Postharvest storage of rambutan (*Nephelium lappaceum* L.) under passive modified atmosphere

Alex G. Sanches¹, Amanda G. Silveira¹, Maryelle B. da Silva², Elaine G. S. Moreira² and Carlos A. M. Cordeiro³

¹Department of Biochemistry and Molecular Biology, Federal University of Ceará, Fortaleza-CE
²Department of Plant Production, State University of Goiás, Ipameri-GO
³Federal University of Pará, Campus Bragança-PA

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Abstract

The rambutan is an exotic tropical fruit that presents high perishability after the harvest due to the intense metabolic activity and the high water content in its chemical composition that together with the darkening process of the pericarp compromise its acceptance by the consumer. In this context, the present research had the objective of evaluating the effect of the passive modified atmosphere with the evaluation of different packing packages aiming at prolonging the useful life of the fruits by the greater acceptance of the final consumer. The rambutans were packaged in polyethylene bags, polyethylene terephthalate (PET) trays, polystyrene styrofoam trays coated with 14 micron PVC plastic film and in cardboard boxes during storage at 10 °C and 85% of RH for 16 days with analyzes performed at four-day intervals on the variables: loss of fresh mass, soluble solids, total soluble sugars, titratable acidity, pH, vitamin C and pericarp appearance. A DIC experimental design with 4x5 factorial was adopted with five replicates and the experimental plot formed by five fruits. The analysis of variance showed no significant effect of the package on the maintenance of fruit quality during storage days. Polyethylene terephthalate (PET) and styrofoam trays made of polystyrene coated with PVC film (BPE + PVC) favored a shelf life of up to 12 days by controlling the physico-chemical changes and the control of browning in the fruit pericarp. The use of the packaging (BPE + PVC) is more suitable for the packaging of the fruits because of the more affordable cost.

Key-words: Exotic Fruit, Packaging, Darkening of the Pericarp, Postharvest Quality

Introduction

Rambutan (*Nephelium lappaceum* L.) is an exotic tropical fruit native to the Malay archipelago and cultivated in countries such as Indonesia, Thailand, Vietnam, India, Philippines, Australia, South Africa, Mexico and Brazil (Sacramento and Andrade, 2014). The fruit has an attractive appearance with ovoid shape and red or yellow pericarp, with long spitnuts and excellent flavor with a white or translucent edible aril, sweet, juicy and rich in vitamin C, being consumed mainly as fresh fruit (Arenas et al., 2012).

As with other tropical fruits, rambutan shows high perishability after harvest due to intense metabolic activity and high water content in its chemical composition (Perez and Pohlan, 2004). The darkening of the pericarp is also one of the obstacles to the commercialization of these fruits since even causing little change in the quality of the pulp, the darkening impairs the appearance of the fruit, a fundamental quality requirement in the purchase of a product by the consumer (Mizobutsi et al., 2010).

The use of handling and storage techniques for selection and packaging, storage and marketing procedures is essential to prolong the shelf life and final product quality (Santos et al., 2009).
One of the storage techniques consists of the passive modified atmosphere, which causes decrease in respiration speed, delay in maturation and decrease in the deterioration of fruits under conditions of composition of the atmosphere different from that present in the atmosphere of normal air, mainly modifying the concentration of gases and ethylene. And can be obtained with the use of plastic materials such as polyethylene, polyvinyl chloride and the like or through the application of products such as waxes and sucrose esters (Figueiredo et al., 2007).

As the use of the modified atmosphere, reducing the rates of respiration and perspiration, the useful life of the fruit products is increased by establishing a gaseous composition inside the packaging other than the air and reducing the metabolic activity of the product (Kader, 2010).

Despite the importance of increasing production and consumption of this fruit species, there is a great lack of information on the post-harvest behavior of these fruits in relation to potential and conservation technologies. Such knowledge is essential to increase storage and commercialization time, without, however, altering the physical, sensorial and nutritional characteristics of the fruits. In view of the above, the present work has the objective of evaluating the conservation and physical-chemical quality of rambutan fruits packed in different packages.

**Material and Methods**

**Plant material and storage**

The present research was carried out with fruits of rambutan harvested at a stage of physiological maturation achieved in red staining free of physiological defects and or affected by pests and diseases in five year old plants belonging to the collection of the Embrapa Experimental Station Eastern Amazon located under the geographical coordinates (latitude 03º 12’ 12’, longitude 52º 12’ 23”) municipality of Brasil Novo, PA, in January 2017.

The fruits were stored in thermal boxes and transported to the Plant Biotechnology Laboratory of CEA Environmental Studies Center, located in the city of Altamira, PA, where they were washed in running water and then sanitized in 5% chlorine solution for a period of three minutes with subsequent rinsing to remove excess from the sanitizing and dried at room temperature.

After drying, the fruits were packed in: i) Styrofoam tray (expanded polystyrene) with lid; ii) styrofoam tray (expanded polystyrene) wrapped with 14 micron PVC film (polyvinyl chloride), iii) polyethylene terephthalate (PET) plastic wrap with lid and iv) polyethylene wrap with lid. The specimens were stored in chambers of B.O.D under 10 ± 2°C and 85% humidity for a period of sixteen days.

**Physical-chemical and sensorial analyzes**

The evaluations were performed at four-day intervals on the following characteristics: loss of fresh mass determined with the aid of a semi-analytical scale with an accuracy of 0,1 g, calculating the difference between the weight at the beginning of the experiment and after each evaluation day, the results being expressed as a percentage (%).

The content of soluble solids was determined with the aid of an ATAGO digital refractometer with automatic temperature compensation following the methodology described by AOAC (2012) and the results expressed in °Brix.

Total soluble sugars were determined according to methodology described by Johnson et al. (1966), using spectrophotometry with a wavelength of 490 nm and standard glucose curve (1%) ranging from 20 to 300 mg and the results expressed in mg.100g⁻¹.

The determination of the total titratable acidity was performed using the technique described by AOAC (2012), by titration, using a digital burette using 10 mL of sample. The titration was done with a solution of 0,1 N NaOH and phenolphthalein (1%) as indicator until turning point, and the result in% of citric acid was expressed.

The pH was determined in the samples of the homogenized pulps using a digital potentiometer DM 20 of Digimed., Calibrated with buffer solutions of pH 4.0 and 7.0, as recommended by AOAC (2012).

The content of vitamin C was determined by the method proposed by Chen and Wang (2002) in a spectrophotometer at 525 nm, the results being expressed in the calibration curve in g.100g⁻¹ of ascorbic acid.
The appearance of the pericarp was evaluated by means of a hedonic scale of five points where: 5 = 100% red; 4 = up to 10% of the darkened shell; 3 = up to 25% of the darkened bark; 2 = up to 50% of the darkened bark and 1 = fruits with fully darkened pericarp. Note 3 was considered the limit for the commercialization of the fruits.

**Experimental design and statistical analysis**

A completely randomized experimental design was used in a 4x5 factorial arrangement, with four types of packages and five storage times (0, 4, 8, 12 and 18 days) with five replicates and the experimental plot composed by 5 fruits.

The data of each analyzed variable were submitted to analysis of variance and the comparison of means by the Tukey test at the level of 5% of probability through the statistical software Assistat 7.7 versão beta.

**Results and discussion**

The data presented in Table 1 show that there was a significant difference by the F test in the interaction (package x days of evaluation) at the 5% level for the variables: loss of fresh mass and titratable acidity and at the level of 1% for solids content Solubles, total sugars and pericarp appearance. For pH and vitamin C, there were differences only in the isolated factors, both at the 5%.

**Table 1.** Mean values for the F test for the variables: fresh weight loss (FMP), total soluble solids (TSS), total soluble sugars (AST), total titratable acidity (ATT), pH (pH), vitamin C (VC), and appearance of the pericarp (AP).

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>Analysis table</th>
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<tr>
<td></td>
<td>GL</td>
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<tr>
<td>Packing</td>
<td>3</td>
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<td>Days</td>
<td>4</td>
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<tr>
<td>Int. Packing x Days</td>
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<td>Treatment</td>
<td>19</td>
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<tr>
<td>CV (%)</td>
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**Significant at the 1% probability level (p <0.01); * Significant at the 5% probability level (0.01 = <p <0.05); Ns = not significant (p> = 0.05).**

![Fig. 1](image-url). Evolution of fresh weight loss (%) during storage of rambutan fruits packed in different storage containers. SPP (polyethylene plastic bag); BPE + PVC (expanded polystyrene tray wrapped with 14 micron PVC film); PET (plastic packaging type PET with lid) and CP (cardboard box).
The weight loss of fresh fruit mass during the storage period is mainly due to the transpiration and the pressure deficit between these and the environment (Pinto et al., 2012).

According to Figure 1, it is observed that the polyethylene plastic bag (SPP) presented the highest percentage of fresh mass loss (6.87%) at the end of sixteen days of analysis followed by the carton box (CP) whose average percentage was 6.21%. The storage of the fruits in the polystyrene styrofoam trays coated with PVC plastic film and in the PET-type packages did not show differences between them and the average was around 4.25% for the same storage time.

The positive effect of these packages on controlling the loss of fresh mass is due to their lower permeability, allowing a lower rate of water vapor transmission and greater relative humidity inside the package, reducing chemical and enzymatic reactions and the transpiration rate of Fruits causing less water loss to the environment (Sanches et al., 2011).

These results corroborate with those verified by Oliveira et al. (2014) who noticed lower variation of the loss of fresh mass in camu-camu when kept in polystyrene packages coated with PVC plastic film and Santos et al. (2009) whose use of modified atmosphere through the use of PET-type packaging effectively reduced the loss of mass in mangaba during the storage period.

The content of total soluble solids represents the water-soluble compounds present in fruits, such as sugars, vitamins, acids, amino acids and some pectins. In most fruits the accumulation of SS is indicative of ripening and the reduction of these compounds is a sign of entry to the senescence stage driven by the use of the compounds in the maintenance of metabolic activity and respiratory activity (Chitarra and Chitarra, 2005).

According to Figure 2 it is observed that the SS content was significantly affected by the effect of the packages during rambutans storage. The mean values of soluble solids ranged from 15.4 to 20.3 °Brix in agreement with the mean values observed by Arenas et al. (2012) whose values ranged from 19.8 to 16.4 °Brix and by Sanches et al. (2016) with contents ranging from 21.4 to 15.8 °Brix.

The plastic polyethylene bag (SPP) and cardboard box (CP) did not differ during the whole experimental period, with the highest SS concentration of 19.6 and 18.9 °Brix, on the eighth day, respectively. On subsequent days, there was a significant reduction with mean at the end of sixteen days of storage below 16.0 °Brix (Figure 2).

![Fig. 2. Soluble solids content (°Brix) during storage of rambutan fruits packed in different storage containers. SPP (polyethylene plastic bag); BPE + PVC (expanded polystyrene tray wrapped with 14 micron PVC film); PET (plastic packaging type PET with lid) and CP (cardboard box).](image-url)
The BPE + PVC packaging presented fruits with little increase in the contents of SS up to the ninth day of storage, but not of the PET packaging, whose maximum peak of the SS concentration is also verified at the twelfth day of analysis with averages of 20.1 and 20.3 °Brix respectively, with subsequent reduction on the last day of evaluation. In general, the lower values of soluble solids observed at the end of the storage period in the different packages indicate that there was a decrease in fruit shelf life (Figure 2).

Silva et al. (2013) noted that PET-type packaging and styrofoam trays coated with PVC film were efficient in maintaining the soluble solids content in minimally processed sleeves without significant differences between them. Vieites et al. (2011) verified that the levels of SS in jabuticabas presented different peaks as a function of the modified atmosphere evaluated, similar to that verified in this research.

Regarding the metabolism of carbohydrates, there is a significant effect of the packaging and storage days on the amount of soluble sugar in the fruit pulp. In general, it can be observed that up to the fourth day of storage a small increase in the amount of AST in the fruits of all the evaluated packages reaching maximum point of 221 mg.100⁻¹ (Figure 3). Such behaviors were also reported by Carneiro et al. (2015) during the storage with different packages in cagaita fruits.

Chitarra and Chitarra (2005) explain that the increase in AST levels during the initial days of storage may be related to the higher energetic demand of fruits for the continuation of metabolic processes, with the hydrolysis of long chain carbohydrates of the cell wall and consequent increase Soluble sugars such as sucrose, fructose and glucose in fruit pulp.

After the fourth day, there was a gradual reduction in the amount of AST in the fruit pulp, most evidenced in fruits packed in cardboard boxes (CP) and in plastic polyethylene bags (SPP) with averages corresponding to 113 and 119 mg.100⁻¹ on the last valuation day, respectively. In the fruits kept in PET and BPE + PVC packages the reduction in AST contents was less significant until the 12th day of storage with averages around 190 mg.100⁻¹, however on the last day of storage there was a marked decrease reaching 150 mg.100⁻¹ in both packages (Figure 3).

According to Taiz and Zeiger (2017), the reduction in the levels of AST (sucrose) during fruit storage is conditioned to the respiratory process that uses these sugars as a substrate, so that the increase in the respiratory rate of the fruits is proportional to the consumption of AST will be degraded to extend...
the service life. In this context, the PET and BPE + PVC packages, as inferring less gas exchange between the fruit and the environment, probably reduced the respiratory activity of the rambutans, showing less pronounced AST degradations when compared to the other packages.

According to Figure 4 it is observed that the acidity of the fruits was significantly affected by the effect of the packages during the storage time. An increase in the mean values in the fruits of all the evaluated packages was observed, from 0.42% of citric acid at day zero to more than 0.84% of citric acid after eight days of storage, followed by reduction to the last day of analysis.

![Fig. 4. Variation in titratable acidity (% citric acid) during rambutan fruit storage in different storage containers. SPP (polyethylene plastic bag); BPE + PVC (expanded polystyrene tray wrapped with 14 micron PVC film); PET (plastic packaging type PET with lid) and CP (cardboard box).](image)

This behavior is similar to that observed by García-Gurría et al. (2013) when evaluating the quality of rambutans submitted to different treatments with modified atmosphere where they observed a slight increase in the acid values with later decline until the end of the refrigerated storage.

After harvesting and during storage, the concentration of organic acids usually declines as a result of its use as a respiratory substrate or its transformation into sugars (Raju et al., 2011).

At the end of sixteen days of storage, the fruits stored in polyethylene plastic bag (SPP) and cardboard box (CP) presented values below that detected on the first day of evaluation, a mean of 0.14 and 0.12% of citric acid, respectively, differing statistically from PET and BPE + PVC packages, which for the same period presented percentages of 0.30% citric acid (Figure 4).

Still according to Figure 4 it can be seen that PET-type and BPE-PVC-type packages did not differ from each other and showed a reduction in the acid values in an attenuated form, probably due to the influence of the higher concentration of CO₂ inside these packages allowing lower metabolic and respiratory activity. In the polyethylene (SPP) and carton (CP) packages, the higher permeability of gas exchange with the environment favored greater variations in fruit metabolism leading to a more pronounced maturation/senescence.

Changes in mean values of titratable acidity during storage in modified atmosphere of abius and cagaita considered as tropical fruits were also observed by Sanches et al. (2016) and Carneiro et al. (2015), which attributed the reduction to fruit ripening.

The pH values during storage ranged from 3.29 to 4.50 in the different packages evaluated (Figure 5). These results are within the range observed by Sacramento et al. (2013) that when evaluating
different genotypes of this species found average values ranging from 3.22 to 4.42.

Damodaran et al. (2010) explain that the increase in pH values during storage is probably due to the beginning of the senescence processes through the respiratory process that consumes the organic acids in greater intensity, causing a decrease in acidity and, consequently, an evolution in fruit maturation.

García-Gurría et al. (2013) evaluating rambutans under different packages in a refrigerated environment noticed oscillations in the initial days of storage with subsequent elevation in pH values and explained this variation as a result of the fruit maturation process.

The analysis on the isolated effect of the packages and the evaluation days showed that there were positive correlations of the use of the packages on the maintenance of the pH of the fruits with the storage time. Agostini et al. (2009) also noticed a positive effect of the modified atmosphere favored by different packages in the maintenance of the pH values during the conservation of jabuticabas.

According to Figure 5, it can be observed that PET and BPE + PVC packages presented lower pH variations until the 12th day of storage, thus acting as an effective barrier in the control of fruit maturation/senescence, corroborating with the statements of Chitarra and Chitarra (2005) where the low pH during storage is considered a desirable technological attribute in the delimitation of the shelf life of the fruits.

Polyethylene bag (SPP) and carton (CP) packages showed a variation in the initial times with a more pronounced increase from the eighth day of evaluation indicating that the fruits presented more advanced stages of maturation (Figure 4).

The vitamin C content in the fruit pulp was determined from the isolated effects between the packing factors and storage days since there was no significant effect on the interaction of these factors.

According to Adriano et al. (2011), the ascorbic acid content decreases with the advancement of fruit maturation, due to the action of the enzyme ascorbic acid oxidase, which is well accentuated in those that ripen quickly.

Arenas et al. (2012) found a reduction in the vitamin C content of rambutans submitted to
different treatments with modified atmosphere with initial values of 75.5 g.100g\(^{-1}\) of ascorbic acid reaching less than 40.0 g.100g\(^{-1}\) of ascorbic acid after ten days of storage at 10 °C, similar to that observed in this study.

Up to the eighth day of storage, the fruits kept in the carton (CP) and polyethylene plastic bag (SPP) presented the highest reductions of vitamin C with a mean value of 28.3 g.100g\(^{-1}\) of ascorbic acid at the end of Storage, differing from the others (Figure 6).

The fruit packaging in the PET and BPE + PVC packages maintained is certain stability in the vitamin C content in the fruit pulp between the fourth and eighth day of storage. This fact may be related to the atmosphere created inside these packages, reducing water loss and availability of O\(_2\) within these assuring less respiratory activity and degradation of the precursor enzyme of vitamin C (Figure 6).

![Fig. 6. Reduction in vitamin C values (g.100g\(^{-1}\) of ascorbic acid) during rambutan fruit storage stored in different storage containers. SPP (polyethylene plastic bag); BPE + PVC (expanded polystyrene tray wrapped with 14 micron PVC film); PET (plastic packaging type PET with lid) and CP (cardboard box).](image)

![Fig. 7. Aspect pericarp during storage of rambutan fruits packed in different storage containers. SPP (polyethylene plastic bag); BPE + PVC (expanded polystyrene tray wrapped with 14 micron PVC film); PET (plastic packaging type PET with lid) and CP (cardboard box).](image)
On the last day of storage, there were no significant differences between PET, BPE + PVC and SPP packaging with mean values ranging from 34.8 to 38.6 g.100g⁻¹ of ascorbic acid (Figure 6).

In the commercialization of fresh fruits the appearance is one of the criteria most used for the evaluation of fruit quality, with this the occurrence of wilt and wrinkling attributes to aspects of bad appearance and loss of quality during the period of commercialization (Vieites et al., 2011).

The darkening of the pericarp is caused by the oxidation of phenolic substrates catalyzed by polyphenoloxidase (PPO) after separation of the enzyme from its substrates due to the compartmentalization of the membranes, is loss of water from the fruit after harvesting, thus initiating the darkening reaction in the Tissues (Ducamp-Collin et al., 2008).

According to Figure 7 the appearance of the fruits was compromised when they reached commercial grade 3 (up to 25% of the darkened epicarp).

The fruits packed in polyethylene plastic bags and in the carton boxes reached note 3 on the eighth day of storage, and were not statistically different from those of polyethylene terephthalate (PET) and expanded polystyrene coated with PVC plastic film (BPE + PVC) whose marketing note was reached only after twelve days of analysis.

Silva et al. (2011) and Sanches et al. (2016) also noticed a positive effect of the modified atmosphere on the prevention of blackening of the pericarp of lychees and rambutans, respectively.

Conclusions

The shelf life of rambutans is limited to 12 days as 25% of fruit appearance is compromised by darkening of the epicarp.

The polyethylene terephthalate (PET) and polystyrene polystyrene trays coated with PVC film (BPE + PVC) were efficient in controlling post-harvest changes such as loss of fresh mass, soluble solids, titratable acidity, pH, Vitamin C content and carbohydrate consumption during the storage period.

The post-harvest storage of rambutans is recommended in styrofoam trays of polystyrene coated with PVC film (BPE + PVC) at the most affordable cost.

Conflict of interest: All authors declare no conflict of interest.

References


