results of fruit color of the studied mango cultivars.

Cultivar	Peel			Pulp		
	L ^a *	C ^b *	h ^o ^c	L*	C*	h ^o
Espada Vermelha	63.19 a	50.59 a	63.21 b	67.74 c	72.90 a	75.11 c
Keitt	45.02 b	26.06 b	74.60 a	73.84 b	66.90 b	88.65 b
Palmer	42.41 b	25.32 b	56.79 b	78.28 a	65.13 c	90.44 a
Average	50.21	33.99	64.87	73.29	68.31	84.73
CV (%)	5.61	11.23	14.52	2.13	2.02	1.72
DMS	3.22	4.36	10.76	1.78	1.58	1.66

^a Lightness, ^b Chroma, ^c Hue angle (h°). Different letters in columns differ by Tukey test at 5% probability.

It was found that Palmer pulp has greater lightness and °H, indicating that the pulp is more yellow than ‘Keitt’ and ‘Espada Vermelha’ (Table 2). Based on the pulp °H, ‘Espada Vermelha’ presented red and yellow coloration. For chroma, this cultivar had the highest average, followed by ‘Keitt’ and ‘Palmer’ (Table 2).

Chemical Characteristics

Regarding titratable acidity, the highest average of citric acid was found in ‘Keitt’ (0.49%), followed by ‘Espada Vermelha’ and ‘Palmer’, i.e. 0.30 and 0.28%, respectively, although, the results did not differ statistically by the Tukey test at 5% probability (Table 3). Suchlike results were reported by Das (2013), while Kaur *et al.* (2014) measured highest average acidity for some varieties. However, it is important to consider that fruit acidity is directly related to the genotype and climate conditions, which is grown (Kaur *et al.*, 2014).

Therefore, it may explain the acidity variation between cultivars, even when grown under the same conditions.

For soluble solids content, there was no significant difference between the data. Soluble solids were 16.91 °Brix in ‘Espada Vermelha’, 17.63° Brix in ‘Keitt’ and 17.21 °Brix in ‘Palmer’ (Table 3). The soluble solids values reported in the literature are very unlike. Das (2013) reported averages varied from 13.22 to 23.20 °Brix, while Kaur *et al.* (2014) found that averages ranged from 11.35 to 28.95 °Brix in the following cultivars: Dasherari, Gola, Langra Banarasi, Langra, Kala Gola, Dharbhanga, Alphonso, Hundel, Malda, Amarpali, and Rettaul e Chausa. However, one must consider the climate and growing conditions for each experiment, in addition to the degree of fruit ripeness at the time of analysis.

When SS/TA ratio was evaluated, the highest averages were obtained in ‘Palmer’ (61.38), followed by ‘Espada Vermelha’ (57.91) (Table 3). In the literature, the

Table 3. The results of fruit chemical characteristics of the studied mango cultivars.

Cultivar	pH	TA ^a	SS ^b	SS/TA	RS ^c (%)	NRS ^d (%)	TS ^e (%)
		(Citric ac. %)	(°Brix)				
Espada Verm.	4.10 b	0.30 b	16.91	57.91 a	6.07 a	8.42 c	14.93 c
Keitt	3.85 c	0.49 a	17.63	36.93 b	3.17 c	20.41 a	24.67 a
Palmer	4.25 a	0.28 b	17.21	61.38 a	3.97 b	12.73 b	17.37 b
Average	4.07	0.359	17.25	52.08	4.41	13.85	18.99
CV (%)	1.48	12.44	4.41	12.31	8.44	12.27	8.04
DMS	0.07	0.05	0.87	7.32	0.42	1.94	1.74

^a Titratable Acidity, ^b Soluble Solids, ^c Reducing, ^d Non-Reducing, and ^e Total Sugars. Different letters in columns differ by Tukey test at 5% probability.

lowest average of SS/TA ratio was reported by Kaur *et al.* (2014). The study of SS/TA ratio makes possible to have a real indication of fruit flavor, since the relationship between soluble solids and titratable acidity is affected by all environmental or physiological factors.

Regarding reducing sugars, the highest average was in 'Espada Vermelha' (6.07%), followed by 'Palmer' (3.97%), while 'Keitt' presented the lowest average (3.17%). Cultivar 'Keitt' stood out when Non-Reducing and Total Sugars were evaluated, with an average of 20.41% (NRS) and 24.67% (TS), followed by 'Palmer' (12.73% NRS and 17.37% TS); while the lowest was found in 'Espada Vermelha' (Table 3). Kaur *et al.* (2014) reported higher averages of reducing sugars, i.e. from 3.40 to 19.27%, while Jilani *et al.* (2010) reported lower levels of total sugar, i.e. from 15 to 20%, by evaluating the following cultivars: Alphanso, Anwar Retual, Dusehri, Fajri, Gulab-e-Khas, Langra, Malda, Sanglaxhi, Sindhri, and Suwarnareeka. These variations in sugar content can be explained by different varieties and climate conditions.

Among climatic factors, solar radiation (luminosity) and temperature are the ones that affect sugar contents in fruits. During photosynthesis, the light that is absorbed by the plants is converted from light energy to chemical energy, producing photo-assimilates, such as sugars (Taiz and Zeiger, 2010). In addition, it is important to note that the use of these substances in plant organs occurs by the water flow, which

means that temperature plays a key role in this event due to the transpiration process (Herter *et al.*, 2011).

Antioxidant Characteristics

Regarding the ascorbic acid content, the highest value (49,80 mg 100 g⁻¹) was found in 'Palmer' (Table 4), similar to Modesto *et al.* (2016) who found that 'Palmer' also presented higher levels of ascorbic acid (64.81 mg 100 g⁻¹) than the other evaluated cultivars. Overall, the results corroborate with Das (2013) results, in which the averages varied from 33.13 to 47.06 mg 100 g⁻¹. Differently, Jilani *et al.* (2010) presented higher ascorbic acid values, ranging from 131 to 179 mg 100 g⁻¹. Ascorbic acid quantification is of great importance, since this chemical component is essential in human nutrition as a major antioxidant (Kim *et al.*, 2002).

For total polyphenols, the highest average (196.22 mg of Gallic acid 100 g⁻¹) was in 'Palmer', followed by 'Espada Vermelha' and 'Keitt' (Table 4). Modesto *et al.* (2016) obtained similar results for total polyphenols content in 'Palmer' over two crop cycles, i.e. 157.14 and 1,153.85 mg of Gallic acid 100 g⁻¹. Feng *et al.* (2013) found lower average for total polyphenols (32.06 mg of Gallic acid 100 g⁻¹) in 'Keitt'. In China, Ma *et al.* (2011) evaluated antioxidant activity and phenolic compounds in eight mango cultivars and obtained an average ranging from 8.71 to 193.36 mg of Gallic acid 100 g⁻¹. The polyphenolic compounds are found in

Table 4. The results of fruit antioxidant characteristics of the studied mango cultivars.^a

Cultivar	Ascorbic acid (mg 100 g ⁻¹)	Total polyphenols (mg of Gallic acid 100 g ⁻¹)	Flavonoids (mg 100 g ⁻¹)	Carotenoids (mg 100 g ⁻¹)	Antioxidants (mg of DPPH 100 g ⁻¹)
Espada Verm.	34.12 b	171.13 b	0.50 a	1.96 a	25.35 c
Keitt	26.97 c	119.86 c	0.40 b	1.43 b	78.75 b
Palmer	49.80 a	196.22 a	0.49 a	1.46 b	97.99 a
Average	36.96	162.41	0.466	1617.01	67.36
CV (%)	7.58	6.50	5.78	7.38	15.06
DMS	3.67	12.05	0.03	136.28	11.59

^a Different letters in columns differ by Tukey test at 5% probability.



most fruits; having an antioxidant capacity in human health. Nevertheless, their concentration is related to the cultivar itself, maturity stage of the fruit, and environmental conditions (Reynerston *et al.*, 2008).

Regarding the total flavonoids content, 'Espada Vermelha' and 'Palmer' had the highest average (0.50 and 0.49 mg 100 g⁻¹, respectively); while the lowest average (0.40 mg 100 g⁻¹) was observed in Keitt (Table 4). Ma *et al.* (2011) observed higher flavonoid content in mangoes than the current study; however, the average flavonoid content found by Modesto *et al.* (2016) was considerably lower. This is due to the different cultivars evaluated and environmental conditions of each experiment, e.g. water availability affects flavonoids content, since there is greater action of the chalcone synthase enzyme, which is responsible for flavonoid synthesis, under water stress (Taiz and Zeiger, 2010).

'Espada Vermelha' stood out for having higher carotenoids content (1.96 mg 100 g⁻¹). There were no significant differences between 'Palmer' (1.46 mg 100 g⁻¹) and 'Keitt' (1.43 mg 100 g⁻¹) (Table 4). Das (2013) observed higher average of total carotenoids in mango, i.e. 7.93-14.06 mg 100 g⁻¹. Likewise, Ribeiro *et al.* (2008) found higher average in 'Palmer' (2.63 mg 100g⁻¹). Carotenoids are natural pigments responsible for the red, yellow, and orange color of fruits and other vegetables, besides having different biological functions and benefits to human health (Minguez-Mosquera *et al.*, 2002).

Regarding the antioxidant capacity, the highest average (97.99 mg of DPPH 100 g⁻¹) was in 'Palmer', followed by (78.75 mg of DPPH 100 g⁻¹) 'Keitt' and (25.35 mg of DPPH 100 g⁻¹) 'Espada Vermelha' (Table 4). Feng *et al.* (2013) evaluated the antioxidant capacity of four mango cultivars in China and found that the lowest average (40.10 mg of DPPH 100 g⁻¹) was in 'Keitt'. The importance of this type of study is the fact that antioxidant substances can prevent the formation of free radicals and,

consequently, cell death in the human body (Halliwell *et al.*, 1995).

The high antioxidant capacity found in 'Palmer' can be justified by the fact that this cultivar had the highest concentrations of total polyphenols, ascorbic acid, and carotenoids among the cultivars evaluated in this study.

In the current study, the highest antioxidant capacity found in 'Palmer' may reflect the high concentration of ascorbic acid. In this case, the greatest antioxidant capacity should not be related to the higher content of total polyphenols because of the methodology used. As Wu *et al.* (2004) state, phenolics are predominantly in the hydrophilic fraction, which presents greater suppression capacity of free radicals by the method of Oxygen Radical Absorbing Capacity (ORAC) as compared to lipophilic fraction. They claim that the phenolic compounds of the hydrophilic fraction account for over 90% of the total antioxidant capacity of fruits that they studied.

CONCLUSIONS

The results showed that the fruits of the cultivars Palmer and Keitt have larger size under subtropical conditions of São Manuel, State of São Paulo, Brazil. In addition, they have higher percentage of pulp at the expense of peel and seed, which presents favorable outcomes also for juice industry.

The fruits of the cultivar Palmer present higher chemical quality, since they stand out with high antioxidant capacity, high ascorbic acid content, greater amount of total polyphenols, suitable quantities of flavonoids and total sugars, besides, a good proportion between soluble solids and titratable acidity.

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تجزیه فیزیکوشیمیایی و آنتی اکسیدانی میوه کولتیوارهای انبه در شرایط نیمه گرمسیری برزیل

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چکیده

مطالعه کولتیوارهای انبه (*Mangifera indica* L.) در مناطق مختلف از اهمیت زیادی برخوردار است زیرا کولتیوارها و هیبریدهای این محصول تنوع زیادی دارند و در آب و هواها و خاکهای گوناگون رشد می کنند. هدف این پژوهش ارزیابی ویژگی های فیزیکوشیمیایی و مواد زیست فعال (bioactive) میوه انبه در شرایط نیمه گرمسیری بود. آزمایش در ایستگاه تحقیقاتی São Manuel در دانشکده کشاورزی، در محل Botucatu، در دانشگاه ایالتی سائو پائولو (UNESP) برزیل اجرا شد. کولتیوارهای آزمایش شامل Espada Vermelha، Keitt و Palmer بود. ارزیابی های فیزیکی عبارت بود از وزن، قطر طولی و عرضی، شکل میوه، عملکرد بافت نرم میوه (پالپ)، پوست میوه، بذر، و رنگ پوست میوه. در مورد ویژگی های شیمیایی و مواد زیست فعال، اسیدیته تیتر شده، مواد جامد محلول، نسبت، قندهای احیا شونده، غیر احیایی، اسکورییک اسید کل، کاروتنوئید، فلاونوئید ها، پلی فنل ها و فعالیت آنتی اکسیدانی تعیین شد. نتایج نشان داد که کولتیوارهای Keitt و Palmer کیفیت فیزیکی بهتری در شرایط نیمه گرمسیری برزیل داشتند (مثلا عملکرد پالپ بیشتر). افزون بر این، کولتیوار Palmer کیفیت شیمیایی بالاتری داشت که انعکاس آن در مقدار کسر SS/TA، ظرفیت بالای آنتی اکسیدانی، داشتن مقدار زیادی اسکورییک اسید، مقدار بیشتر کل پلی فنول ها و مقادیر مناسبی از فلاونوئید ها و قندها مشاهده شد.