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Physicochemical quality of Murici covered with starch-based coverings and stored at different temperatures

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The aim of this work was to evaluate the physicochemical characteristics of murici (*Byrsonima crassifolia* (L.) Rich.) covered with starch-based coverings and stored at different temperatures. The fruits were harvested on EMBRAPA experimental farm, in the city of Pacajus-Ceará, where they were taken to the lab, washed, sanitized and naturally dried. Afterwards, they were treated with coverings made out of different concentrations of manioc starch solution and conditioned at 12 and 25°C. We carried out assessments on: pH, titratable acidity, soluble solids, ratio, ascorbic acid, average weight, color, humidity and water activity. The murici fruits were able to maintain their physical and chemical properties for ten days of storage at a temperature of 12°C. Out of the different concentrations of manioc starch-based coverings, the fruits treated with 4% solutions kept their good quality for commercialization.

Key words: Murici fruits, temperatures, starch.

INTRODUCTION

Brazil is one of the largest citrus producers in the world, producing more than 128,000 tons a year (FAO, 2012). Citrus fruits are consumed all year long, *in natura*, or in the form of processed juice, compote and jelly (Rodrigo et al., 2013); however, they are perishable products and tend to postharvest degradation and reduced quality due to their physical aspects, such as loss of mass, and their chemical characteristics, like vitamin C (Mannheim and Soffer, 1996). The quality of citrus fruits is extremely important for marketing reasons, either for *in natura* consumption or industrial processing. The quality characteristics refer to citrus aspect, taste, smell, texture, and nutritive value. Recently, due to people's increasing concern about human health and environmental Brazil is the third largest fruit producer in the world, following India and China. In 2008, Brazil produced more than 43 million

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tons of fruits (4.5% more than the previous year), and this growth is a milestone in Brazilian agribusiness. By the end of 2013, the state of Ceará alone produced 1,650 thousand tons of fruit, according to data from IBGE (2013).

Tropical fruits are mainly produced in semi-arid regions. By stimulating this industry in these historically fragile areas, local economies can be developed, jobs created and manpower enhanced, in addition to improving the income in local communities (Quintino et al., 2010).

Murici (*Byrsonima crassifolia* (L.) Rich.) is one of the most important fruit in these areas, being native to Cerrado. These berries are found from December through March in the mountainous areas of the southeastern region of Brazil, in cerrados in Mato Grosso and Goiás and on the coast of North and Northeast Brazil, where they are consumed in many ways, such as: canned goods, candies, ice creams, snacks, juices and liqueurs (Avidos, 2000). It is estimated that 250,000 plant species have been described worldwide and Brazil contains approximately 55,000 – 60,000 species, being considered the richest biodiversity in the world (22%) (Aragão et al., 2002). However, not all species are consumable or domesticated.

Murici fruits are spherical or pyriform (1 to 2 cm in diameter) and are extremely appreciated by local populations because of their typical characteristics, such as their slight cheese-like scent. Furthermore, other parts of the plant (leaves, seeds and fruits) can be used as medicinal products for gastrointestinal affections, gynecological inflammations, skin infections and snakebites (Mariutti et al., 2013; Ferreira, 2005). They are rich in phenolic compounds, carotenoids and other bioactive agents, and studying them may open fields for the discovery of new products that may interest the population and contribute with the producing region (Mariutti et al., 2014). Nevertheless, there are few studies on this fruit; therefore, knowledge on its physicochemical, chemical and biological properties is scarce.

During storage, fruits are susceptible to a series of chemical, physical and biochemical alterations, which decrease their quality, lead to their senescence and change their characteristics, causing them to be unsuitable for consumption. Regarding conservation, refrigeration is one of the most used methods for long-term storage of fresh fruits, in addition to the application of coverings and other postharvest techniques (Vasconcelos and Melo filho, 2010). Thus, the aim of this study was to assess the postharvest characteristics of murici fruits (*B. crassifolia* (L.) Rich.) stored at different temperatures and covered with manioc starch-based covering solutions at different concentrations.

MATERIALS AND METHODS

Sample preparation

The ripe fruits (yellow) used in this study were collected from seven Murici trees on the Empresa Brasileira de Pesquisas Agropecuárias (EMBRAPA) experimental farm in the city of Pacajus, Ceará, Brazil, in early 2013, and taken to the Laboratory of Food Quality Control and Drying from the Department of Food Technology in the Federal University of Ceará, where they were selected, washed and sanitized with a solution of sodium hypochlorite at 1%.

Covering application

The fruits were divided into the following four groups: (1) control, only washed and sanitized fruits; (2) Manioc starch at 2%; (3) Manioc starch at 4% and (4) Manioc starch at 6%. All concetrations of the soluctions were for suspension manioc starch in destilled water and heating to 70°C under constant stirring and after left to reach until 25°C. We immersed the fruits into the respective treatments for two minutes; then they were removed and placed on nylon sieves (ø 21 cm) to dry for 4 h at room temperature. Afterwards, 40 fruits from each treatment were placed on polyethylene trays, wrapped in PVC film (density 20 mm) and stored at different temperatures (12 and 25°C).

Sample storage

The fruits were divided into two groups: the first one was stored at room temperature (25 ± 2°C) and controlled relative humidity (46 ± 5%), whereas the second group was stored under refrigeration in B.O.D. TE-390 (Tecnal, Brazil), at 12 ± 2°C, and controlled relative humidity (85 ± 5%). We stored the fruits for a period of 10 days, during which we carried out physicochemical analyses every two days.

pH

A potentiometry was used to determine pH and the results were read directly in a pHmeter “Hanna Instruments”, model HI221. This methodology was in accordance with Method No. 981.12 by (AOAC, 1997).

Titratable acidity (TA)

This determination was quantified by titration with NaOH 0.1 M standardized, the pH of the solution was monitored by potentiometer to the pH ranger (8.2 - 8.4). 5 g of pulp of Murici fruit was diluted with destilled water and homogenized for titration. The results are expressed as % of citric acid, according to methodology from (Brasil, 2005).

Soluble solids (SS)

This determination was carried out with concentrated juice, the aid of a digital refractometer (Pocket) PAL – 1, brand ATAGO. The results were expressed as ˚Brix, according to method No. 932.12 – (AOAC, 1997).

Ratio (SS/TA)

Ratio was calculated by the method described by Brasil (2005), which demonstrates the relation between SS and TA.

Ascorbic acid

The Tilmans methods was used to determine ascorbic acid content.

Table 1. Average pH values for Muricis (*B. crassifolia*) (L.) Rich.) treated with different coverings and temperatures during storage.

Time (Days)	pH (12°C)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	3.58^{aA}	3.58^{aA}	3.58^{aA}	3.58^{aA}
2	3.45^{bA}	3.56^{aA}	3.43^{aA}	3.47^{aA}
4	3.39^{bA}	3.45^{aA}	3.54^{aA}	3.56^{aA}
6	3.48^{aA}	3.77^{aA}	3.78^{aA}	3.52^{aA}
8	3.43^{bA}	3.56^{aA}	3.47^{aA}	3.51^{aA}
10	3.35^{bA}	3.52^{aA}	3.45^{aA}	3.50^{aA}
CV(%)		3.7		

Time (Days)	pH (25°C)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	3.59^{aA}	3.58^{aA}	3.58^{aA}	3.58^{aA}
2	3.47^{bA}	3.30^{cC}	3.27^{cC}	3.60^{aB}
4	3.41^{cB}	3.42^{bB}	3.19^{dC}	3.47^{bA}
6	3.29^{dB}	3.30^{cB}	3.33^{bB}	3.47^{bA}
8	..	..	..	..
10	..	..	..	..
CV(%)		2.10		

Different lowercase letters in the same column have significant differences between them by Tukey test (p<0.05). Different uppercase letters in the same line and in the same temperature have significant differences between them by Tukey test (p<0.05). cv (%) = Coefficient of variation .(..) Treatments discarded due to rotten fruits.

5 g of pulp of Murici fruit was diluted with oxalic acid, homogenized and titration with 2,6-diclorophenolindophenol until turning point that indicates the degradation os ascorbic acid. The results were expressed as mg/100 g of pulp (Brasil, 2005).

Average weight

Every two days, until the end of the storage period, the fruits were weighed in a semi-analytic scale brand Labstore model PK 200. The results were calculated for weight difference and expressed as grams (g) according to the methodology described by Citadin et al. (2005).

Color determination

The color of murici fruits was determined by colorimeter model CR – 10, brand Konica Minolta and recorded as *L, *C and *H color system, where *L consists of luminance or lightness component; *C defines the chromaticity or chroma, where values range from 0 (neutral colors) to 60 (intense colors) and *H represents hue angle from 0 to 360° (0°: red; 90°: yellow; 180°: green and 270°: blue). The analysis was made according to Vaillant et al. (2005).

Moisture

We assessed humidity by using a hot house (brand Marconi, model MA 035) with forced hot air circulation, under conditions of controlled temperature (60 to 70°C). The samples were weighed several times until they reached constant weight (AOAC, 1997).

Water activity (aw)

The sample was homogenized and analyzed in Aqualab (model CX-2, Decagon. Inc.) was used to analyze water activity, which was expressed by the ratio between the sample's water steam pressure and pressure of water steam, duly calibrated, according to Harris (1995).

Statistical analysis

All analyses were carried out in triplicates and reported as average ± standard deviation. Then, they were submitted to analysis of variance (ANOVA) and, in order to compare the averages, we used Tukey test at the level of 5% of probability, using the statistical software SISVAR (Ferreira, 2008). The plots were generated with Software Origin 5.0.

RESULTS AND DISCUSSION

pH

The average results for murici (*B. crassifolia* (L.) Rich.) fruits were significantly different, measured from 3.19 and 3.77 (Table 1). It is observed decreased of pH values, indicating increased organic acid and the treatments were not influenced during storage. Canuto et al. (2010), while studying several Amazonian fruits, obtained a pH average of 3.70, for Murici pulps, while Guimarães and

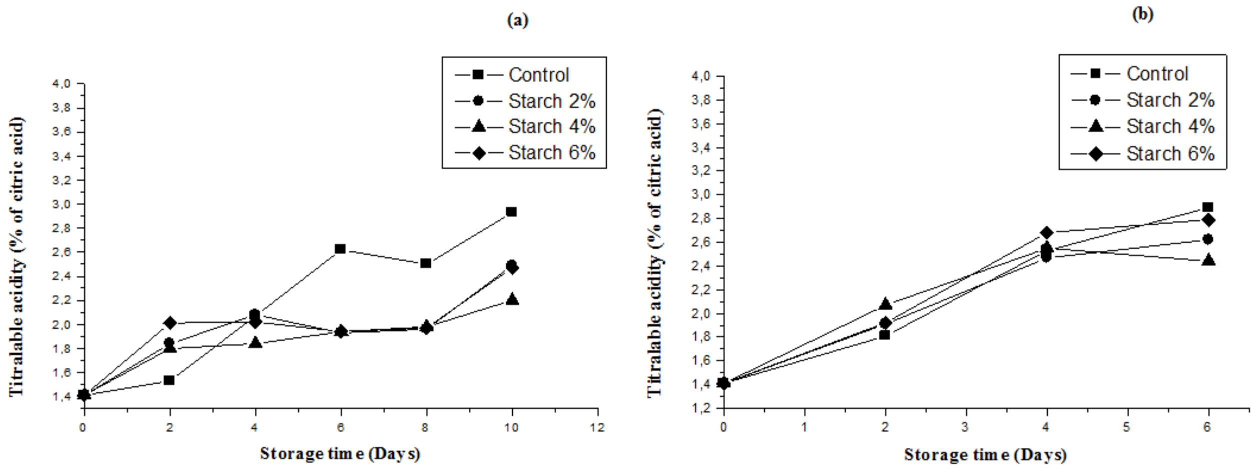

Figure 1. Average values of titratable acidity (% of citric acid) in Murici fruits submitted to different coverings and temperatures of (a) 12°C and (b) 25°C during storage.

Silva (2008), with fresh and dehydrated Murici fruits, var. *Byrsonima verbascifolia,* found numbers that remained below 4.50.

Titratable acidity (TA)

The stored fruits showed values between 1.41 to 2.93% of citric acid, and during storage, there was an increase, regardless of the treatment, as it can be observed in Figure 1. The increase in concentration of organic acids in fruit content can explain such situation, since it points out that the respiratory process consumed other compounds. Belisário and Coneglian (2013) found values of 1.68% of citric acid for Murici fruits stored at 12°C and 1.47% for fruits stored at 25°C. The author also observed a decrease in acidity on the eighth day of storage in both temperatures. These results were similar to the ones found in the study.

Soluble solids (SS)

The average values for soluble solids of Muricis fruits in both treatments remained between 9.67 and 22.00 °Brix (Table 2). The coverings and temperatures applied did not influence the averages during storage, when compared to the control treatment, which showed non-uniform values. At the end of storage, at both temperatures, some treatments tended to a slight decrease in averages of SS, which can be explained by the consumption of sugars in fruit respiration (Souza et al., 2008). The content of soluble solids is an important quality factor for flavor, and the average content superior to 9% is quite desirable from the commercial point of view. Thus, the results obtained in this experiment prove that Murici fruits are great for commercialization and industrialization (Menezes et al., 2001).

Ratio (SS/TA)

This relation is one of the most used forms to evaluate flavor, since it is more representative than the isolated measure of sugars or acidity. Moreover, it shows the balance between those two components and indicates sweetness in foods (Chitarra and Chitarra, 2005). In our results (Table 3), the values varied between 4.64 and 11.13, at 12°C, and 5.62 and 9.80, at 25°C. The Murici fruits decreased quality at the end of the storage. Their averages were 5.72 and 8.10, respectively.

Ascorbic acid

The values of ascorbic acid decreased from 128.00 mg/100 g and 20.24 mg/100 g during the storage days (Figure 2). There was no significant difference between the various concentrations of covering. We still need to consider that the temperature was the determining factor for the results, since the temperature of 12°C retarded the degradation of ascorbic acid. Ascorbic acid content in Murici fruits is equivalent to *Anacardium occidentale* L., which has around 119.70 mg/100 g, and *Psidium guajava* L. fruits, with 99.20 mg/100 g (TACO, 2011).

Average weight (g)

During the days of storage, the average values decreased from 2.60 to 1.83 g (Figure 3). The control treatment showed the highest loss, at both temperatures, whereas the treatments with starch, regardless of concentration, did not lose as much weight, which influenced

Table 2. Average values of soluble solids in Muricis (*Byrsonima crassifolia*) (L.) Rich.) treated with different coverings and temperatures during storage.

Time (Days)	Soluble solids (12 ºC)			
	Control	**Starch 2%**	**Starch 4%**	**Starch 6%**
0	13.67^{cA}	13.67^{cA}	13.67^{cA}	13.67^{dA}
2	9.67^{dC}	19.00^{aB}	17.00^{abB}	22.33^{aA}
4	16.33^{cB}	19.00^{aA}	19.00^{aA}	17.33^{bcAB}
6	19.33^{aA}	16.33^{bB}	15.67^{bcB}	16.33^{cB}
8	17.67^{abAB}	16.33^{bB}	17.00^{abAB}	18.67^{cA}
10	13.67^{cB}	17.67^{abA}	17.67^{abA}	19.00^{bA}
CV(%)	6.38			

Time (Days)	Soluble solids (25 ºC)			
	Control	**Starch 2%**	**Starch 4%**	**Starch 6%**
0	13.67^{bA}	13.67^{cA}	13.67^{cA}	13.67^{cA}
2	11.00^{cC}	18.67^{bA}	16.00^{bB}	16.00^{bB}
4	21.33^{aA}	20.33^{abA}	21.00^{aA}	21.00^{cA}
6	20.00^{aB}	22.00^{aA}	15.67^{bC}	15.67^{bC}
8	..	..	..	..
10	..	..	..	..
CV(%)	4.98			

Different lowercase letters in the same column have significant differences between them by Tukey test ($p<0.05$). Different uppercase letters in the same line and in the same temperature have significant differences between them by Tukey test ($p<0.05$). cv (%) = Coefficient of variation (..) Treatments discarded due to rotten fruits.

the final results. The results published by Damiani et al. (2008), while studying fruits of *Caryocar brasiliense*, Camb., demonstrated that the higher the temperature, the larger the weight loss, Nevertheless, the same result was not observed in this study, given the fact that there were no significant differences. Fruit mass loss during storage occurs mainly because of two factors: transpiration and respiration. Transpiration is the major cause of mass loss because it is the mechanism by which water is lost due to differences of water steam pressure between the atmosphere and the fruit surface. Respiration also causes mass reduction because the fruit loses carbon atoms whenever a molecule of CO_2 is released to the atmosphere, thus altering fruit quality (Browmk and Pan, 1992; Castricini et al., 2010).

Color

Color indicates whether or not the fruit suffered many alterations during the days of storage. Canuto et al. (2010) evaluated pulp color in different Amazonian fruits, and nances had an average for L* (Lightness) of 45.8 (Figure 4), which are similar values to the ones presented in this study. As for *Spondias mombin* L., a fruit that presents a yellow coloration similar to Murici's, they found average values of 47.9. Chroma (C*) (Figure 4S) stands for color intensity, and Muricis had a vivid and intense color on the first days of storage; the averages varied between 40.65 and 58.78 for fruits stored at 12°C, and from 40.72 to 56.28 for fruits stored at 25°C. On the last days of storage, these values were lower at both temperatures. °Hue is a parameter that represents degree of coloration, going on a scale from 0° to 360°. The results we found for the fruits stored at both temperatures dropped during storage, ranging from 94.00 to 80.00 (yellow), and there were no significant differences between the applied coverings (Figure 4). According to Silva (2000) fruit color must remain attractive with the application of different conservation methods; otherwise consumers will neither taste nor consume the food. We finished our experiment when more than 50% of the fruits had wilted or damaged.

Moisture

In all treatments, the averages range between 82.48 and 84.81%, which are values that were significantly different (Table 4), but apparently were not influenced by the treatments. We can observe that fresh fruits have high moisture content and some values similar to these were found for *Persea americana* Mill. (84%) and *Malus domestica* (82%) (TACO, 2011). Moisture content in a given food is related to its stability, quality and composition, which are factors that must be taken into

Table 3. Average values of Ratio in Muricis treated with different coverings and temperatures during storage in days.

Time (Days)	*Ratio* (12 ºC)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	9.72^{aA}	9.72^{aA}	9.71^{abA}	9.71^{abA}
2	6.33^{bcB}	10.45^{aA}	7.74^{bB}	11.13^{aA}
4	8.13^{abB}	9.26^{abAB}	10.38^{aA}	8.59^{bAB}
6	7.44^{abB}	8.49^{abAB}	9.59^{abA}	9.54^{abA}
8	7.14^{bB}	8.36^{abAB}	9.72^{abA}	9.57^{abA}
10	4.64^{cB}	7.12^{bA}	8.04^{aA}	7.70^{bA}
CV(%)	11.1			

Time (Days)	*Ratio* (25 ºC)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	9.72^{aA}	9.72^{aA}	9.71^{aA}	9.71^{aA}
2	6.08^{cC}	9.80^{aA}	7.75^{bB}	8.33^{bB}
4	8.44^{bA}	8.26^{bA}	6.91^{bcB}	7.82^{bAB}
6	6.94^{cB}	8.41^{bA}	6.49^{cBC}	5.62^{cC}
8	..	..	..	..
10	..	..	..	..
CV(%)	6.48			

Different lowercase letters in the same column have significant differences between them by Tukey test ($p<0.05$). Different uppercase letters in the same line and in the same temperature have significant differences between them by Tukey test ($p<0.05$). cv (%) = Coefficient of variation (..) Treatments discarded due to rotten fruits.

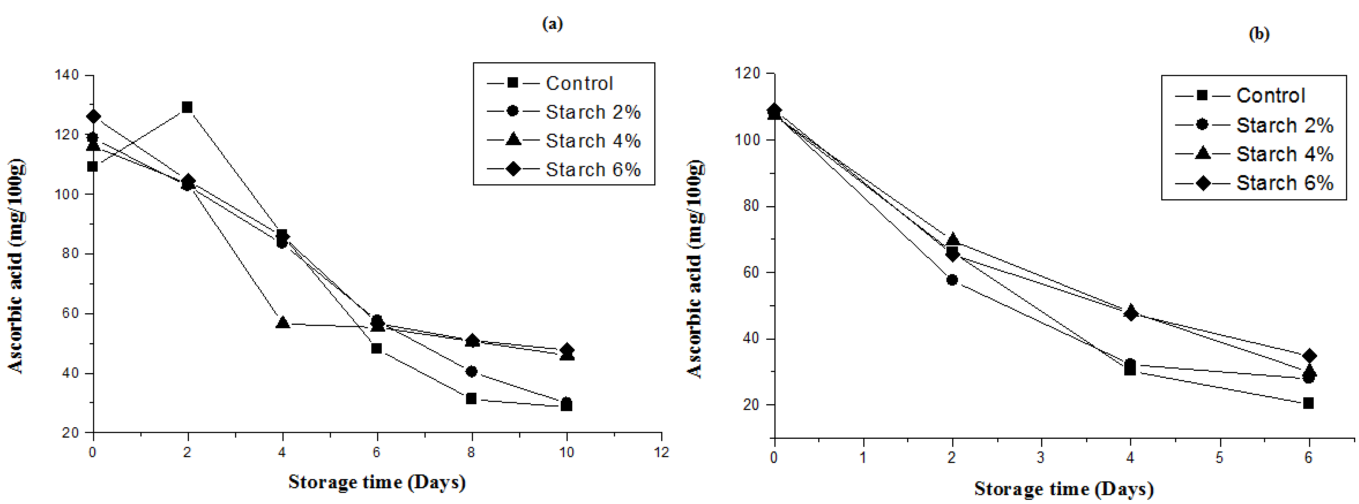

Figure 2. Average values of ascorbic acid (mg/100 g) in Murici fruits submitted to different coverings and temperatures of (a) 12°C and (b) 25°C during storage.

consideration while choosing methods to conserve them.

Water activity (aw)

The water activity predicting the stability and safety of Murici. This parameter has interaction to the chemical, physical and biological characteristics of fruits than moisture content, thus have an effect on reactions and microorganisms proliferations. There were no significant differences among the fruits, which can be characterized as foods with high free water content (aw > 0.9). The average values in both treatments and storages remained unaltered, ranging between 0.96 and 0.97

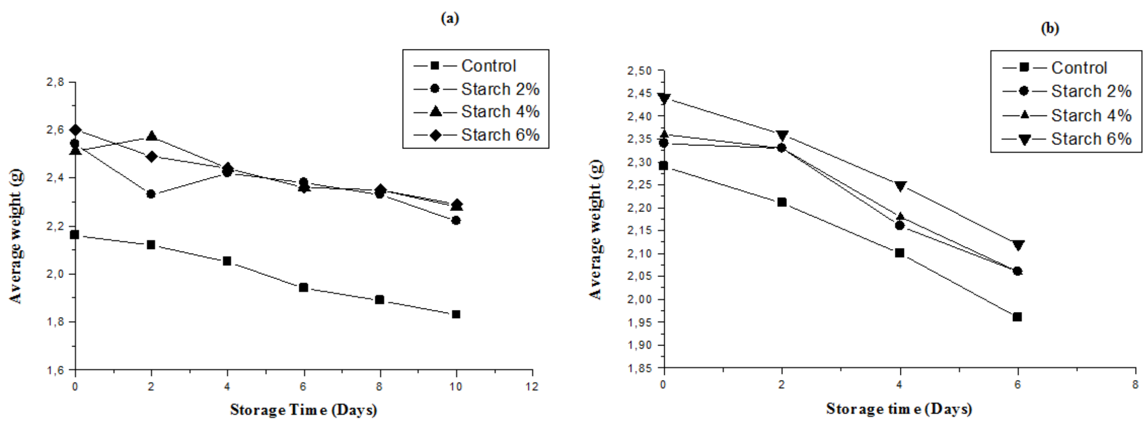

Figure 3. Average values of weight (g) for murici fruits submitted to different coverings and temperatures of (a) 12°C and (b) 25°C during storage.

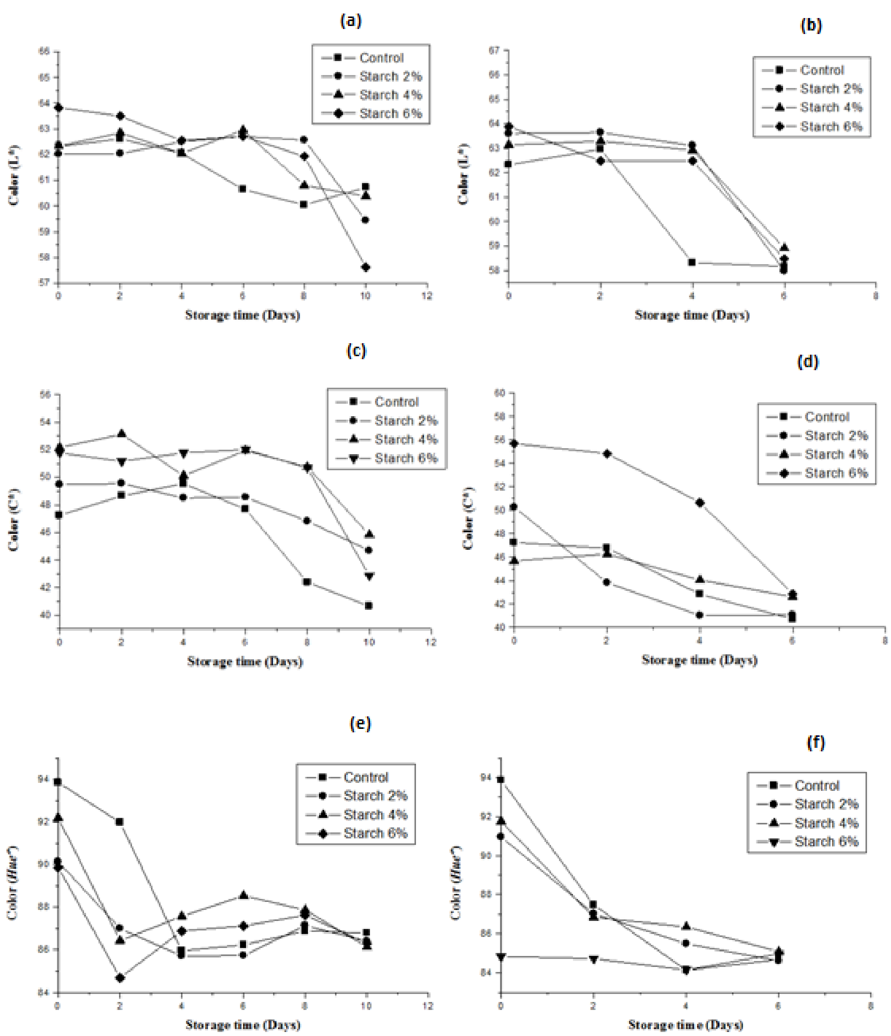

Figure 4. Average values of color (L*) for murici fruits submitted to different coverings and temperatures of (a) 12°C and (b) 25°C during storage. Average values of color (C*) for murici fruits submitted to different coverings and temperatures of (c) 12°C and (d) 25°C during storage. Average values of color (*Hue°*) for murici fruits submitted to different coverings and temperatures of (e) 12°C and (f) 25°C during storage.

Table 4. Average moisture values (%) of Muricis fruits (*Byrsonima crassifolia*) (L.) Rich.) treated with different coverings and temperatures during storage.

Time (Days)	Moisture (12 ºC)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	83.48abA	83.46abA	83.48aA	83.48abA
2	83.50abA	84.81bA	83.85aA	83.99abA
4	82.74aA	83.81abAB	84.21aB	84.42bB
6	84.14abB	82.71aA	83.93aAB	84.41bB
8	84.51bA	83.45abA	83.92aA	84.44bA
10	83.00abAB	84.06abB	84.31aB	82.69aA
CV(%)¹	3.89			

Time (Days)	Moisture (25 ºC)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	83.48aA	82.71aA	83.48aA	83.48aA
2	83.42aA	82.74aA	83.94aA	83.74aA
4	84.04aA	83.97aA	83.14aA	83.50aA
6	84.51aB	84.49aB	84.37aB	82.48aA
8	..	..	..	..
10	..	..	..	..
CV(%)¹	4.6			

Different lowercase letters in the same column have significant differences between them by Tukey test (p<0.05). Different uppercase letters in the same line and in the same temperature have significant differences between them by Tukey test (p<0.05). cv (%) = Coefficient of variation .(..) Treatments discarded due to rotten fruits.

Table 5. Average values of water activity (aw) in fruits of Muricizeiro (*Byrsonima crassifolia*) (L.) Rich.) treated with different coverings and temperatures during storage (n = 3).

Time (Days)	Aw (12°C)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	0.97abA	0.97abA	0.97abA	0.97abA
2	0.97abA	0.97aA	0.97aA	0.97aA
4	0.96abA	0.97abA	0.97aA	0.97aA
6	0.97abA	0.96abA	0.96bA	0.96bA
8	0.96bB	0.97abAB	0.97aA	0.96bB
10	0.97aA	0.96bB	0.97abAB	0.96bB
CV(%)	0.35			

Time (Days)	Aw (25°C)			
	Control	Starch 2%	Starch 4%	Starch 6%
0	0.97aA	0.97aA	0.97abA	0.97aA
2	0.96aA	0.96aA	0.97aA	0.96aA
4	0.96aB	0.97aAB	0.96bcB	0.97aA
6	0.96aB	0.97aA	0.96cB	0.97aA
8	..	..	..	..
10	..	..	..	..
CV(%)	0.41			

Different lowercase letters in the same column have significant differences between them by Tukey test (p<0.05). Different uppercase letters in the same line and in the same temperature have significant differences between them by Tukey test (p<0.05). cv (%) = Coefficient of variation .(..) Treatments discarded due to rotten fruits.

(Table 5). Similar results were observed by Guimarães et al. (2008), while studying Murici (0.98).

Conclusion

The physical and chemical properties of Muricis (*B. crassifolia*) (L.) Rich.) not showed interaction between treatments during storage of the evaluation time (10 days) at a temperature of 12°C. For the temperature 25°C, the same showed lower shelf life. Out of the concentrations of covering solutions applied to the fruits, those with manioc starch at 4% maintained the best quality during the period under analysis.

Conflict of Interests

The authors have not declared any conflict of interests.

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