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# Refrigerated storage of the fruits of buriti (*Mauritia flexuosa* L.)

**E. Fujita[*], R.L. Vieites[*], É.R. Daiuto[*], R.E. Smith[**(1)]**

* *UNESP Botucatu, Faculty of Agronomic Sciences, UNESP, C.P. 237, Botucatu 18610307, SP, Brasil.*

** *FDA, 11510 W 80th Street, Lenexa, KS 66224, Kansas, USA.*

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**Abstract: The objective of this study was to evaluate different storage conditions to maximize the shelf-life of buriti fruits; under ambient conditions the fruits last only 2-3 days. Buriti fruits were stored refrigerated at 10, 12 and 15°C with 85±5% relative humidity, and at room temperature (23±5°C) and 60±5% relative humidity. Fruits were analyzed every three days over a 12-day period for weight loss, respiratory activity, soluble solids, pH, titratable acidity, lipids, protein and fiber. Under the considered conditions, refrigeration at 15°C was found to give the best results.**

## 1. Introduction

Buriti (*Mauritia flexuosa* L.) is a palm tree found from the Atlantic forest to the cerrado (a vast tropical savanna ecoregion) of the Brazilian north, northeast and mid-west in the state of Minas Gerais (Manzi and Coomes, 2009). It also extends to the state of Mato Grosso, as well as Bolivia, Colombia, Ecuador and Peru. There is debate between Brazilian and Peruvian scientists about its origin (Cavalcante, 1991).

Female buriti palm trees produce four to eight infructescences, and each raceme bears 500-2000 fruits (Goulding and Smith, 2007). The fruit is a reddish-brown drupe, with a thin oily yellow-orange pulp that surrounds a relatively large seed (Manzi and Coomes, 2009). The oil contains tocopherols (de França *et al*., 1999; Albuquerque *et al*., 2005), carotenoids (Mariath *et al*., 1989; Silva *et al*., 2009) and pro-vitamin A (Mariath *et al*., 1989; Klemm *et al*., 2008). Moreover, candy made from buriti is an effective treatment of xerophthalmia in children in northeastern Brazil, but the fruit used to make it is not easily preserved. It is good for no more than two to three days under ambient conditions.

The buriti fruit has a hard, red shell that covers an oily pulp that contains carotenoids and ascorbic acid (EMBRAPA, 2007; Silva *et al.*, 2007). The local population collects the fruits when they are released from the mother plant and most of the fruits on the ground are near the desired state of maturity. A 55-kg bunch produces 40 kg of fruits. The local population collects the fruits that they are going to use from the ground.

(1) Corresponding author: Robert.Smith@fda.hhs.gov

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Buriti and products made from it are widespread in the Brazilian cerrado. The fruit pulp is used to make a flour for a porridge that helps meet the nutritional requirements of the locals (Almeida and Silva, 1994). The fruit is also a source of vegetable oil, as described by Albuquerque *et al.* (2003). These authors obtained an IR spectrum of the oil that revealed the presence of triolein, the triglyceride of oleic acid, which could be used to control cholesterol in the blood. The oil has been reported to have a relatively high concentration of so-called monounsaturated fatty acids (de França *et al*., 1999), although it really contains fatty acyls that are a part of mono-, di- and triglycerides. That is, the oil had to be hydrolyzed to break down the mono-, di- and triglycerides, forming glycerol plus non-volatile free fatty acids, which are then converted to volatile fatty acid methyl esters and analyzed by gas chromatography (de França *et al*., 1999; AOAC, 2003). In order for the fruits to be used, they must be preserved properly. This is discussed in the next paragraph.

Usually the fruits are collected in a form that is not easily preserved. The palm trees are cut to facilitate the removal of the fruits, drastically reducing the population of buriti trees in the Amazonian region of Peru. This forces the harvesters to travel long distances to gather a significant quantity. The management of buriti via extractavism is small compared to the demands of the regional market (Manzi and Coomes, 2009; Horn *et al*., 2012). Extractavism refers to natural tropical forest areas that are reserved for the extraction of potentially renewable commercial forest products. So, better storage methods are needed to meet the needs of the market and provide social benefits, which are described next.

Buriti offers social benefits to the local population as a source of wealth and employment in the manufacture of products such as licorice, wine, candy, juice and sorbets.

However, these activities have not been given the technical or scientific support needed to make them sustainable and more profitable. While an adequate storage method has not yet been well defined, it is known that the fruit must be scraped off the seeds and dehydrated at room temperature, followed by refrigeration for an undetermined period of time (Almeida and Silva, 1994).

Therefore, the objective of this study was to evaluate different storage conditions for buriti fruits in order to find the best way to maximize shelf-life with attention to the post-harvest behavior of the fruits so as to maintain their quality.

## 2. Materials and Methods

The fruits used in the study were from the ecological preserve in Jalapão, near the city of Dianópolis in the state of Tocantins at 11°37'40" south latitude and 46°49'14" west longitude at an altitude of 691 m above sea level, where the trees grow in sandy soil. The fruits were picked from the trees when they were 3-4 cm in diameter and dark yellow to brown. The trees were not cut. Due to the height of the tree (10 m), a scaffolding was erected so that the bunches of fruit could be removed with the utmost caution, to prevent damage caused by falling. The bunches were placed in a ventilated polystyrene box to maintain a temperature of 16°C.

After collection, the fruits were sent to the Laboratório de Frutas e Hortaliças do Departamento de Gestão e Tecnologia Agroindustrial da Faculdade de Ciências Agronômicas – UNESP, Botucatu, São Paulo, where they arrived after two days. They were separated randomly into four lots, each containing ten fruits. Three were stored under refrigeration at 10, 12 and 15°C and 85±5% relative humidity. The fourth lot (control) was stored under ambient conditions (23±5°C and 60±5% relative humidity). The following analyses were carried out on ten fruits for each storage condition: weight loss, respiratory activity, soluble solids, titratable acidity, and pH. Analyses were carried out for fruits that were viable for commercialization.

Respiratory activity was determined by the release of $CO_2$ in each package according to the method of Bleinroth *et al.* (1976), using a saturated solution of barium hydroxide and 0.1 N KOH (0.1 Normal KOH, which is the same as 1 mol/L KOH) and using the formula:

$$TCO_2 = \frac{2.2\ (Vo - V_1)\ 10}{m\ t}$$

where:

$TCO_2$ is the rate of respiration (mL of $CO_2$ $Kg^{-1}h^{-1}$);

Vo = mL of HCl needed to titrate the KOH as a standard before the absorption of $CO_2$;

$V_1$ = mL of HCl needed to titrate the KOH after the absorption of $CO_2$;

m = mass of the fruits;

t = respiration time;

2.2 = equivalent weight of $CO_2$ (44/2), multiplied by the concentration of HCl;

10 = adjustment for the total amount of KOH used.

Soluble solids, pH and titratable acidity were determined by the method of the Instituto Adolf Lutz (IAL, 2008). Soluble solids were measured with a digital Palette PR - 32 refractometer (ATAGO Inc., Bellevue, WA), equipped with automatic temperature compensation. Results were expressed directly in °Brix. The pH was measured with a pH meter and titratable acidity was measured by titrating the acidic fruits with 0.1 mol/L NaOH. The amount of total sugars, lipids, proteins and fibers were determined using the method of Somogyi (1945) and Nelson (1944) by reacting samples with the Somogyi reagent and measuring the absorbance at 535 nm using a Micronal B382 spectrophotometer (Micronal, São Paulo, SP, Brazil). In detail, samples were diluted sufficiently so that an absorbance between 0.2 and 0.8 was produced after reacting 1 mL of neutralized and filtered sample with 1 mL of Somogyi reagent. After putting the samples in a boiling water bath for 10 min, they were cooled to room temperature. Then, 1 mL of the Nelson reagent and 7 mL of water were added. Finally, the absorbance at 535 nm was read. The Somogyi reagent is an arsenomolybdate complex formed by the reaction of ammonium molybdate with sodium arsenate. The Nelson reagent was made of two parts: Part A contained 2.5 g each of $Na_2CO_3$ and potassium sodium tartrate, 2 g each of $NaHCO_3$ and $Na_2SO_4$ in 100 mL water. Part B contained 7.5 g $CuSO_4 \cdot 5H_2O$ per 100 mL water, acidified with a drop of conc $H_2SO_4$. Glucose was used to construct a calibration curve.

Total lipids were determined by performing a 2-h Soxhlet extraction on 3 g of sample using 200 mL of petroleum ether, evaporating off the solvent and weighing the residue. Protein was determined on 0.1 to 0.2 g of sample using the Kjeldahl method using a conversion factor of 6.5 to convert percent nitrogen to percent protein.

The experimental data were analyzed as a 4x5 matrix (temperature x time) by the SISVAR 4.6 program. Averages were evaluated by the Tukey test at 5% probability (Gomes, 1987).

## 3. Results and Discussion

Beginning on the third day of storage, a weight loss of >10% was found in all storage conditions. The fruits stored at 10 and 23°C had the greatest loss of mass after 12 days. The lowest loss was at 15°C (Table 1). All weight losses were calculated by comparing weights to day zero. Ten fruits were analyzed in each experiment. According to Finger and Vieira (2002) the weight loss of most fresh fruits should be 5-10% to avoid withering or wrinkling. Thus, buriti fruits examined suffered a weight loss that reduced their commercial value.

Buriti fruits demonstrated respiratory behavior that is characteristic of climacteric fruits, as shown in Table 2. According to Chitarra and Chitarra (2005) they are characterized by a rapid increase in respiration and ethylene production during ripening.

The apparent peak at day three of storage was probably due to an adaptation of the fruits to the storage conditions. The fruits that were kept at ambient temperature had their peak respiration on the sixth day of storage, while the fruits stored under other conditions had their peak respiration on the ninth day of storage. The lowest respiratory activity (lowest production of $CO_2$) was found in fruits stored at 10ºC, i.e. with the lowest production of $CO_2$. Therefore, a temperature of 15ºC proved to be the most effective for storing the fruits as it resulted in the lowest loss of weight and the latest peak in respiratory activity.

The amounts of soluble solids, pH and titratable acidity are shown in Table 3.

Table 1 - Weights of buriti when stored refrigerated

| Temperature | Initial Wt. (g) | 3 days (g) | 6 days (g) | 9 days (g) | 12 days (g) |
|---|---|---|---|---|---|
| 10°C | 263.03±7.81 a | 238.43±5.74 a | 214.50±6.78 a | 197.95±3.98 a | 191.60±2.45 b |
| 12°C | 256.32±6.82 a | 237.31±4.81 a | 222.10 ±4.91 c | 212.56±4.89 c | 208.59± 3.99 c |
| 15°C | 261.23±5.73 a | 245.60±5.97 b | 233.65±5.60 d | 226.13±6.71 d | 223.12± 4.58 d |
| Ambient | 274.75±6.99 b | 251.80±6.52 c | 229.53±4.57 b | 207.65± 5.86 b | 194.47±4.98 a |

Averages followed by the same lower case letter do not differ significantly from others in the same column and those followed by the same upper case letter do not differ significantly from others in the same row by the Tukey test at 5% probability.

Table 2 - Respiratory activity in buriti fruits stored under refrigeration and 80 ± 5% relative humidity for 12 days

| Temperature | Respiratory Activity | | | | |
|---|---|---|---|---|---|
| | Days of storage | | | | |
| | 0 | 3 | 6 | 9 | 12 |
| 10°C | 24.5±0.64 | 35.1±1.90 | 18.5±0.99 | 35.5±0.42 | 13.8±0.64 |
| 12°C | 24.5±0.64 | 12.1±0.14 | 17.3±0.42 | 58.6±2.62 | 44.2±3.11 |
| 15°C | 24.5±0.64 | 31.4±0.35 | 17.9±0.78 | 70.9±0.28 | 36.8±0.64 |
| Ambient | 24.5±0.64 | 54.2±0.28 | 55.6±0.07 | 50.8±0.35 | - |

Averages followed by the same lower case letter do not differ significantly from others in the same column and those followed by the same upper case letter do not differ significantly from others in the same row by the Tukey test at 5% probability.

Table 3 - Soluble solids (°Brix), pH and titratable acidity (g of acid $100g^{-1}$ fresh weight) in buriti fruits under refrigerated storage (80±5% relative humidity) and ambient conditions (23±5ºC and 60±5% relative humidity)

| Temperature | Days of storage | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 |
| | | | Soluble solids | | |
| 10°C | 12.37±1.51 aB | 14.67±0.58 aAB | 16.33±2.52 aA | 15.00±1.73 aAB | 16.00±0.00 aA |
| 12°C | 12.37 ±1.51 aA | 14.67±0,58 aA | 14.00±0 abA | 13.66±0.58 aA | 14.67±1.53 aA |
| 15°C | 12.37 ±1.51 aB | 14.67±1.53 aAB | 13.33 ±2.08 bcAB | 12.67± 0.58 aB | 16.00 ±0.0 aA |
| Ambient | 12.37±1.51 aA | 10.33±0,58 bB | 10.80±0.00 cB | - | - |
| C.V. (%) | 9.37 | | | | |
| | | | pH | | |
| 10°C | 3.83± 0.06 aC | 3.77± 0.58 abC | 4.33±0.15 aAB | 4.57±0.06 aA | 4.1±0.00 abB |
| 12°C | 3.83 ±0.06aC aBC | 3.73±0.58 abC | 4.07 ±0.15 bAB | 3.93± 0.23 bBC | 4.23±0.25 aA |
| 15°C | 3.83± 0.06aC aBC | 3.67±1.53 bC | 4.13±0.06 abA | 4.00±0.10 bAB | 3.97±0.12b AB |
| Ambient | 3.83±0.06aC aB | 3.90±0.58 aAB | 4.10 ±0.0 bA | - | - |
| C.V. (%) | 2.63 | | | | |
| | | | Titratable acidity | | |
| 10°C | 0.68±0.06 aB | 0.84±0.02 aA | 0.41±0.02 aC | 0.47±0.07 bC | 0.60±0.00 Ab |
| 12°C | 0.68 ±0.06 aB | 0.84±0.02 aA | 0.51 ±0.03 aC | 0.60 ±0.04 aBC | 0.52±0.05 aC |
| 15°C | 0.68 ±0.06 aAB | 0.76 ±0.02 aA | 0.49±0.02 aC | 0.58±0.04 abBC | 0.60 ±0.01 aAB |
| Ambient | 0.68± 0.06 aA | 0.63±0.02 bA | 0.42±0.00 aB | - | - |
| C.V. (%) | 9.54 | | | | |

Averages followed by the same lower case letter do not differ significantly from others in the same column and those followed by the same upper case letter do not differ significantly from others in the same row by the Tukey test at 5% probability.

The amount of soluble solids did not show a significant difference when stored at 10, 12 or 15°C. The fruits stored under ambient conditions exhibited a decrease in soluble solids on day three, but it dropped no further on day six. On the ninth day, contamination by the fungus *Monilinia fructicola* was observed and this made the fruits unsuitable for consumption. The fruits stored under ambient conditions maintained a relatively low amount of soluble solids during the experimental period, possibly due to the lower respiratory rate compared to refrigerated storage. The small increase in the concentration of soluble solids at the end of the experiment could be related to the weight loss.

On the third day of storage, there was a tendency for the pH to increase, as shown in Table 3. In the case of ambient storage, this can be due to the process of senescence (Chitarra and Chitarra, 2005). The increase in pH was seen throughout the experiment. When stored at 10°C, the pH was nearly constant on day three, but increased on days six and nine, followed by a decrease on day 12. When stored under ambient conditions, the pH increased until the last day of analysis.

The titratable acidity increased on day three under all storage conditions, followed by a decrease on subsequent days. Ambient storage presented the lowest amount of titratable acidity, probably due to infestation by pathogens that consumed acid in their metabolism (Chitarra and Chitarra, 2005; Özcan and Haciseferogullari, 2007).

The data on total sugars, lipids and protein are presented in Table 4.

Albuquerque *et al*. (2005) reported levels of total sugars in buriti that varied by about 2.10%, similar to what we found. Moreover, Hiane *et al.* (1992) reported values of 11.36% ± 1.81, which are higher than those found in the present experiment.

The amount of total sugars increased from day zero to the third day of storage, followed by a decrease on the sixth day and increases on subsequent days. Carbohydrates are oxidized by the respiratory process (Chitarra and Chitarra, 2005; Rodriguez-Guisado *et al*., 2009), causing the decrease. The increase in concentration on later days was probably related to the loss of weight.

According to Cavalcante (1991), buriti fruit contains a relatively large amount of lipids, which are an important source of energy. This was also reported by de França *et al*. (1999), Albuquerque *et al*. (2005), and Silva *et al*. (2009), Rodrigues *et al.* (2010). However, all these authors reported finding free fatty acids, when they were most likely fatty acyls as a part of mono-, di- and triglycerides.

Table 4 - Amounts of total sugars, lipids, protein and fiber (%) in buriti fruits under refrigerated storage (80±5% relative humidity) and ambient conditions (23±5ºC and 60±5% relative humidity) for 12 days

| Temperature | Storage Days | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 |
| | | | Total sugars | | |
| 10°C | 2.22 aB | 3.25 aA | 0.91 aC | 1.29 bC | 2.72 aAB |
| 12°C | 2.22 aB | 2.93 aA | 0.80 aC | 2.69 aAB | 2.42 aAB |
| 15°C | 2.22 aB | 3.09 aA | 0.83 aC | 2.40 aB | 2.68 aAB |
| Ambient | 2.22 aB | 3.07 aA | 0.96 aC | - | - |
| C.V. (%) | 12.64 | | | | |
| | | | Lipids | | |
| 10°C | 14.00 aC | 18.67 aB | 18.53 aB | 14.80 cC | 21.00 aA |
| 12°C | 14.00 aC | 18.13 aB | 17.30 abB | 18.23 aB | 21.33 aA |
| 15°C | 14.00 aC | 15.67 bB | 16.93 abB | 16.70 bB | 20.47 aA |
| Ambient | 14.00 aB | 13.30 cB | 18.00 bA | - | - |
| C.V. (%) | 3.65 | | | | |
| | | | Protein | | |
| 10°C | 0.26 aD | 0.26 aB | 0.35 aB | 0.37 aC | 0.33 aA |
| 12°C | 0.26 aC | 0.25 aB | 0.21 cB | 0.29 bB | 0.31 bA |
| 15°C | 0.26 aB | 0.21 bB | 0.35 aB | 0.27 bB | 0.26 cA |
| Ambient | 0.26 aB | 0.22 bB | 0.29 bA | - | - |
| C.V. (%) | 2.75 | | | | |
| | | | Fiber | | |
| 10°C | 10.43 aC | 10.73 aBC | 10.10 bC | 11.30 aB | 13.00 aA |
| 12°C | 10.43 aC | 9.60 bD | 10.37 abCD | 11.70 aB | 12.67 aA |
| 15°C | 10.43 aC | 8.50 cD | 10.90 aC | 11.53 aAB | 11.83 bA |
| Ambient | 10.43 aA | 8.70 cB | 10.50 abA | - | - |
| C.V. (%) | 3.37 | | | | |

Averages followed by the same lower case letter do not differ significantly from others in the same column and those followed by the same upper case letter do not differ significantly from others in the same row by the Tukey test at 5% probability.

This is a common mistake which is made when fatty acyl amounts are determined by gas chromatography (GC) only after hydrolyzing the glycerides. This forms free fatty acids, which are then esterified to form fatty acid methyl esters (FAMEs) that are volatile enough to be analyzed by GC. Therefore, a clever marketing or sales representative from producers of a competing company could say that all these studies demonstrate that buriti fruits rapidly turn rancid, since free fatty acids were supposedly found. When oils (glycerides) turn rancid, it is due to partial hydrolysis of glycerides to form malodorous free fatty acids. The article by Silva *et al*. (2009) is especially confusing, since it reports actually finding 3.1% free fatty acids in buriti oil, based on their separation by size exclusion chromatography: it is not clear whether the authors really meant free fatty acids or fatty acyls that are part of triglycerides. They go on to report the profile of free fatty acids, but it is based on GC analysis of FAMEs, so it refers to the fatty acyl profile of mono-, di- and triglycerides. Vegetable oils contain mono-, di- and triglycerides, and therefore the analysis method requires that they be hydrolyzed into free fatty acids and glycerol, followed by forming volatile fatty acid methyl esters (FAMEs), which can be analyzed by gas chromatography (Mannina *et al*., 1999; AOAC, 2003). It is not clear whether the 3.1% free fatty acids separated by size exclusion chromatography were part of glycerides or if they were truly free fatty acids, caused by the oil turning rancid.

However, the present experiment truly measured total lipids and found more than the 2.5 to 5.5% reported by Hiane *et al.* (1992) and Donadio *et al*. (2002). Albuquerque *et al*. (2005) reported finding 11.24% lipids. Carneiro and Carneiro (2011) found 18.16% lipids in buriti pulp.

The amount of lipids increased starting on the third day of storage and stayed almost constant throughout the 12-day experiment (Table 4). On the third day, the fruits stored at 10 and 12°C showed no significant differences, but more lipids were found when stored at 15°C. The fruits stored under ambient conditions had fewer lipids that the fruits stored under refrigeration. On day 12 there were no significant differences in lipid content in the refrigerated samples. The increase in lipid concentration with time could be related to the weight loss that occurred.

According to Donadio *et al*. (2002) buriti fruits had about 2.3 to 5.5% protein, while Hiane *et al*. (1992) found 2.12%, Carneiro and Carneiro (2011) found 1.30% and Darnet *et al*. (2011) found 3.7%. In the present study, there were no significant differences in protein concentrations in fruits stored at 10 and 12°C, but these values were higher than those of fruits stored at 15°C and under ambient conditions, which were not statistically different from each other. On the sixth day of storage, there was an increase in protein concentration, with the exception of those stored at 12°C. On the ninth day, the concentration of protein increased in the fruits stored at 10 and 12°C, while those stored at 15°C showed a decrease.

Donadio *et al*. (2002) found that the fiber content in buriti fruits varied from 10.4 to 27.5%. Hiane *et al*. (1992) reported about 12.31% fiber. Darnet *et al*. (2011) found 22.8% dietary fiber in buriti fruits from the Amazon. The concentrations of fiber found in the current study ranged from 8.5 to 13.0%: on the third day, the fruits stored at 10°C had the highest concentration of fiber, followed by those stored at 12°C; those stored at 15°C and under ambient conditions had the lowest concentrations and were not significantly different from each other. Starting on the third day there was an increase in the concentration of fiber which then continued slowly throughout the 12-day experiment. The increase could be simply due to the loss of weight, so the total amounts were about the same.

## 4. Conclusions

Refrigeration was effective in extending the shelf-life of buriti fruits, increasing it by at least three days. The data presented regarding the decrease in weight and respiratory activity demonstrate that a temperature of 15°C was the most effective in maintaining the quality of buriti fruits.

This work should not be taken as reflecting FDA policy or regulation.

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