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COMPOSICIÓN FÍSICA E QUÍMICA DA FRUTA DA CARAMBOLA (*Averrhoa carambola* L.) EN TRES ESTADOS DE MADUREZ

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Abstract

The carambola (*Averrhoa carambola* L.) fruit is known for its unique star shape and rich golden color. The fruit varies widely in its composition during maturation. However, no single study has been performed to monitor the changes in physical and chemical characteristics of the fruit at different stages of maturity. The objective of the present study was to analyze the composition of the fruit during maturation. The fruit was found to be oblong in shape, being on an average, 7.92 cm long and 5.24 cm in width. The weight of the green mature fruits was significantly different than those of half-ripe and ripe fruits. The pH of the fruit increased with the advance in maturity. Ripe fruits were significantly less acidic (pH 3.44) than green mature (pH 2.40) and half-ripe (pH 2.71) fruits. The titratable acidity, reducing sugars and tannin contents of the fruits were significantly different in fruits among all stages of maturity. The calcium content of the fruits was higher in the ripe stage and it was significantly different than the fruits at green mature or half-ripe stages.

Key words: Carambola, *Averrhoa carambola*, maturation

Resumen

La fruta carambola (*Averrhoa carambola* L.) llama la atención por su característica forma en estrella y su fuerte color dorado. La composición de esta fruta varía ampliamente durante la maduración. Sin embargo, no se han realizado estudios para determinar los cambios en las características fisicoquímicas de la fruta en los diversos estados de maduración. El objetivo de este trabajo ha sido analizar la composición de la fruta durante la maduración. La fruta es oblonda y tiene de media una longitud de 7.92 cm y una anchura de 5.24 cm. El peso de la fruta verde fue significativamente diferente a la de la fruta medio madura y madura. El pH de la fruta se incrementa según avanza la duración. La fruta madura fue significativamente menos acida (pH 3.44) que la verde (pH 2.40) y la medio madura (pH 2.71). La acidez titratable, azúcares reductores y taninos de la fruta fueron significativamente diferentes entre los estados de maduración. El contenido en calcio fue mayor en la fruta madura y significativamente diferente al obtenido en los otros estados de maduración.

Palabras clave: Carambola, *Averrhoa carambola*, maduración

Resumo

A froita carambola (*Averrhoa carambola* L.) llama a atención pola súa característica forma en estrela e o seu forte color dourado. A composición desta froita varía amplamente durante a maduración. Sen embargo, non se realizaron estudios para determinar os cambios nas características fisicoquímicas da froita nos diversos estados de maduración. O obxectivo deste traballo foi analizar a composición da froita durante a maduración. A froita e blonda e ten de media unha lonxitude de 7,92 cm e unha anchura de 5,24 cm. O peso da froita verde foi significativamente diferente a da froita medio madura e madura. O pH da froita increméntase segundo avanza a duración. A froita madura foi significativamente menos ácida (pH 3,44) que a verde (pH 2,40) e a medio madura (pH 2,71). A acidez titratable, azucres reductores e taninos da froita foron significativamente diferentes entre os estados de maduración. O contido en calcio foi maior na froita madura e significativamente diferente a obtida nos outros estados de maduración.

Palabras chave: Carambola, *Averrhoa carambola*, maduración

INTRODUCTION

The oxalidaceae family possesses seven genera representing more than two hundred species, which are distributed principally in the tropical and sub-tropical regions of the world (Hayes, 1960). The genus *Averrhoa* contains two species: Bilimbi (*Averrhoa bilimbi* L.) and carambola (*Averrhoa carambola* L.). Carambola is also known as star fruit. It is considered the more important between the two species. The fruit is cultivated extensively in India and China (Hayes, 1960). Selection and improvement of cultivars was initiated in Florida in 1935 (Campbell *et al.*, 1985) and by 1985, the fruit had attained the status of a popular commercial crop in the United States (Campbell, 1986). The unique star shape and rich golden color, in addition to its use as a fresh fruit and in jelly making, provide a considerable market potential as a garnish for salads and drinks. In western countries, the fruit is generally eaten at a ripe stage when it is yellow. However, in some Asian countries, the green mature fruit is relished and consumed as fresh and in pickle preparations.

Some reports are available on the physical (Bezerrea *et al.*, 1989; Oliveira *et al.*, 1989a), physico-chemical (Bezerra *et al.*, 1989; Oliveira *et al.*, 1989b) and chemical (Lima *et al.*, 1965; Oliveira, 1974, Oliveira *et al.*, 1989b) composition of yellow colored carambola fruit. Herrman (1994) reviewed data on the chemical composition of this fruit. The mineral, aminoacids, volatile flavors and carotenoid compositions of the fruit have been reported (Hall *et al.*, 1980; Burguera *et al.*, 1992). In a study on the process of ripening of the carambola fruit, Mitcham and Mcdonald (1991) associated it to changes in color, firmness, cellulose, hemicelluloses and pectin contents and reported that the color represents an accurate means to determine the fruit ripeness.

The capability of the fruit for storage at longer periods without damaging its quality and its ability to ripen normally at 23°C, can be programmed to supply fruits of required maturity such as green mature, half ripe or full ripe, to the consumer market depending upon the preference of consumers as well as to the fruit processing industries. However, scientific information on the physical and chemical characteristics of the fruit is generally scanty and almost all the data reported are for the fruits at unique point of maturity - the ripe stage. Therefore, the objective of the present study was to determine the physical, physico-chemical and chemical characteristics at different stages of maturity as related to the apparent color variations in carambola fruit.

MATERIALS AND METHODS

Carambola fruits

Mature carambola (*Averrhoa carambola* L.) fruits pertaining to the cultivar Golden Star grown in the state of Paraíba, Brazil were utilized in the present study. After the harvest, the fruits were washed in running water, dried with a towel and classified into three apparent maturities according to their firmness and skin color: (1) Green mature - firm texture and skin 100% green; (2) Half-ripe - firm texture and skin yellowish green, and (3) Ripe - soft texture and skin 100% yellow.

Physical Analysis

Twenty-five fruits of each maturity group were individually analyzed for physical characteristics. Length and diameter were measured with a vernier caliper. The measurement of length was made in the polar axis of fruit, i.e. between apex and stem. The maximum width of the fruit, measured in the direction perpendicular to the polar axis, was denominated as diameter. The measurements for the ridges were made for length and its maximum width.

Chemical Analysis

The edible portion of the fruit was separated manually from the seeds using a stainless steel knife, and triturated in a domestic mixer to form a homogeneous mass. Moisture, ash, lipid, reducing and non-reducing sugars, total acids, pectin, tannin, ascorbic acid, iron, calcium and phosphorus contents were determined according to the methods described by Ranganna (1986). The protein content was determined by the method of Lowry, modified by Schacterle and Pollack (1973). Five samples of each maturity group were analyzed in triplicate.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences windows version 5.0. Tukey's studentized range test (Steel and Torrie, 1980) was performed to compare all the mean differences.

RESULTS AND DISCUSSION

The dimensions of the carambola fruit and its components are presented in Table 1. The length of the fruit varied from 6.75 cm for green mature to 7.92 cm for the fully ripe fruit. The diameter of the ripe fruits was also larger (5.24 cm) than that of the green mature (4.69 cm) fruits. The length and diameter data on the fruit at all stages of maturity relate to its oblong shape. Bezerra *et al.* (1989) in a study on the 32 fruit selections, cultivated in the states of Pernambuco and Rio Grande do Norte in Brazil, reported a range of 6.8 to 9.6 cm for length and 4.1 to 5.5 cm for diameter of yellow fruits. Oliveira et al. (1989a) also reported the values of 7.74 and 4.51 cm, respectively, for length and diameter of mostly ripe carambola fruits. They also reported average fruit weight of 56.75 g, which is within the range of 52.36 g for green mature to 60.38 g for ripe fruits, found in our study (Table 2). However, there was a great variation in the weights of individual fruits at different stages of ripeness. The weight of the green mature fruit was found to be significantly different than those of half-ripe and ripe fruits. Bezzerra *et al.* (1989) also reported fruit weights ranging from 39.6 to 89.5 g. The edible portion of the fruits in our study was almost same (98.8 %) for fruits at all stages of maturity.

Table 1.- Dimensions of the carambola fruit and its components. Means in each row followed by different subscript letters were significantly different ($P < 0.05$). Standard Deviation (SD) < 0.01 is reported as 0.01.

Parameter	Apparent maturity			All the fruits
	Green	Half-ripe	Ripe	
Length of fruit (cm)	$6.75^{a} \pm 0.61$	$7.65^{b} \pm 0.58$	$7.92^{b} \pm 0.95$	7.44 ± 0.24
Diameter of fruit (cm)	$4.69^{a} \pm 0.38$	$5.22^{b} \pm 0.43$	$5.24^{b} \pm 0.60$	5.03 ± 0.32
Length/Diameter Ratio	$1.44^{a} \pm 0.13$	$1.47^{a} \pm 0.17$	$1.51^{a} \pm 0.17$	1.47 ± 0.14
Number of ridges	$4.80^{a} \pm 0.70$	$4.90^{a} \pm 0.31$	$5.00^{a} \pm 0.01$	4.90 ± 0.32
Length of ridges (cm)	$7.03^{a} \pm 0.67$	$7.91^{b} \pm 0.67$	$8.04^{b} \pm 0.97$	7.66 ± 0.41
Width of ridges (cm)	$1.52^{a} \pm 0.18$	$1.77^{b} \pm 0.20$	$1.71^{b} \pm 0.18$	1.69 ± 0.19
Number of seeds	$5.19^{a} \pm 1.50$	$4.89^{a} \pm 1.81$	$4.76^{a} \pm 1.87$	4.95 ± 1.83

Table 2.- Weight of different components of the Carambola fruit. Means in each row followed by different subscript letters were significantly different ($P < 0.05$).

Parameter	Apparent maturity			All the fruits
	Green	Half-ripe	Ripe	
Weight of fruit (g)	$52.36^{a} \pm 17.81$	$59.23^{b} \pm 16.36$	$60.38^{b} \pm 19.56$	57.32 ± 20.26
Weight of seed (g)	$0.71^{a} \pm 0.42$	$0.68^{a} \pm 0.24$	$0.72^{a} \pm 0.41$	0.70 ± 0.37
Weight of edible portion:				
g	51.65	58.55	59.66	56.62
%	98.64	98.85	98.80	98.76
Density of fruit (g/cm^3)	$1.06^{a} \pm 0.15$	$1.01^{a} \pm 0.13$	$1.04^{a} \pm 0.14$	1.03 ± 0.13

Table 3.- Physico-chemical parameters of the carambola fruit pulp. Means in each row followed by different subscript letters were significantly different ($P < 0.05$).

Parameter	Apparent maturity			All the fruits
	Green	Half-ripe	Ripe	
pH	$2.40^{a} \pm 0.23$	$2.71^{a} \pm 0.33$	$3.44^{b} \pm 0.05$	2.85 ± 0.48
Degree Brix	$6.01^{a} \pm 0.86$	$7.30^{a} \pm 1.01$	$10.83^{b} \pm 0.29$	8.04 ± 2.12
^{o}Brix/Titratable acidity	$6.13^{a} \pm 2.13$	$14.31^{b} \pm 2.99$	$30.08^{c} \pm 1.70$	16.84 ± 3.77

The data on physico-chemical parameters of the pulp of carambola fruit are presented in Table 3. The pH of the fruits increased with the advance in maturity, being 2.4 for green mature, 2.7 for half-ripe and 3.44 for ripe fruits. These relatively lower pH values characterized the acidic flavor of the pulp. Accompanying the pH values, the titratable acidity decreased with advances in maturity (Table 4). Ripe fruits were less acidic (0.36 %), being significantly different than green mature (0.98 %) and half-ripe (0.51 %) fruits. The average soluble solid (^{o}Brix) content was lowest (6.01) in green mature fruits, increased to 7.3 in half-ripe fruits and reached the maximum (10.83) in ripe fruits. Consequently, the ^{o}Brix/acid ratio increased from 6.13 for green mature to 30.08 for ripe fruits, being significantly different among all stages of maturity.

The results on chemical analysis of pulp of carambola fruits at different maturities are presented in Table 4. On an average, the carambola fruit pulp had moisture content of about 90 % at all stages of ripeness. The total sugars increased from 2.91% for green mature to 5.60 % for ripe fruits. Reducing sugars increased from 2.80 % for the green mature to 5.04 % for the ripe stage of maturity. The total and reducing sugar contents were significantly different at all stages of maturity. Lima *et al.* (1965) and Oliveira *et al.* (1989b) reported values of 2.48 and 4.07 % for reducing sugars and 3.21 and 5.93 % for

Table 4.- Chemical composition of carambola fruit per 100 g of edible portion. Means in each row followed by different subscript letters were significantly different ($P < 0.05$). Standard Deviation (SD) < 0.01 is reported as 0.01.

Parameter	Apparent maturity			All the fruits
	Green	Half-ripe	Ripe	
Moisture(g)	$90.65^{a} \pm 0.58$	$90.32^{a} \pm 0.98$	$89.96^{a} \pm 0.39$	90.31 ± 0.89
Protein (g)	$0.39^{a} \pm 0.02$	$0.40^{a} \pm 0.02$	$0.45^{a} \pm 0.01$	0.41 ± 0.03
Lipid (g)	$0.31^{a} \pm 0.03$	$0.29^{a} \pm 0.02$	$0.32^{a} \pm 0.01$	0.31 ± 0.03
Crude fiber (g)	$0.92^{a} \pm 0.17$	$1.08^{a} \pm 0.34$	$0.96^{a} \pm 0.08$	0.98 ± 0.13
Reducing sugars (g)	$2.80^{a} \pm 0.46$	$4.31^{b} \pm 0.48$	$5.04^{c} \pm 0.44$	4.05 ± 0.76
Total sugars (expressed as g reducing sugars)	$2.91^{a} \pm 0.61$	$4.69^{b} \pm 0.59$	$5.60^{c} \pm 0.73$	4.40 ± 0.71
Pectin (as g calcium Pectate)	$1.64^{b} \pm 0.98$	$1.08^{a} \pm 0.53$	$1.02^{a} \pm 0.45$	1.25 ± 0.69
Starch (g)	$1.92^{b} \pm 0.37$	$1.28^{a} \pm 0.03$	$1.04^{a} \pm 0.02$	1.41 ± 0.34
Titratable acidity (as g anhydrous citric acid)	$0.98^{a} \pm 0.07$	$0.51^{b} \pm 0.09$	$0.36^{c} \pm 0.02$	0.62 ± 0.21
Ascorbic acid (mg)	$25.2^{a} \pm 0.35$	$25.9^{a} \pm 0.51$	$23.4^{a} \pm 0.22$	24.8 ± 0.71
Tannin (mg)	$0.28^{a} \pm 0.01$	$0.22^{b} \pm 0.01$	$0.14^{c} \pm 0.01$	0.21 ± 0.01

Table 5.- Mineral content (mg) of carambola fruit per 100 g of edible portion. Means in each row followed by different subscript letters were significantly different ($P < 0.05$). Standard Deviation (SD) < 0.01 is reported as 0.01.

Parameter	Apparent maturity			All the fruits
	Green	Half-ripe	Ripe	
Ash	$330^{a} \pm 13$	$328^{a} \pm 25$	$351^{a} \pm 20$	336 ± 38
Iron	$0.55^{a} \pm 0.37$	$0.52^{a} \pm 0.24$	$0.49^{a} \pm 0.34$	0.52 ± 0.55
Calcium	$2.87^{a} \pm 0.56$	$3.55^{a} \pm 0.85$	$4.83^{b} \pm 0.27$	3.75 ± 0.88
Phosphorus	$20.50^{a} \pm 2.88$	$21.62^{a} \pm 3.43$	$19.24^{a} \pm 2.12$	20.45 ± 3.69

total sugars, respectively. The pectin content expressed as calcium pectate decreased with advance in ripeness, being 1.64 % for green mature and 1.02 % for the ripe fruit while ascorbic acid remained almost constant. Lima *et al.* (1965) and Oliveira *et al.* (1989b) reported similar values of ascorbic acid in ripe fruit pulp, being 29.5 and 23.6 mg/100 g, respectively. Tannin content also decreased with advance in maturity, revealing a significant difference in the fruits in all stages of maturity.

The data on ash, iron, calcium and phosphorus contents are presented in Table 5. No set pattern was observed between the concentrations of mineral constituents and the stage of ripeness of the fruits. Lima *et al.* (1965), Oliveira (1974) and Oliveira *et al.* (1989b) have reported a large variation in the mineral composition of the fruit. In our study, the phosphorus content varied little among fruits of different stages of maturity but calcium content in the ripe fruits was significantly different from that of the green mature and half-ripe fruits.

CONCLUSIONS

The current study reveals a large variation in the physical and chemical composition of the carambola fruit during maturation from green mature stage to ripe fruits. The fruit changes its color from the green mature stage when it is firm and green in color to half-ripe when although its texture is still firm but color changes to yellowish green to finally leading to the ripe stage when the fruit possesses a soft texture and its color turns to a total yellow. The pH of the fruit increases with the advance in maturity and ripe fruits are significantly less acidic (pH 3.44) than green mature (pH 2.40) and half-ripe (pH 2.71) fruits. The ratio of

ºBrix and titratable acidity increases appreciably during the maturation, varying from 6.13 in green mature to 30.08 in ripe fruits. The titratable acidity, reducing sugars and tannin contents of the fruits vary significantly ($p<0.05$) in fruits among all stages of maturity.

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