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PHYSICO-CHEMICAL CHARACTERIZATION OF SUGAR APPLE (*Annona squamosa* L.) FRUITS STORED WITH PVC FILM IN DIFFERENT CONTROLLED TEMPERATURES

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ABSTRACT: Sugar apple (*Annona squamosa* L.) is tropical climacteric fruit with a very short shelf life, ripening completely in just a few days under favorable conditions. Among the techniques employed to increase the time of conservation are the use of modified atmosphere and cooling. The objective of this work was to study the use of PVC film and cooling to increase the shelf-life time of fresh fruits of sugar apple cv. Crioula. Fruits were harvested at the stage of physiological ripeness, stored in paperboard boxes (33cm x 27cm x 10cm) covered or not with PVC film and placed in refrigerators with temperatures set to 18ºC, 21ºC, 24ºC and room temperature (average 27°C±2). The experiment was set in a completely randomized design and the treatments evaluated in a factorial scheme 2x4 (with and without PVC film and 4 temperatures) with four replications and three fruits per plot. The results showed that lower temperatures did not affect physical-chemical characteristics of the fruits, but increased the time of post-harvesting conservation by three fold. The use of PVC film helps to preserve the weight and the external and internal quality of the fruits, but it reduced the amount of total solid soluble of the fruit pulp on the consumption point.

KEYWORDS: Custard-apple. Post-harvesting, Conservation.

CARACTERIZAÇÃO FÍSICO-QUÍMICA DE FRUTOS DE PINHEIRA (*Annona squamosa* L.) ARMAZENADOS COM FILME DE PVC E TEMPERATURA CONTROLADA

RESUMO: A pinha é um fruto tropical climatérico que possui vida de prateleira muito curta e em condições ambientais favoráveis os frutos completam o amadurecimento em, no máximo, uma semana após a colheita. O objetivo deste trabalho foi estudar o uso do resfriamento e de embalagens de papelão cobertas com filme de PVC para aumentar o tempo de conservação pós-colheita de frutos de pinha cv. Crioula. Os frutos foram colhidos no estágio de maturidade fisiológica e armazenados em camada única em caixas de papelão (33cm x 27cm x 10cm) cobertas ou não com filme de PVC e postos em câmaras frigoríficas com temperaturas ajustadas para 18ºC, 21ºC e 24ºC e à temperatura ambiente (média de 27±2ºC). O delineamento experimental utilizado foi o inteiramente casualizado, e os tratamentos avaliados em esquema fatorial 2x4 (com e sem PVC e 4 temperaturas), com quatro repetições e três frutos por parcela. Os resultados mostraram que as temperaturas mais baixas não afetaram as características físico-químicas dos frutos, mas aumentaram o tempo de conservação pós-colheita em até três vezes. O uso da película de PVC favoreceu a manutenção do peso e da aparência externa e interna dos frutos, mas reduziu o teor de sólidos solúveis totais da polpa no ponto de consumo.

PALAVRAS-CHAVE: Fruta-do-conde, Pós-colheita, Conservação.

Sugar apple (*Annona squamosa* L.), native fruit from Central America, has in Brazil one of the main centres for production and consumer market. It is estimated that there are near 6000 hectares cultivated with this species in Brazil, mostly in the Northeast region (Lemos, 2014). Its production is primarily meant for the fresh fruit market of the large Brazilian cities, with considerable distances to be overcome in poorly maintained roads and transport not always adequate (Pinto et al., 2005). This scenario, together with the vulnerable nature of this fruit and the little knowledge of fruit preservation methods by the producers, lead to high post-harvest losses (Durigan, 2013).

The high losses observed in this production chain showed the need to establish procedures to

improve fruit harvesting and conservation to minimize losses and maximize fruit shelf-life. Because sugar apple has a climacteric respiration pattern, the fruit has a rapidly maturing and perishing behaviour during the post harvesting period under favorable conditions (Silva et al, 2013). Among the techniques employed to increase shelf-life of fruits and vegetables are the use of controlled atmosphere by refrigerating and modified atmosphere by packaging (Reis et al, 2014). This work aimed to study the duration of fruit shelf-life using packaging protected or not with PVC film under different temperatures.

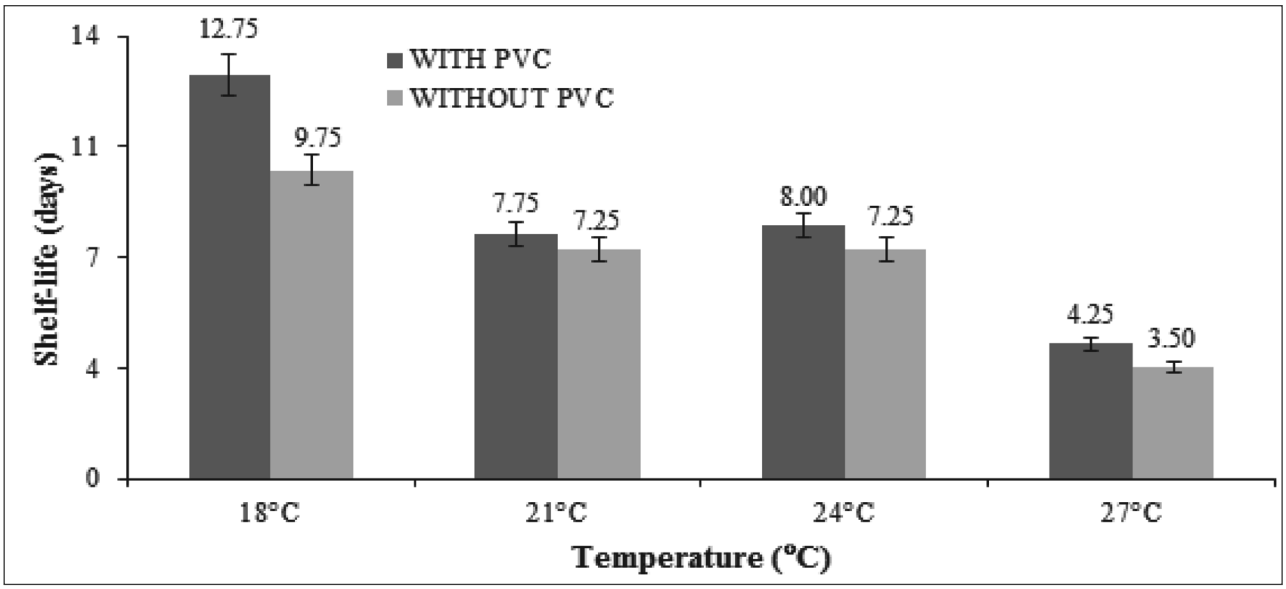
Sugar apple cv. Crioula fruits were obtained from a commercial orchard of Paxiuba Farm, in the Palmeira dos Indios, Alagoas, Brazil (9 26 '22.4' 'S, 36 41' 2.6 W and 295 m altitude). The fruits were harvested weighing between 250 and 300 grams at the physiological maturity, stage when the green exocarp segments initiate separation (3 to 4 mm) and exhibit a whitish color in the grooves. The harvested fruits were placed in plastic bins in separated layers by a soft sheet of paper to prevent abrasion during transport.

In the laboratory the fruits were selected, weighed, identified and placed in groups of 12 into paperboard boxes (33cm x 27cm x 10cm) in a single layer. The boxes with fruits were organized according to the following treatments: covered or not covered with Polyvinyl Chloride (PVC) film R105 Lusafilm; and stored in FS-224 SOLAB incubator with temperatures adjusted to 18ºC; 21ºC; 24ºC; and room temperature (average 27 °C ± 2, control treatment).

During the storage period, the fruits were sampled daily to identify the adequate point of consumption, determined physically by the softening of the exocarp (0.30 - 0.40 kg on the segment and 0.10 - 0.20 kg between segments) measured by digital bench penetrometer (SoilControl, TDBC -200). At this point, the fruits were removed from the boxes to carry out physical and chemical analysis: lateral and transverse diameters; fruit mass, the mass of peel, pulp and seeds; total soluble solids (°Brix); pH; titratable acidity (TTA); external appearance (exocarp) (EA), calculated using a scale of notes at the consumption point varying from 1 to 4, where 1 = > 40% blackish segments, 2 = > 20%<30% blackish segments, 3 = >1%<10% blackish segments, 4 = no blackish segments. The internal appearance (pulp) (IA), was calculated using a scale of notes also varying from 1 to 4, where 1 = brown pulp, 2 = moderately brown pulp, 3 = pale yellow pulp, 4 = white pulp. The experiment was organized on a completely randomized design in a factorial 2 x 4, with four replications and three fruits per plot. Data were subjected to analysis of variance and the means were compared by F test at 5% probability.

The shelf-life of sugar apple fruits varied with the storage temperatures and with PVC film cover. At room temperature, the fruit ripening process completed and reached the point of consumption with best quality in 3 to 4 days for treated and untreated PVC film, respectively (Figure 1). Fruit behavior for the evaluated characteristics, even for those in which the effect was not significant, is shown in Tables 1 and 2. At lower temperatures (24°C and 21°C) the fruit was conserved for a longer period of time (between 7 and 8 days) although the visual quality thereof was preserved only in treatments with PVC packaging.

Figure 1. Shelf-life of *Annona squamosa* L. fruits covered or not with PVC film subjected to different temperatures.



Guimarães et al. (2003) observed that sugar apple nuts kept at 10 ° C with the PVC film had the fruit peel affected, but the internal quality was satisfactory until the 12th day, without changes in the pulp, such as darkening or injury by cold. At the temperature of 18°C the fruits could be stored for up to 13 days without significant loss on its external (note 3.29) or internal (note 3.52) quality in the treatment with PVC film. By contrast, fruits stored in not covered boxes reached the consumption point after 9 days with a reasonable pulp quality (note 3,04) to be consumed, but their external appearance was very poor (note 2,31) to be commercialized (Table 1).

Table 1. Effect of the PVC film on appearance and chemical characteristics of *Annona squamosa* L. fruits during a storage period of 15 days.

PVC Film	EA	IA	TSS	pH	TTA	TSS/TTA
With	3.29a	3.52a	25.05b	5.17a	4.53a	5.55b
Without	2.31b	3.04b	28.29a	4.74b	4.32a	6.56a
Mean	-	-	-	-	4.42	-

Means followed by the same letter in columns did not differ by F Test (p=0.05). EA (External Apearance), IA (Internal Apearance), TSS (Total Solid Solubles (°brix), pH, TTA (Total Titrate Acidity) and the ratio Total Solid Solubles x Total Titrate Acidity (TSS/TTA).

Silva et al. (2009) did not observe any significant difference between treatments of atemoya fruits (*Annona cherimola* × *A. squamosa*) conserved individually in PVC film or packed in styrofoam trays. Fruit darkening observed in all treatments was a natural consequente of the fruits ripenning, however, fruits conserved in PVC film showed less darkening. Similarly, Mizobutsi et al. (2012) using controled atmosphere and refrigeration to conserve sugar apple fruits observed that the combination of PVC film and 12 ºC preserve the natural green color of the fruit skin during storage longer than at the room temperature. The use of the film reduces the fruit metabolism and consequently slow down ripenning speed. The PVC barrier formed between the fruits and the air creates a modified atmosphere next to the fruit that is low in O_2, as a consequence, respiration, ethylene production and clorophil degradation are reduced (Yamashita et al.; 2002).

Melo et al. (2002) observed that fruits of cherimoya (*Annona cherimoya* Mill.) could be kept for up to two weeks (15 days) when chilled without PVC film and up to four weeks (30 days) when chilled and wrapped in PVC film. The results presented here showed to be possible to increase more than three fold the shelf-life of sugar apple fruits refrigerated at 18°C, when compared to fruits conserved at room temperature (27°C), without any significant loss in external and internal quality.

The titratable total acidity (TTA) of the fruits pulp did not change significantly between treatments (Table 1), although the fruit maturation process leads to a reduction in the organic acids content of the pulp due to the respiratory process (Chitarra and Chitarra, 2005). Silva et al. (2003), analyzing sugar apple fruits stored at a temperature of 15 °C (wrapped or not in low density polyethylene), observed a decrease in the values of titratable acidity. Nevertheless, Vila et al. (2005), using cassava starch as a film coating to modify the atmosphere in sugar apples fruits stored at 18 ºC, observed that there was an increase in the titratable acidity values up to the 4th day of storage, but this value decreased after that until the last day of analysis.

Regarding the total soluble solids (TSS), the treatments without PVC packaging provided higher concentration of sugars (28.29 °Brix) than the treatment with PVC (25.05 °Brix). These results show that the use of PVC film interfered on the conservation of the fruits by reducing respiration and transpiration and, consequently, delaying ripening and maintaining higher water content in the fruit, thus affecting the concentration of sugars in the pulp (Melo et al., 2002). As fruit ripening progress, total soluble solids increases in the fruit tissues throughout storage as a result of the transformation of the accumulated reserves (usually starch) into sugars and is also corroborated by the loss of water (Silva et al., 2009).

Considering only the studied storage temperatures, there were no significant differences on physical and chemical characteristics of sugar apple fruits. However, the analysis of variance showed a

significant interaction between the use of PVC film and the storage temperatures for certain variables. The weight of the fruit (exocarp + pulp) decreased considerably when the PVC film was not used, showing its physical barrier effect against dehydration of the fruit (Silva et al., 2014). PVC film represents a physical barrier to dehydration, preventing fruit from losing mass through the process of transpiration and, at the same time, reducing its respiratory activity. Morais et al. (2010) observed that by modifying the atmosphere with the use of the PVC packaging the integrity of papaya fruits peel was preserved, thus reducing the loss of water and its mass.

The PVC film also contributed to preserve the visual characteristics of the fruit, maintaining high notes for exocarp and pulp, which means almost no damage and perfect marketable conditions. The higher sugar content found in fruits without the cover film shows the effect of dehydration and, therefore, the soluble solids concentration in the pulp. The modified atmosphere of the paperboard boxes by the PVC film have shown its protection against dehydration and its consequent dilution of sugars present in the pulp (Mizobutsi et al., 2012).

The fruits kept in boxes covered with PVC film presented a superior average weight (155.69 g) than treatment without film (133.68 g) evidencing the protection of the film against the dehydration of the fruits exposed in all temperatures studied (Table 2).

Table 2. Effect of the PVC film on physical characteristics of *Annona squamosa* L. during storage period of 15 days.

PVC Film	IW	FW	LW	ID	FD	WE	WP	WS
	---------- g ----------			---------mm---------		---------- g ----------		
With	167.52a	155.69a	11.82b	73.12a	71.43a	71.23a	82.52a	1.93a
Without	167.76a	133.68b	34.07a	73.17a	67.56b	58.04b	74.44b	1.19a
Mean	167.64	-	-	73.14	-	-	-	1.56

Means followed by the same letter in columns did not differ by F Test (p=0.05). IW (Initial weight), FW (Final weight), LW (Loss of weight), ID (Initial diameter), FD (Final diameter), WE (Weight of exocarp), WP (Weight of pulp) e WS (Weight of seeds).

Fruits in a passive modified atmosphere, as the ones covered with the PVC film, maintain their fresh matter due to a possible increase of the relative humidity of the air inside the package, saturating the atmosphere around the fruit, which leads to the decrease of the vapor pressure deficit of water in relation to the environment (Silva et al., 2009).

Fruits of sugar apple conserved at temperature of 18 °C in paperboard boxes covered with PVC film have their shelf-life extended up to 3 times conserving their marketable appearance and main physic chemical characteristics in the postharvest period.

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