MODIFIED PASSIVE ATMOSPHERE IN POST-HARVEST MANGABA FRUIT CONSERVATION IN THREE MATURITY DEGREES

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ABSTRACT

Mangaba fruits are highly perishable, presenting short shelf life, rapid maturation and delicate and fragile bark, making it difficult to commercialize over long distances.Objective of this study was to evaluate the best harvest maturity degree as well as the most suitable modified atmosphere for post-harvest quality preservation.Mangaba fruits maturity degrees were: green, middle-mature and mature; and packed in three types of modified atmosphere: polyethylene terephthalate – PET; expanded polystyrene tray with polyvinyl chloride film (PVC) and low density polyethylene (LDPE) packaging with lid. In each evaluation were analysed: loss of fresh mass, firmness, ascorbic acid, soluble solids, titratable acidity, pH and reducing sugars. Falling (mature) mangabas limit the storage period in 6 days, regardless modified atmosphere used, presenting greater loss of mass(2.,39 a 2.91%), reducing sugar (4.05 a 4.58%) content and less firmness (0,98 a 1,47 N).These fruits must be destined to processing, in order to add value to the product.Mangabas harvested in middle-mature stage conditioned in polyethylene tray with PVC stored at a temperature 3 ° C ± 1 and 80% ± 1 RU maintains ascorbic acid contents during the storage period.

Key words: *Hancorniaspeciosa*Gomes; packing; storage.

ATMOSFERA MODIFICADA PASSIVA NA CONSERVAÇÃO PÓS-COLHEITA DE MANGABA EM TRÊS GRAUS DE MATURAÇÃO

RESUMO

Os frutos da mangabeira são altamente perecíveis, apresentando vida de prateleira curta, maturação rápida e casca delicada e frágil, dificultando sua comercialização a longas distâncias.Objetivou-se avaliar o melhor grau de maturação para colheita assim como a atmosfera modificada mais adequada para a conservação da qualidade pós-colheita da mangaba.Foram utilizados frutos de mangaba nos estádios verde, de vez e maduro; e acondicionadas em três tipos de atmosfera modificada: polietileno tereftalato – PET, bandeja de poliestireno expandido, com filme de cloreto de polivinila (PVC) e embalagem de polietileno de baixa densidade (PEBD) com fechamento.A cada retirada foram analisadas:perda de massa fresca, firmeza, ácido ascórbico, sólidos solúveis, acidez titulável, pH e açúcares redutores.Mangabas de caída ou maduras limitam até 6 dias o período de armazenamento, independente da atmosfera modificada utilizada, apresentando maior perda de massa (2,39 a 2,91%),teor de açúcar redutor (4,05 a 4,58%) e menor firmeza (0,98 a 1,47 N).Esses frutos devem ser destinados ao processamento, de modo a agregar valor ao produto.Mangabas colhidas no estádio de vez acondicionadas em bandeja de polietileno com PVC armazenadas em temperatura de 3°C ± 1 e 80% ± 1 UR mantém teores de ácido ascórbico no período de armazenamento.

Palavras-chave:armazenamento; embalagem; *Hancorniaspeciosa*Gomes.

INTRODUCTION

The mangaba tree (*Hancorniaspeciosa* Gomes) belongs to Apocynaceae family, produces berry type fruits, and presents climacteric behaviour and high metabolic activity. When physiologically mature the fruit detaches itself from plant and falls to the ground(LEDERMAN et al., 2000;MOURA, 2005;SANTOS et al., 2009).

Mangaba is rich in iron, phenolic compounds (tannins), presents great antioxidant potential and high levels of vitamin C, an important trait whereas human body does not synthesize this vitamin. The fruit exhibits an extraordinary flavour and aroma, besides presenting low caloric value (43 to 60 Kcal), being widely used by Northeast Statesfood industries (SILVA JUNIOR, 2004; CHITARRA; CHITARRA, 2005; PEREIRA et al., 2006; CARNELOSSI et al., 2009;ALMEIDA et al., 2011).

The maturity degree during harvest time is one of the main determinants of chemical composition and nutritional value, especially in climacteric fruits. Immature harvested fruits are more prone to wrinkling and mechanical damage, in addition to exhibit inferior flavour and aroma when they are mature. However if they are harvested much matured, they become very soft, losing flavour as soon as harvested and in both situations fruits become more susceptible to physiological disorders(CHITARRA; CHITARRA, 2005).

Carnelossi et al. (2004) reportedsuccess of tropical fruits commercialization is directly related to their adequate storage. Modification in atmosphere aims to decrease the metabolism of conditioned product, reducing oxygen levels and raising carbon dioxide content to increase storage period and consequently commercialization (VIEITES et al., 2014; STEFFENS et al., 2009).

Mangaba fruits are highly perishable, presenting short shelf-life, rapid maturation and delicate and fragile bark, making it difficult to commercialize over long distances. In Brazilian *Cerrado* region, trees present short period of harvest and alternation of production (PEREIRA et al., 2006), which makes necessary to know post-harvest physiology in order to obtaining technical information that contributes to increase fruit storage without altering physical, sensorial and nutritional characteristics(DREHMER; AMARANTE, 2008).

The objective of this study was to evaluate the best harvest maturity degree as well as the most suitable modified atmosphere for post-harvest quality preservation.

MATERIAL AND METHODS

The experiment was conductedat Food Technology Laboratory, located at UniversidadeEstadualPaulista "Júlio de MesquitaFilho" (UNESP), Campus ofIlhaSolteira - SP, with mangaba fruits produced at Farm of Teaching, Research and Extension (UNESP).

Fruits in green, middle-mature and mature maturity stages were used. Green and middle-mature fruits were classified subjectively by colour of epidermis (green: green epidermis and middle-mature: greenish yellow epidermis) and firmness (green: hard and middle-mature: slightly hard). Fruits were conditioned in plastic boxes and sent to laboratory where they were selected for lothomogenization. Afterwards, they were washed and sanitized with sodium hypochlorite (10 mg L^{-1}) for 10 minutes, drained and air-dried for experiment assembly (VIEIRA et al., 2010; NARAIN; FERREIRA, 2003; PEREIRA et al., 2006).

All selected fruits were divided in three groups (maturity degrees) and conditioned in three types of modified atmosphere: polyethylene terephthalate package (PET), expanded polystyrene tray (18 cm x 12.5 cm x 4 cm) covered with12 µm polyvinyl chloride film (PVC) and low density polyethylene (LDPE) package with lid (18 cm x 23 cm, 0.1 mm of thickness). Each experimental unit had300 g, approximately, and package in B.O.D. storage at 3 °C ± 1.00temperatureand 80% ± 1.00 relative humidity for six days.

The used temperature was the result of a preliminary test before the implantation of this experiment, in which different controlled temperatures (in B.O.D.) were tested: 3 °C ± 1.00; 8 °C ± 1.00 and room temperature (26 °C ± 1.00), with 80% ± 1.00 (temperature 3 °C and 8 °C) and 50% ± 7.00 (ambient) relative humidity. Although it was a tropical fruit, mangaba showed better conservation at 3 °C ± 1.00 without presenting cold damagesymptoms (chilling), as expected with low temperature conservation.Probably the exposure period (six days) was not sufficient for development of these phenomena. The storage period was reduced to six days due to loss of mature fruits treatments.

The treatments were: T1 = green fruits in low density polyethylene packaging with lid (LDPE); T2 = green fruits inpolyethylene terephthalate package (PET); T3 = green fruits inexpanded polystyrene tray covered with polyvinyl chloride film (EP-PVC); T4 = middle-mature fruits in LDPE; T5 = middle-mature fruits in PET; T6 = middle-mature fruits in EP-PVC; T7 = mature fruits in LDPE; T8 = mature fruits in PET; T9 = mature fruits in EP-PVC.

The experimental design was completely randomized, in a 9 x 3 factorial scheme (treatments x evaluation periods - implantation day, three and six days), with two replicates per treatment. According to Pimentel Gomes (2009), it

is important to consider a number of repetitions in order to have at least 10 degrees of freedom for residue, therefore for this research two replicates were used (residue degrees of freedom = 26)(Table 1).

At each evaluation were analysed: fresh mass loss, firmness, ascorbic acid, soluble solids, titratable acidity, maturity index, pH and reducing sugars. The mass loss was calculated from mass differences of experimental unitsandinitial fruit mass as reference, using precision scale Marte® AS 5500 and results expressed in percentage (%). Fruit firmness was measured using manual penetrometer determined in two distinct points (central and apexregions) in each fruit.

Ascorbic acid contents were determined by titration, and the results expressed as mg of ascorbic acid 100 g^{-1} of pulp. Soluble solids determination were performed by direct reading on a table refractometer VEB Carl Zeiss Jenz- DDR®, with temperature correction to 20 °C, expressing the results in °Brix. The titratable acidity was obtained by titration with 0.01N NaOH solution and phenolphthalein indicator and results expressed in g of citric acid 100 g^{-1} of pulp.Maturity index was calculated by the ratio between soluble solid and titratable acidity contents. The pH was performed in the mangaba fruit pulp, using digital potentiometer modelDMPH-2 Digimed. Reducing sugar content was determined by Lane-Eynon method and results expressed in percentage of glucose. All chemical and physico-chemical traits were analysed according toAdolfoLutz Institute (1985) methodologies.

Data were submitted to analysis of variance and means were compared by Tukey test at 5% of probability. The mass loss data were transformed by √ (x + 1/2), but in Table 2 the original data were used.

RESULTS AND DISCUSSION

At Table 1 it was possible to note mass loss, firmness, ascorbic acid content, soluble solids, titratable acidity, maturity index, pH and reducing sugar were significantly influenced by treatments. In storage period and interaction (treatment x time), there was significance for loss of mass, firmness, ascorbic acid, soluble solids, titratable acidity, maturity index and reducing sugar.

The mass loss was influenced by treatment ($p < 0.01$ – Table 1) and the largest mass losses were observed in six-days-storage fruits, mature stage inpolyethylene terephthalate package (PET) (2.91%) (Table 2). However, in low density polyethylene packaging with lid (LDPE) and expanded polystyrene tray covered with polyvinyl chloride film (EP-PVC) did not also differ statistically, with loss of 2.39% and 2.47%, respectively. In the other hand, lower mass losses were noticed for green fruits in LDPE (0.06%) and middle-mature fruits in LDPE (0.14%) (Table 2).The highest losses in mature fruits (fallen fruits) are possibly related to loss of solutes due to high respiration caused by the fall. These losses cause fruits depreciation and limitedexperiment in six days. Three to 6% of fresh mass losses are sufficient to cause drop of quality in vegetables (CHITARRA; CHITARRA, 2005).

Table 1. Mean square values and significance levels for mangaba fruits evaluated traits in three maturity degrees in different modified atmosphere, storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.Massloss data weretransformedbyV(x+1/2).

Variation	DF	ML	FF	AA	SS
Treatments	8	0.227**	14732.1**	12038.7**	16.8**
Time	2	1.764**	1431.9**	42584.1**	0.28**
Interaction	16	0.077*	405.5**	3146.5**	2.78**
Residue	26	0.035	137.9	539.0	0.82
Overall mean	-	1.02	66.43	232.90	13.90
C.V. (%)	-	18.70	17.60	9.90	6.40
Variation	DF	TA	MI	pH	RS
Treatments	8	0.167**	110.8**	0.06**	8.09**
Time	2	0.778**	136.5**	0.09**	0.91**
Interaction	16	0.078**	8.51**	0.01ns	0.18**
Residue	26	0.001	2.48	0.01	0.02
Overall mean	-	0.912	16.50	3.80	2.30
C.V. (%)	-	4.60	9.50	3.10	6.00

** (p<0,01); * (p<0,05); ns (not significant). C.V. (%): Coefficient of experimental variation. ML: mass loss (%), FF: fruit firmness (Newton), AA: ascorbic acid (mg of ascorbic acid 100 $g^{-1}$of pulp); SS: soluble solid (ºBrix); AT: titratable acidity (g of citric acid 100 $g^{-1}$of pulp); MI: maturity indexeRS: reducing sugar (%).

FigueiredoNeto et al. (2013) studying papaya cv. Formosa subjected to mechanical damage by injury, mentioned that fruits which suffered post-harvest impacts presented greater loss of solubles andmass. Opposite result was found by Santos et al. (2009), that studying mangabas in three maturity stages observed greater losses in green fruits compared to middle-mature fruits.

Another factor that may have influenced mangabamass loss was package constituent material. It was generally knownthatmaterials havedifferent transmission intensity of water vapour and gas. According to Chitarra and Chitarra (2005) PVC film is classified as low water vapour barrier (8 g m^{-2} day^{-1} atm^{-1}), while LDPE is considered as a high barrier (4 g m^{-2} day^{-1} atm^{-1}).

Fruit storage increased fresh mass loss during evaluated period ($p<0.01$ – Table 1) and influenced significantly green and middle-maturestagesin EP-PVC treatment and mature fruits in all packages.This behaviour corroborates with Santos et al. (2009) and Campos et al. (2011), which working with storage mangaba observed increase of fresh mass loss during storage period. There was no influence ($p>0.05$) on green and middle-mature fruits packed in LDPE and PET. These modified atmospheres present a greater barrier against gas exchange and loss of water to the environment, probably this characteristic may have contributed to this lower loss (moisture retention inside the package). Simón et al. (2008) cited that mass loss is due to water loss by transpiration and evaporation of stored product which is directly influenced by package water vapour transmission rate.

Table 2. Mangaba fruits mass loss (%) in three maturity degrees under different modified atmospheres,storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.Massloss data weretransformedby√(x+1/2).

Maturity degrees	Packages	Storage period (days)			Mean
		0	3	6	
Green	LDPE	0 a A	0.03 a A	0.06 c A	0.03
	PET	0 a A	0.53 a A	0.84 bc A	0.45
	EP-PVC	0 a B	0.65 a AB	1.49 abc A	0.71
Middle-mature	LDPE	0 a A	0.03 a A	0.14 c A	0.06
	PET	0 a A	0.44 a A	1.15 abc A	0.53
	EP-PVC	0 a B	0.74 a B	1.58 abc A	0.77
Mature	LDPE	0 a B	0.21 a B	2.39 ab A	0.87
	PET	0 a B	1.44 a B	2.91 a A	1.45
	EP-PVC	0 a B	1.15 a B	2.47 ab A	1.21
Mean		0	0.58	1.45	

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

Mangaba firmness mean values (Table 3) were significant among treatments ($p<0.01$), with the highest firmness observed in green stage conditioned in LDPE (121.1 N) at sixth day of storage, however, not statistically different in relation to green stage in PET (88.7 N), green and middle-matudein EP-PVC (104.9 N and 91.6 N, respectively).

It is known firmness loss is a particularity of fruit ripening process. Its measurement on fruit shows changes in cellular structure due to biochemical transformations, responsible for texture, furthermore, it is considered as quality attribute and with other traits is used for evaluating products shelf-life (CHITARRA; CHITARRA, 2005). Perfeito et al. (2015) cited that firmness might be used as an attribute to indicate mangabamaturity degree, as there is a significant difference between fruit firmness of middle-mature and those with advanced maturation, as in the present research.

In shelf-life period, there was a significant influence ($p<0.01$) on treatments green in PET and middle-mature in all storages, in these atmospheres a decrease in firmness during storage was observed agreeingwith Silva et al. (2013) and Santos et al. (2009) who verified mangaba firmness decrease in relation to storage period and maturation degrees studied. They cited the

difficulty in analysing firmness in falling fruits due to compromised texture of them.

Table 3. Mangaba fruit firmness (N) in three maturity degreesunder different modified atmospheres, storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)						Mean
		0			3			6			
	LDPE	121.6	a	A	103.4	a	A	121.1	a	A	115.3
Green	PET	121.6	a	A	98.5	ab	AB	88.7	abc	B	102.9
	EP-PVC	121.6	a	A	93.1	ab	A	104.9	ab	A	106.5
	LDPE	105.4	a	A	119.6	a	A	72.0	bc	B	99.0
Middle-mature	PET	105.4	a	A	86.7	ab	B	53.4	c	B	81.8
	EP-PVC	105.4	a	A	67.7	b	B	91.6	abc	AB	86.9
	LDPE	2.45	b	A	0.98	c	A	1.47	c	A	1.63
Mature	PET	2.45	b	A	0.98	a	A	0.98	c	A	1.96
	EP-PVC	2.45	b	A	2.45	c	A	0.98	c	A	1.47
Mean		76.5			63.3			59.5			

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

In relation to ascorbic acid it was observed 259 mg of ascorbic acid 100 g^{-1} of pulp in green fruits, 284.6 mg of ascorbic acid 100 g^{-1} of pulp in middle-mature stage and 299.2 mg of ascorbic acid 100 g^{-1} of pulp in mature (Fallen fruits) (Table 4). Similar contents were found by Carnelossi et al. (2004) in middle-mature (274.7 mg of ascorbic acid 100 g^{-1} of pulp) and mature mangaba fruits stage (252.7 mg of ascorbic acid 100 g^{-1} of pulp) harvested in Northeast region and Plácido et al. (2015) cited values of 133.07 and 232.48 mg of ascorbic acid 100 g^{-1} of pulp for the same maturity degrees order in Brazilian *Cerrado*. Perfeito et al. (2015) also observed an increase in ascorbic acid content according tomangaba maturity degree produced in Brazilian *Cerrado*. However, the values were 34.5 and 56.1 mg of ascorbic acid 100^{-1} g of pulp for middle-mature and mature stages, respectively.

Influence was detectedin storage period in relation to treatments ($p<0.01$), with decrease contents at sixth day, except in middle-mature stage conditioned in EP-PVC, which maintained ascorbic acid values throughout the days, probably for maintaining fruits quality. Chitarraand Chitarra (2005) mentioned ascorbic acid levels tend to decrease with fruit maturation and storage due to direct action of ascorbic acid oxidase enzyme or oxidizing enzymes (peroxidase) action. Carnelossi et al. (2004) reported ascorbic acid levels might be used as quality loss indicative for mangaba fruit.

Ascorbic acid content was more conserved in middle-mature fruits reducing only 15% in LDPE package, 20.7% in PET and 1.8% in EP-PVC at the end of storage (Table 4). In the other hand, higher losses were noticed for green fruits: 56.2% (LDPE), 50% (PET) and 58.8% (EP-PVC) and mature stage 43.5% (LDPE), 41.1% (PET) and 29.5% (EP-PVC).

Table 4. Mangaba ascorbic acid content (mg of ascorbic acid 100 g^{-1} of pulp), in three maturity degreesunder different modified atmospheres,storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturitydegrees	Packages	Storageperiod (days)									Mean
		0			3			6			
Green	LDPE	259.0	a	A	190.9	de	B	113.4	c	C	187.7
	PET	259.0	a	A	183.2	de	B	129.5	c	B	190.5
	EP-PVC	259.0	a	A	168.9	e	B	107.4	c	C	178.4
Middle-mature	LDPE	284.6	a	B	362.0	a	A	241.8	ab	B	296.1
	PET	284.6	a	A	306.6	ab	A	225.5	ab	B	272.2
	EP-PVC	284.6	a	A	287.4	abc	A	279.4	a	A	283.8
Mature	LDPE	299.2	a	A	216.6	cde	B	169.1	bc	B	228.3
	PET	299.2	b	A	143.8	e	B	176.1	bc	B	206.4
	EP-PVC	299.2	a	A	247.1	abc	AB	211.0	ab	B	252.4
Mean		280.9			234.1			183.6			

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

In fruit characterization, there was an increase in soluble solids contents with maturation progression (Table 5), with the lowest values observed in green fruits (11.7 °Brix), the highest in mature fruits (15.8 °Brix) and intermediate values for middle-mature stage (14.1 °Brix). Chitarra and Chitarra (2005) pointed out thatsolublesolids increase occurs during fruit maturation due to sugars deterioration, reaching the maximum value at the end of ripening, conferring quality to the product. Similar contents were found by Carnelossi et al. (2004) in mangaba fruits: 15.2 °Brix and 13.1 °Brix in mature and middle-mature stages, respectively.

A significant difference was observed in soluble solids among treatments ($p<0.01$), on third day of storage, mangabas conditioned in EP-PVC presented, in general, better conservation in contents and on sixth day green and middle-mature in the same atmosphere. Soluble solids contents were also influenced by storage ($p<0.01$), only in mature treatment in EP-PVC provided the greatest increase in contents, about 15.8% at sixth day of storage. Soares Junior et al. (2008) researching mangaba fruit cited soluble solids increase during shelf-life and justified this behaviour because of fruits ripening.

Table 5. Mangabasoluble solids content (°Brix), in three maturity degreesunder different modified atmospheres,storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)									Mean
		0			3			6			
Green	LDPE	11.7	b	A	12.5	cd	A	12.4	cdA		12.2
	PET	11.7	b	A	12.5	cd	A	12.7	cdA		12.3
	EP-PVC	11.7	b	A	11.2	d	A	10.5	dA		11.1
Middle-mature	LDPE	14.1	ab	A	15.9	a	A	14.7	bcA		14.9
	PET	14.1	ab	A	15.1	abc	A	14.0	bcA		14.4
	EP-PVC	14.1	ab	A	14.9	abc	A	13.3	bcdA		14.1
Mature	LDPE	15.8	a	A	15.8	ab	A	15.2	bcA		15.6
	PET	15.8	a	A	14.5	abc	A	16.0	abA		15.4
	EP-PVC	15.8	a	B	12.8	bcd	C	18.3	aA		15.6
Mean		13.9			13.9			14.1			

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

In relation to titratable acidity (Table 6), the highest levels were observed in green fruits (1.64 g of citric acid 100g^{-1} of pulp) statistically different from middle-mature fruits (1.01 g of citric acid 100g^{-1} of pulp) and mature stage (0.79 g of citric acid 100g^{-1} of pulp), at assembly experiment time.

Titratable acidity contents were influenced by treatments ($p<0.01$) and by storage period ($p<0.01$), with organic acids content decreasing until sixth day with levels of 0.62 to 0.91 g of citric acid 100 g^{-1} of pulp.

Fruits packed in EP-PET presented the lowest contents at sixth day of storage (0.62 g of citric acid 100 g^{-1} of pulp) in relation to other treatments. However, it was observed that green fruits conditioned in all atmospheres lost 48.3% of acidity on average in shelf-life and smaller losses were perceived in middle-mature (13.6%) and mature fruits (7.5%). Chitarra and Chitarra (2005) justify that fruits acids content decreases with maturation, as they are used like respiration substrate or transformed into sugars, presenting important role in flavour and aroma.

Table 6. Mangaba titratable acidity content (g of citric acid 100g^{-1} of pulp), in three maturity degreesunder different modified atmospheres,storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)			Mean
		0	3	6	
	LDPE	1.64 a A	0.88 a B	0.86 a B	1.12
Green	PET	1.64 a A	0.76 abc B	0.85 a B	1.08
	EP-PVC	1.64 a A	0.87 a B	0.83 a B	1.11
	LDPE	1.02 b A	0.86 a B	0.88 a B	0.92
Middle-mature	PET	1.02 b A	0.77 abc C	0.91 a B	0.90
	EP-PVC	1.02 b A	0.80 ab B	0.84 a B	0.89
	LDPE	0.79 c A	0.64 cd B	0.79 a A	0.74
Mature	PET	0.79 c A	0.71 bcd AB	0.62 b B	0.70
	EP-PVC	0.79 c A	0.59 d B	0.78 a A	0.72
Mean		1.15	0.76	0.81	

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

In maturation index (MI) there was significant difference ($p<0.01$), the highest values were observed in mature fruits (20.0) followed by middle-mature (13.0) and green (6.98) at assembly experiment time. SS/TA ratio is the most used method for flavour evaluation, being more representative than independent analysis of carbohydrates or organic acids (CHITARRA; CHITARRA, 2005).

MI values were influenced by treatment and the storage ($p<0.01$), except in mature treatment in EP-PVC ($p>0.05$). A tendency to increase the values at sixth day of storage was observed, varying from 12.6 to 25.7. However, it is observed that the green fruits increased the indexes by 102%average, indicating a higher ripening speed, while in middle-mature stage presented percentages of 28.5% (LDPE), 18.5 (PET) and 20.7% (EP-PVC).

Table 7. Mangaba maturity index (SS/AT), in three maturity degreesunder different modified atmospheres,storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)			Mean
		0	3	6	
Green	LDPE	6.98 c B	14.1 de A	14.5 cd A	11.8
	PET	6.98 c B	16.3 cde A	15.3 cd A	12.8
	EP-PVC	6.98 c B	12.9 e A	12.6 d A	10.8
Middle-mature	LDPE	13.0 b B	18.4 bcd A	16.7 cd AB	16.1
	PET	13.0 b B	19.5 abc A	15.4 cd B	16.0
	EP-PVC	13.0 b B	18.6 bcd A	15.7 cd AB	15.8
Mature	LDPE	20.0 a B	24.4 a A	19.2 bc B	21.2
	PET	20.0 a B	20.4 abc B	25.7 a A	22.0
	EP-PVC	20.0 a A	21.7 ab A	23.3 ab A	21.6
Mean		13.3	18.5	17.6	

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

The pH varied as maturation stage function. Green fruits presented pH 3.84, middle-mature pH 3.87 and mature pH 4.07. Nascimento, Cardoso and Cocozza (2014), characterizing mature mangaba fruits in West region of Bahia found values of 3.45 to 4.39, similar to the present study. Although, Perfeito et al. (2015) presented pH 3.47in green fruits, pH 3.79 in middle-mature and pH 3.97 in mature stage.

In the other hand, lower values were cited by Carnelossi et al. (2004), about 3.5 for middle-mature and mature stages. Souza et al. (2007) observed pH values ranging from 2.58 to 3.17 in fruits harvested at physiological maturity.

Treatment has been influenced by pH ($p<0.01$) and storage ($p<0.01$). Among treatments, a larger value was observed in mature fruits in PET (4.07), not statistically different from LDPE (4.01), PVC (3.96) and green stage in LDPE (3.84). The pH values increase with acidity reduction indicating maturation (CHITARRA; CHITARRA, 2005).

During storage period, there was statistical difference between pH values ($p<0.01$), at assembly experiment time mean value was 3.93, decreasing on third day to 3.8 and returning to 3.93 on the sixth day.Opposite result was found by Carnelossi et al. (2004), who observed increased pH values in mangaba fruits stored at 25 °Cand during storage, Silva et al. (2013) reported decreases in pH values in middle-mature fruits.

Table 8. Mangaba pH values, in three maturity degrees under different modified atmospheres, storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)			Mean
		0	3	6	
Green	LDPE	3.84	3.79	3.89	3.84 ab
	PET	3.84	3.65	3.89	3.79 b
	EP-PVC	3.84	3.78	3.89	3.84 b
Middle-mature	LDPE	3.87	3.68	3.87	3.81 b
	PET	3.87	3.84	3.81	3.84 b
	EP-PVC	3.87	3.73	3.88	3.82 b
Mature	LDPE	4.07	3.85	4.11	4.01 ab
	PET	4.07	3.94	4.22	4.07 ab
	EP-PVC	4.07	3.99	3.82	3.96 ab
Mean		3.93 A	3.80 B	3.93 A	

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

In reducing sugar contents reported in Table 9, mangaba fruits were influenced by maturation stage, and presented the highest values in mature fruits (3.97%), followed bygreen

(1.54%) and middle-mature (1.37%). In fruits, the main sugars are reducers, especially glucose. During ripening, there is an increase in content of these simple sugars until complete maturation accompanied byacidity reduction. This is due to long-chain carbohydrateshydrolysis and consequent increase in sucrose, fructose and glucose contents (CHITARRA; CHITARRA, 2005; OLIVEIRA et al., 2001).

Souza et al. (2007) observed in 10 mangaba clones, at physiological maturation stage, levels from 6.6% to 11.05% for reducing sugar, higher than found in the present study. According to Fagundes and Yamanishi (2001), quality attributes are influenced by climatic conditions, precipitation, soil, cultivar, temperature, season and harvest site, which could explain these differences with the mentioned literature.

The reduction sugar content was influenced by treatments and storage ($p<0.01$), there was statistical difference in green mangabas in PET;middle-mature in LDPE;mature in LDPE, PET and EP-PVC, with an increase of 23.4%, 42.4%, 2.0%, 5.0% and 15.4% on sixth day of storage showing higher ripening speed in these atmospheres. Silva et al. (2016) reported that levels of reducing sugar in atemoya increased during shelf-life, with or without using LDPE.

Table 9. Mangaba reducing sugars contents (%), in three maturity degreesunder different modified atmospheres, storage at 3°C ±1.00 and80%±1.00 relative humidity for six days.

Maturity degrees	Packages	Storage period (days)			Mean
		0	3	6	
Green	LDPE	1.54 b A	1.58 c A	1.83 c A	1.65
	PET	1.54 b B	1.66 c AB	1.90 c A	1.70
	EP-PVC	1.54 b A	1.57 c A	1.78 c A	1.63
Middle-mature	LDPE	1.32 b B	1.61 c AB	1.88 c A	1.60
	PET	1.32 b A	1.33 c A	1.55 c A	1.40
	EP-PVC	1.32 b A	1.51 c A	1.56 c A	1.46
Mature	LDPE	3.97 a AB	3.69 a B	4.05 b A	3.90
	PET	3.97 a A	2.51 b B	4.17 ab A	3.55
	EP-PVC	3.97 a B	3.92 a B	4.58 a A	4.16
Mean		2.28	2.15	2.59	

Means followed by the same letter, uppercase in the line and lowercase in the column, do not differ significantly from each other at 95% probability, by the Tukey test. LDPE: low density polyethylene package with lid. PET: polyethylene terephthalate package. EP-PVC: expanded polystyrene tray covered with 12 µm polyvinyl chloride film.

CONCLUSIONS

Falling (mature) mangabas limited storage period in six days, regardless modified atmosphere used, presenting greater mass loss, reducing sugar content and less firmness. These fruits must be destined to processing, in order to add value to the product.

Mangabas harvested in middle-mature stage conditioned in EP-PVC stored storage at 3°C ±1.00 and80%±1.00 relative humidity for six days maintain acceptable ascorbic acid contents.

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