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Frutos de Mutamba (*Guazuma ulmifolia* Lam.) - caracterización física, fisicoquímica y antioxidante

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Resumo

Guazuma ulmifolia Lam., popularmente conhecida como mutamba, mutambo e mucungo, é difundida em toda a América Latina. Estudos sobre as características físico-químicas e a aplicação tecnológica de seus constituintes podem dar suporte ao seu uso como matéria-prima para enriquecimento e/ou formulação de produtos alimentícios. Este estudo teve como objetivo identificar substâncias de interesse alimentar derivadas de frutos de mutamba, através da caracterização de compostos físicos, físico-químicos, centesimais, minerais, bioativos e atividade antioxidante em dois estágios de maturação. A maturação fisiológica incompleta e completa apresentou massa média de 5,52 e 3,54 g, respectivamente, com pH ácido em média 4,84. O teor de sólidos solúveis aumentou com a maturidade atingindo 32,9 °Brix. Em relação à composição centesimal, observou-se aumento de proteínas, lipídios, fibras brutas e cinzas; e redução de umidade em 80%. Os minerais mais concentrados foram K, N, Ca, P e Mg. O teor de antocianinas, polifenóis, flavonoides amarelos e atividade antioxidante aumentaram com a maturação, enquanto a vitamina C permaneceu em 1500 mg.100 g^{-1}. Este estudo é inovador, pois frutos de mutamba com maturação fisiológica incompleta foram caracterizados pela primeira vez. Os frutos de mutamba, independentemente da maturação fisiológica, têm potencial de exploração na indústria alimentícia, devido ao seu alto teor de sólidos solúveis, bem como no enriquecimento de outros produtos alimentícios como fonte de vitamina C e minerais.

Palavras-chave: Antioxidante; Composição; Minerais; Vitamina C.

Abstract

Guazuma ulmifolia Lam., popularly known as mutamba, mutambo and mucungo, is widespread throughout Latin America. Studies on the physicochemical characteristics and the technological application of its constituents can support its use as raw material for enrichment and formulation of food products. This study aimed at to identify substances of food interest

derived from mutamba fruit, through its physical, physicochemical, proximate, mineral, bioactive compounds and antioxidant activity characterization in two maturation stages. The incomplete and full physiological maturation had, on average, mass of 5.52 and 3.54 g, respectively, and acid pH of 4.84 on average. Soluble solids content increased with maturity reaching 32.9 °Brix. Regarding proximate composition, it was observed an increase in protein, lipid, crude fiber and ash; and reduction of 80% in moisture. The most concentrated minerals were K, N, Ca, P and Mg. The content of anthocyanins, polyphenols, yellow flavonoids and the antioxidant activity increased with maturation, while vitamin C remained at 1500 mg.100 g^{-1}. This study is innovative as mutamba fruits with incomplete physiological maturation were characterized for the first time. That mutamba fruits, no matter the physiological maturation, have potential of exploitation in the food industry, due to their high content of soluble solids, as well as in the enrichment of other food products as source of vitamin C and minerals.

Keywords: Antioxidant; Composition; Minerals; Vitamin C.

Resumen

Guazuma ulmifolia Lam., conocida popularmente como mutamba, mutambo y mucungo, está muy extendido en toda América Latina. Los estudios sobre las características fisicoquímicas y la aplicación tecnológica de sus componentes pueden apoyar su uso como materia prima para el enriquecimiento y la formulación de productos alimenticios. El objetivo del estudio fue identificar sustancias de interés alimentario derivadas de la fruta mutamba, mediante la caracterización física, fisicoquímica, centesimal, mineral, compuestos bioactivos y actividad antioxidante en dos etapas de maduración. La maduración fisiológica incompleta y completa mostró una masa media de 5.52 y 3.54 g, respectivamente, con un pH ácido de 4.84 en promedio. El contenido de sólidos solubles se incrementó con la madurez alcanzando el 32.9 °Brix. En cuanto a la composición centesimal, se observó un aumento de proteínas, lípidos, fibra cruda y cenizas; y reducción del 80% en humedad. Los minerales más concentrados fueron K, N, Ca, P y Mg. El contenido de antocianinas, polifenoles, flavonoides amarillos y actividad antioxidante aumentó con la maduración, mientras que la vitamina C se mantuvo en 1500 mg.100 g^{-1}. Este estudio es innovador ya que la fruta mutamba con maduración fisiológica incompleta se caracterizó por primera vez. La fruta mutamba, sin importar la madurez fisiológica, tiene un potencial de explotación en la industria alimentaria, debido a su alto contenido de sólidos solubles, así como en el enriquecimiento de otros productos alimenticios como fuente de vitamina C y minerales.

Palabras clave: Antioxidante; Composición; Minerales; Vitamina C.

1. Introduction

Guazuma ulmifolia Lam., popularly known as mutamba, mutambo and mucungo, is widespread throughout Latin America. It comes from a perennial tree plant, with a height ranging from 7 to 30 meters. The leaves are oval and hairy, with small flowers that show long light yellow hue filiform appendages measuring from 5 to 10 mm long, and slightly perfumed (Brandão et al., 2002; Carvalho, 2010). The fruit is a subglobose, dry, warty capsule (Gómez-Gurrola et al., 2014), of green color when immature and black when ripe, with small whitish seeds; it is hard and varies in length from 1.5 to 4.0 cm, containing, on average, 87 seeds (Pereira et al., 2019).

The mutamba tree is highly recommended as a pioneer species for reforestation of riparian forests throughout Latin America, considering its rapid development and easy rooting in different types of soils (Araújo Neto & Aguiar, 1999). The plant (leaves and stem) is well studied because it is an excellent source of alkaloids, flavonoids, tannins, sesquiterpenes, triterpenes, diterpenes, β-sitosterol, cyanogenic glycosides (Seigler et al., 2005). Researches on mutamba trees have demonstrated biological activities such as anti-hyperglycemic (Alarcon-Aguilara et al., 1998, Alonso-Castro & Salazar-Olivo, 2008), antifungal (Morais et al., 2017), antibacterial (Lopes et al., 2009; Galina et al., 2005), antiprotozoal, and cardioprotective agents (Santos et al., 2018).

Leaves and stem leverage researches related to antiretroviral action (HIV - human immunodeficiency virus and herpesvirus) and against androgenic alopecia, being used to treat numerous other diseases such as diarrhea, asthma, bronchitis, fever, elephantiasis, syphilis, obesity, leprosy, dysentery, among others, in the form of herbal infusion or essential oil (Lopes et al., 2009). Regarding the mutamba fruits, whether ripe or green, studies are still taking place very timidly, but it is already possible to find some works on the proximate and phytochemical composition of maturity mutamba fruit (Pereira et al., 2020), as well as its application in the form of flour for the production of tea, bread and popsicles (Assis et al., 2019; Tene et al., 2007).

The aim of this work was to identify substances of food interest derived from mutamba fruit, through the physical, physicochemical, centesimal, mineral, bioactive compounds and antioxidant activity characterization of fruits in two maturity stages Fruit with Incomplete Physiological Maturity and Fruit with Full Physiological Maturity.

2. Materials and Methods

This work corresponds to a basic research of experimental nature and quantitative approach. This research can be classified as explanatory in terms of objectives, since it seeks to verify cause and effect relationships from data collected in the laboratory (Cervo et al., 2007; Pereira et al., 2018). Its purpose is to identify in mutamba fruits substances of food interest, through the physical, physical-chemical, centesimal, minerals, bioactive compounds and antioxidant activity characterization of fruits in two maturity stages, by obtaining numerical data and statistical evaluation.

2.1 Chemicals

All standards and reagents were of analytical grade. The solutions were also prepared with reagents of analytical grade.

Folin-Ciocalteu, Monohydrated Gallic Acid Standard, Methyl Alcohol, Ethyl Alcohol, Acetone, and Heptahydrated Ferrous Sulphate,were obtained from Dinâmica. TPTZ (2,4,6-Tris (2-pyridyl)-s-triazine), Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), DPPH (2,2-Diphenyl-1-picryl-hidrazil) and ABTS (2,2′-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt) were obtained from Sigma-Aldrich.

2.2 Plant material

The Fruits with Incomplete Physiological Maturity (FIPM), which are green, and the Fruits with Full Physiological Maturity (FFPM), which are black (Figure 1), were manually collected from mutamba trees located on rural properties of Limoeiro do Norte, Ceará, a tropical climate city with dry season (AW), located at 05º 08' 44" South, 38º 05' 53" West, with an altitude of 30 meters in relation to sea level, showing average annual temperature and rainfall of 27.6 °C and 762 mm, respectively.

Figure 1 - Stages of maturation the mutamba fruits collected in Limoeiro do Norte, Ceará. Fruits with incomplete physiological maturation: green (a) and fruits with full physiological maturation: black (b).

Source: authors.

2.3 Physical and physicochemical analyses

For each maturation stage, 20 fruits were used to determine the average mass, in an analytical balance, and the transversal diameter and longitudinal diameter, with a manual caliper. The shape index was calculated by the ratio between the transversal diameter and the longitudinal diameter. The physicochemical determinations and the subsequent analyses were performed in four replicates in triplicate, totaling 200 fruits for each maturation stage. The material analyzed consisted of a ground mixture (fruit + seed). The pH was measured in 10% (w/v) aqueous solutions (pH meter Quimis Q799-02, Diadema, Brazil). Soluble solids were measured in a digital refractometer and the results expressed as °Brix. The titratable acidity was determined by titration with 0.1 N sodium hydroxide (method 942.15) according to Association of Official Analytical Chemists (2005) and the results were expressed as percentage of citric, malic, tartaric and acetic acid using the conversion factor 0.6404, 0.6704, 0.7504, 0.6005, respectively. Water activity was determined using the Aqualab Lite meter (Decagon Devices Inc., Pullman, USA), at 25 °C.

2.4 Proximate composition

The following variables were determined: moisture (method 934.06), ash (method 940.26), lipids (Soxhlet) (method 930.09) and proteins (Kjeldahl, N × 6.25) (method 920.152) according to Association of Official Analytical Chemists (2005). Crude fiber was analyzed by

the Ankom Filter Bag Technique (method Ba 6a-05) according to American Oil Chemist's Society (2009), and sugars (reducing and total) and starch followed the methods described by Maldonade et al. (2013).

2.5 Minerals

The samples were calcined in a muffle furnace at 550 °C for 16 h. The ashes were then digested according to the method described by Malavolta et al. (1989). Macrominerals (Ca and Mg) and microminerals (Cu, Fe, Mn and Zn) were determined by atomic absorption spectrophotometry (iCE 3300; Thermo Scientifc, USA); Phosphor (P) was quantified by the molybdenum blue colorimetric method and sulfur (S) by the barium chloride turbidimetry.

2.6 Bioactive compounds

The vitamin C content was determined by titrimetry (method 985.33; Association of Official Analytical Chemists, 2005) and the results were expressed as mg.100 g^{-1}. Anthocyanins and yellow flavonoids were quantified by spectrophotometric techniques with absorbances measurement at 535 and 374 nm, respectively, and the results were expressed as mg.100 g^{-1} (Francis, 1982).

For total extractable polyphenols (TEP) and antioxidant activity determinations, an extract of each sample was prepared by adding 40 of methyl alcohol 50% (v/v) to 17 g of sample, keeping the mixture at room temperature protected from the light for 60 minutes. After that, it was centrifuged (Eppendorf 5804) at 5000 rpm for 20 minutes, and the supernatant was filtered to a 100 mL volumetric balloon. The procedure was repeated with the residue by adding acetone 70% (v/v), and the supernatant was filtered and added to the same volumetric balloon, whose total volume was completed with distilled water. The extract was kept refrigerated, protected from the light until the moment of the analysis, up to one month.

The total extractable polyphenols were determined by the method described by Obanda et al. (1997) and Larrauri et al. (1997), using Folin-Ciocalteau reagent and a calibration curve of gallic acid. The blank consisted of the same mixture prepared for the samples, replacing it by water. The absorbances were measured in spectrophotometer FEMTO 600 Plus, at 700 nm, and the results were expressed in mg.g^{-1} of gallic acid.

2.7 Antioxidant activity

The antioxidant activity of the mutamba fruits was quantified using the methodologies described by Rufino et al. (2010).

Ferric reducing antioxidant power (FRAP) assay: a calibration curve of ferrous sulphate ($FeSO_4$) was used and the absorbances were measured in spectrophotometer FEMTO 600 Plus, at 595 nm. FRAP reagent was used as blanket and the results were expressed as µM of $FeSO_4.g^{-1}$ of sample.

$ABTS^{\bullet+}$ radical scavenging assay: a calibration curve of Trolox was used and the absorbances were measured in spectrophotometer FEMTO 600 Plus, at 734 nm. Ethyl alcohol was used as blanket and the results were expressed as µM of $Trolox.g^{-1}$ of sample.

DPPH radical scavenging assay: a calibration curve of DPPH radical was used and the absorbances were measured after their stabilization in spectrophotometer FEMTO 600 Plus at 515 nm. Methyl alcohol was used as blanket and the results were expressed as EC_{50}, which means the amount of sample, in g, necessary to reduce to half the initial concentration, also in g, of DPPH free radical (g of $sample.g^{-1}$ DPPH).

2.8 Statistical Analysis

Statistical analyses were performed using the Statistica 7.0 software (Statsoft, 2007) and the null hypothesis between the data was verified with Student's t-test, where a significant difference was considered if $p < 0.05$. Pearson's correlation matrix was applied to some parameters.

3. Results and Discussion

The mutamba fruits studied presented average mass of 5.52 ± 0.46 g for FIPM and 3.54 ± 0.53 g for FFPM (Table 1). This result can be justified by the marked water loss that occurred during ripening.

Table 1 - Proximate composition (g.100 g^{-1}) and physicochemical parameter of mutamba fruits with incomplete physiological maturation and full physiological maturation, collected in Limoeiro do Norte, Ceará.

Parameters	Mutamba*	
	FIPM	FFPM
Proximate composition		
Moisture	71.14a ± 0.10	14.11b ± 0.00
Ash	1.51b ± 0.01	4.56a ± 0.36
Crude Fiber	13.49b ± 1.77	48.86a ± 1.92
Lipid	0.08b ± 0.00	0.82a ± 0.02
Protein	5.41b ± 0.22	10.19a ± 0.87
Total Sugar	6.55a ± 0.68	4.27a ± 0.44
Physicochemical parameter		
pH	4.98a ± 0.06	4.70b ± 0.07
Water Activity	0.77a ± 0.01	0.23b ± 0.00
Titratable Acidity (% citric ac.)	5.42b ± 0.68	16.99a ± 1.08
Titratable Acidity (% malic ac.)	5.62b ± 0.70	17.62a ± 1.12
Titratable Acidity (% tartaric ac.)	6.28b ± 0.78	20.37a ± 1.35
Titratable Acidity (% acetic ac.)	5.15b ± 0.89	15.78a ± 1.00
Soluble Solids (°Brix)	4.70b ± 0.20	32.90a ± 0.30
Reducing Sugars (g.100 g^{-1})	1.77b ± 0.24	10.11a ± 0.29
Starch (g.100 g^{-1})	5.20a ± 0.49	4.54b ± 0.18

*FIPM: fruit with incomplete physiological maturation. FFPM: fruit with full physiological maturation. Results obtained from the average of 4 replicates of 50 fruits. Means followed by the same letter in the line do not differ significantly ($p \geq 0.05$) by Student's t-distribution.
Source: authors.

The average diameter values of FIPM were 2.32 ± 0.14 cm for the transversal one and 2.08 ± 0.18 cm for longitudinal one; while the FFPM presented a transversal diameter of 2.07 ± 0.23 cm and longitudinal diameter of 2.74 ± 0.28 cm; resulting in an shape index of 1.12 ± 0.13 for FIPM and 0.76 ± 0.10 for FFPM. Shape index other than one indicates that the fruits are oval shaped, being equatorially elongated if shape index is greater than one or longitudinally elongated if shape index is smaller than one. The change of orientation in the shape of the fruits can be justified by the loss of moisture which occurs until the end of the maturation stage (Table 1). Knowledge of this parameter is important for fruits that will undergo selections or mechanized processes (Kill et al., 2010).

The mutamba fruits showed 80% of water loss during the ripening process, from 71.14 g.100 g^{-1} (FIPM) to 14.11 g.100 g^{-1} (FFPM) of moisture, and the water activity followed the same behavior, from 0.77 in the FIPM to 0.23 in those FFPM. This low moisture contents can justify the hardness and the dryness in the FFPM fruits. The ash content was 1.51 and 4.56 g.100 g^{-1} for FIPM and FFPM, respectively (Table 1). This shows that the mutamba fruits, at

both maturation stages, are good sources of minerals compared to other crops such as noni (*Morinda citrifolia* L.) (Palioto et al., 2015), which presents only 0.75 g.100 g^{-1} of mineral matter in its composition.

For the crude fiber content, we observed that the FIPM showed a value of 13.49 g.100 g^{-1}, while this value reached 48.86 g.100 g^{-1} for FFPM. This feature is of great interest mainly to the dietetic products industry, which exploits high-fiber foods.

The lipid fraction found was 0.08 g.100 g^{-1} for the FIPM and 0.82 g.100 g^{-1} for the FFPM, well below the values found by Gómez-Gurrola et al. (2014), ranging from 3.50 to 6.11 g.100 g^{-1} in mutambas.

Protein values, of 5.41 g.100 g^{-1} for FIPM and 10.19 g.100 g^{-1} for FFPM, were similar to those reported in the literature, where levels ranging from 7.95 to 14.91 g.100 g^{-1}were found in mutambas (Miranda et al., 2008, Rojas-Hernández et al., 2013, Gómez-Gurrola et al., 2014, Rojas-Hernández et al., 2015).

The pH of the fruits was shown to be acid in both FIPM and FFPM mutambas, with values of 4.98 and 4.70, respectively (Table 1), the latter being similar to the results found by Pereira et al. (2020). The titratable acidity was expressed as a function of different acids, since there is no record of the predominant organic acid in that fruit. In general, it can be observed that the FFPM had three times the acidity of those FIPM.

As expected, the soluble solids (Table 1) increased during maturation, ranging from 4.70 °Brix in the FIPM to 32.90 °Brix in the FFPM, a value much higher than those reported in the main raw materials that presents high contents: pineapple (14 °Brix), sugarcane (16 °Brix), grape (18-26 °Brix), but smaller than tamarind (39-42 °Brix) (Dellacassa et al., 2017, Amorim et al., 2016, Urcan et al., 2017, Taha et al., 2016). Fruits with this feature are usually exploited in the production of fermented beverages, considering that soluble solids are one of the factors that interfere in the alcoholic fermentation (Casimiro et al., 2000). During must fermentation, soluble solids usually show a marked decrease, stabilizing around 5 °Brix.

Fruits as ata (*Annona squamosal* L.) and siriguela (*Spondias purpurea* L.) present high content of reducing sugars, 15.9 and 6.7 g.100 g^{-1}, respectively, as well as mutamba with FFPM, which presented 10 g.100 g^{-1} reducing sugars. The greater the quantity of fermentable sugars, the faster its consumption during must production. Mutambas with FIPM presented a starch content of 5.20 g.100 g^{-1}, while in fruits with FFPM this value was 4.54 g.100 g^{-1} (Table 1). Fruits with a high content of starch, such as siriguela (1 g.100 g^{-1}), when used to produce fermented beverages, undergo partial enzymatic hydrolysis of starch during the process, which raises the percentage of soluble solids (Muniz et al., 2002).

Reducing sugars, total sugars, soluble solids and titratable acidity presented a very strong positive correlation ($p < 0.01$) during the maturation of the mutamba fruits (Table 2). On the other side, starch showed a very strong negative correlation with reducing sugars ($r = -0.6886$; $p = 0.0002$), total sugars ($r = -0.6886$; $p = 0.0002$), soluble solids ($r = -0.6790$; $p = 0.0003$) and titratable acidity ($r = -0.6130$; $p = 0.0014$), demonstrating that the increase of sugars, soluble solids and titratable acidity is due to the degradation of starch during the maturation process of the mutamba fruits.

Table 2 - Correlation matrix between reducing sugars, total sugars, starch, soluble solids and titratable acidity (average) during the maturation of the mutamba fruits collected in Limoeiro do Norte, Ceará.

	Reducing Sugars	Total Sugars	Starch	Soluble Solids	Titratable Acidity
Reducing Sugars	1				
Total Sugars	0.9945*	1			
Starch	-0.6886*	-0.6886*	1		
Soluble Solids	0.9982*	0.9937*	-0.6790*	1	
Titratable Acidity	0.9668*	0.9534*	-0.6130*	0.9724*	1

*Indicates a significant (very strong) correlation, $p < 0.01$.
Source: authors.

Vitamin C levels of 1521.09 mg.100 g^{-1} for FIPM and 1563.06 mg.100 g^{-1} for FFPM were found (Table 3). These values are higher than those found in plants known as good sources of this vitamin: spinach (30.65 mg.100 g^{-1}), orange (62.00 mg.100 g^{-1}), strawberry (67.25 mg.100 g^{-1}) and broccoli (118.00 mg.100 g^{-1}); being only lower than acerola (2844.55 mg.100 g^{-1}) and camu-camu (4752.23 mg.100 g^{-1}) (Phillips et al., 2016; Neves et al., 2015; Malegori et al., 2017). This result indicates that the mutamba fruit has high concentration of vitamin C, according to Brazilian legislation, since 100 g of the fruit provide more than 30% of the recommended daily intake for adults (45 mg.100 g^{-1}) (Brasil 2005; 2012).

Table 3 - Bioactive compounds and total antioxidant activity of mutamba fruits with incomplete physiological maturation and full physiological maturation, collected in Limoeiro do Norte, Ceará.

Parameters	Mutamba*	
	FIPM	FFPM
Vitamin C (mg.100 g^{-1})**	1521.09a ± 250.75	1563.06a ± 74.34
Total extractable polyphenols (mg.100 g^{-1})**	229.37b ± 0.70	645.14a ± 5.23
Anthocyanins (mg.100 g^{-1})**	5.51b ± 0.16	5.84a ± 0.27
Yellow flavonoids (mg.100 g^{-1})**	28.65b ± 1.01	54.76a ± 0.63
FRAP (μM $FeSO_4$. g^{-1})	216114.46b ± 2654.58	446535.02a ± 4265.87
$ABTS^{\bullet+}$ (μM trolox. g^{-1})	17409.25a ± 1278.82	5414.62b ± 98.58
DPPH (EC_{50})***	0.015241b ± 0.000692	0.035885a ± 0.009618

*FIPM: incomplete physiological maturation. FFPM: full physiological maturation. Results obtained from the average of 4 replicates of 50 fruits. Means followed by the same letter in the line did not differ significantly ($p \geq 0.05$) by Student's t-distribution; **Results expressed as dry basis; ***Amount of sample, in g, necessary to reduce to half the initial concentration, also in g, of DPPH free radical.
Source: authors.

The values for total extractable polyphenols found in mutambas (229.37 mg.100 g^{-1} IPM and 645.14 mg.100 g^{-1} FPM) were greater than those found in pear (*Pyrus communis* L.), 107.85 mg.100 g^{-1}; apple (*Malus pumila* Mill.), 101.3 mg.100 g^{-1}; plum (*Prunus domestica* L.), 303.6 mg.100 g^{-1}; green beans (*Phaseolus vulgaris* L.), 35.5 mg.100 g^{-1}; garlic (*Allium porrum* L.), 27.7 mg.100 g^{-1}, radish (*Raphanus sativus* L., var. *Radicula*), 160.0 mg.100 g^{-1}; pitaya (*Hylocereus undatus* (Haw.) Britton & Rose), 2.38 mg.100 g^{-1}; and caja (*Spondias mombin* L.), 29-102 mg.100 g^{-1} (Marinova et al., 2005, Lima et al., 2013, Silva et al., 2012).

In mutambas, FFPM presented the higher concentration of anthocyanins and yellow flavonoids (5.84 mg.100 g^{-1} and 54.76 mg.100 g^{-1}, respectively), which reflects higher ferric reducing antioxidant power (FRAP) in these fruits, since yellow flavonoids donate hydrogens and electrons to free radicals due to their hydroxyl groups and to the fact that anthocyanins can capture unpaired electrons in biological systems. The contents of these compounds vary greatly depending on the plant, as is the case with the anthocyanins in blackberry (*Rubus fruticosus* L.), 89.0 mg.100 g^{-1}; white currant (*Ribes sativum* (Rchb.) Syme), 1.4 mg.100 g^{-1}; and blueberry (*Vaccinium corymbosum* L.), 84.0 mg.100 g^{-1}; and with the yellow flavonoids in pitaya (*Hylocereus undatus* (Haw.) Britton & Rose), 12.16 mg.100 g^{-1}; and caja (*Spondias mombin* L), 2-5 mg.100 g^{-1} (Marinova et al., 2005, Lima et al., 2013, Silva et al., 2012, Pantelidis et al., 2007).

FIPM, in turn, presented antioxidant activity related mainly to the ability to capture the $ABTS^{\bullet+}$ and the DPPH radicals, in view of the high content of vitamin C and its free radical

chelating properties. It is important to highlight that in DPPH method as lower is the antioxidant activity value as higher is the free DPPH radical scavenging capacity of the sample, so FIPM showed the higher antioxidant activity considering that method.

The correlation matrix (Table 4) shows that both anthocyanins and yellow flavonoids showed a very strong correlation ($p < 0.01$) with antioxidant activity in the mutamba fruits, except for the ratio between anthocyanins and antioxidants by the DPPH method ($r = 0.3913$; $p = 0.0586$), which was characterized as a strong correlation ($0.01 \leq p < 0.05$). This demonstrates the effectiveness of these compounds, present in the fruit, as antioxidant by electrons and hydrogens scavenging and by neutralizing free radicals. There was no significant correlation ($p > 0.05$) between vitamin C and total phenolics with the antioxidant activity of the mutamba fruits.

Table 4 - Correlation matrix of the bioactive compounds (vitamin C (Vit C), total extractable polyphenols (TEP), anthocyanins (ANT), yellow flavonoids (YEL FL)) and antioxidant activity (DPPH, ABTS and FRAP) during the maturation of the mutamba fruits collected in Limoeiro do Norte, Ceará.

	Vit C	TEP	ANT	YEL FL	DPPH	$ABTS^{\bullet+}$	FRAP
Vit C	1						
TEP	0.2000	1					
ANT	-0.0740	0.1541	1				
YEL FL	0.0897	0.3494	0.6225^{**}	1			
DPPH	0.0398	0.2993	0.3913^{*}	0.8849^{**}	1		
$ABTS^{\bullet+}$	-0.1289	-0.3247	-0.6152^{**}	-0.9914^{**}	-0.8688^{**}	1	
FRAP	0.1145	0.3609	0.5764^{**}	0.9843^{**}	0.8836^{**}	-0.9741^{**}	1

*Indicates strong significant correlation ($0.01 \leq p < 0.05$); **Indicates very strong significant correlation ($p < 0.01$).
Source: authors.

Concerning the quantification of macrominerals and microminerals, it was observed that in 100 grams of mutamba, at both maturation stages, P and Ca can supply 1/3 of the Reference Daily Intake (RDI) for adults, while Mg supplies half of it. P and Mg act by regulating enzymatic systems; P, Ca and Mg may have a synergistic function or act individually in the formation of bones and teeth, as well as in the process of muscle contraction (Melo et al., 2020). P alone is responsible for the absorption of glucose and the metabolism of proteins, fats and carbohydrates. In the FIPM, the amount of Mn present is higher than the RDI, while Fe presents half of its value. As for the FFPM, an inverse relationship is observed (Table 5) (Brasil, 2005). Both Fe and Mn have important

participations in the proper functioning of enzymes, especially those which act as antioxidants, retarding cellular oxidation. Fe alone acts by forming hemoglobin, and Mn acts in energy production processes.

Table 5 - Mineral composition of mutamba fruits with incomplete physiological maturation and full physiological maturation, collected in Limoeiro do Norte, Ceará.

Mutamba*	Macrominerals (g.100 g^{-1})						Microminerals (mg.100 g^{-1})					
	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B	Na
FIPM	16.9	2.5	18.0	3.8	1.6	1.2	6.9	1.4	1.0	2.5	1.1	20.0
FFPM	14.0	2.3	20.6	3.4	1.3	1.1	14.1	0.9	0.5	1.6	1.0	20.6

*FIPM: incomplete physiological maturation. FFPM: full physiological maturation. Results obtained from the average of 4 replicates of 50 fruits.
Source: authors.

According to the Brazilian resolution which regulates complementary nutritional information (Brasil, 2012), mutambas FIPM and FFPM can be classified as fruits with high content of P, Ca, Mg, Fe and Mn.

4. Conclusions

The food industry currently seeks innovative and sustainable products. This study characterizes for the first time mutamba fruits with incomplete physiological maturation and shows that regardless the maturity stage, mutamba fruits are an excellent source of vitamin C, besides their soluble solids, fibers, proteins and essential minerals (P, Ca, Mg, Fe and Mn) content, being promising for the enrichment of food products.

The high soluble solids content in the mutamba fruit with full physiological maturation indicates that it has potential for exploitation in the food industry with respect to fermented products.

Toxicological and anti-nutrients tests are suggested to be carried out on mutamba fruit with incomplete physiological maturation before their application in human food.

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