LIMA, K. S.; SANCHES, A. G.; CORDEIRO, C. A. M.; Evalution of packaging in the conservation of minimally processed squash. **Applied Research & Agrotechnology,** Guarapuava-PR, v.12, n.3, p.75-84, Set-Dez., 2019. DOI: 10.5935/PAeT.V12.N3.07

Scientific Paper

Evalution of packaging in the conservation of minimally processed squash

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Abstract

Squash (*Cucurbita moschata* Duch.) is a fruit with high nutritional value and minimal processing is the main alternative to reduce post-harvest losses and to add value to the product, however, processed products are more perishable and therefore need conservation and the use of plastic packaging for the preservation of quality during storage. In this sense, the objective of this work was to evaluate the efficiency of packaging for the storage of minimally processed squash. Ripe squash were purchased locally, processed in 3.0 cm cubes, sanitized, packed in different plastic containers and stored in a refrigerator (10 ºC) for a period of 12 days. The experimental design was completely randomized in a 3x5 factorial arrangement, comprising three packages (polypropylene plastic bag, expanded polystyrene tray covered with PVC film and polyethylene terephthalate) and five days of evaluation (0, 3, 6, 9 and 12 days) with three replicates. Loss of fresh mass, firmness, soluble solids, titratable acidity, pH, TSS/ATT ratio, pulp color, incidence of whiteness and overall quality were evaluated every three days. The physical-chemical and sensorial quality of the squash was compromised throughout the storage time ($p<0.05$). On the other hand, polystyrene tray coating with PVC film (BPE + PVC) resulted in lower fresh mass loss, maintenance of firmness and lower degradation of soluble solids, and preservation of sensorial characteristics during 12 days of storage at 10 °C.

Keywords: *Curcubita moschata* Duch., modified atmosphere, minimum processing.

Avaliação de embalagens na conservação de abóbora minimamente processada

Resumo

A abóbora (*Cucurbita moschata* Duch.) é fruto com alto valor nutricional e o processamento mínimo é a principal alternativa para reduzir as perdas pós-colheita e agregar valor ao produto, contudo, produtos processados são mais perecíveis e, portanto, necessitam de tecnologias de conservação coo o uso de embalagens plásticas para a preservação da qualidade durante o armazenamento. Nesse sentido, o objetivo deste trabalho foi avaliar a eficiência de embalagens para o armazenamento de abóboras minimamente processadas. Abóboras maduras foram adquiridas no comércio local, processadas em cubos de 3,0 cm, sanitizadas, acondicionadas em diferentes embalagens plásticas e armazenadas em refrigerador (10 ºC) por um período de 12 dias. O delineamento experimental adotado foi o inteiramente casualizado em arranjo fatorial 3x5 que compreende três embalagens (saco plástico de polipropileno, bandeja de poliestireno expandido recoberta com filme de PVC e polietileno tereftalato) e cinco dias de avaliação (0, 3, 6, 9 e 12 dias) com três repetições. A cada três dias avaliou-se a perda de massa fresca, firmeza, sólidos solúveis, acidez titulável, pH, relação SST/ATT, coloração da polpa, incidência de esbranquiçamento e a qualidade geral. A qualidade físico-química e sensorial das abóboras foi comprometida ao longo do tempo de armazenamento ($p<0,05$). Já o acondicionamento em bandeja de poliestireno revestida com filme de PVC (BPE+PVC) resultou em menor perda de massa fresca, manutenção da firmeza e menor degradação de sólidos solúveis, além de garantir preservação das características sensoriais ao longo de 12 dias de armazenamento a 10 °C.

Palavras-chave: *Curcubita moschata* Duch., atmosfera modificada, processamento mínimo.

Brazilian Journal of Applied Technology for Agricultural Science, Guarapuava-PR, v.12, n.3 p.75-84, 2019

Received at: 17/04/2019 Accepted for publication at: 03/08/2019

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Evaluación de paquetes para conservación de calabaza minimamente

Resumen

La calabaza (*Cucurbita moschata* Duch.) es una fruta con un alto valor nutricional y el procesamiento mínimo es la principal alternativa para reducir las pérdidas posteriores a la cosecha y agregar valor al producto, sin embargo, los productos procesados son más perecibles y, por lo tanto, requieren tecnologías más eficientes, omo el uso de envases de plástico para la conservación de calidad durante el almacenamiento. En este sentido, el objetivo de este trabajo fue evaluar la eficiencia del empaque para el almacenamiento de calabazas mínimamente procesadas. Las calabazas fueran comprados localmente, procesadas en cubos de 3,0 cm, desinfectadas, envasadas en diferentes recipientes de plástico y se almacenaron en un refrigerador (10 ºC) durante un período de 12 días. El diseño experimental fue completamente al azar en una disposición factorial 3x5, que comprende tres paquetes (bolsa de plástico de polipropileno, bandeja de poliestireno expandido cubierta con película de PVC y tereftalato de polietileno) y cinco días de evaluación (0, 3, 6, 9 y 12 días) con tres repeticiones. Cada tres días se evaluó la pérdida de masa fresca, firmeza, sólidos solubles, acidez titulable, pH, relación SST / ATT, color de la pulpa, incidencia de blancura y calidad general. La calidad fisicoquímica y sensorial de las calabazas se vio comprometida durante el tiempo de almacenamiento ($p < 0.05$). El embalaje en una bandeja de poliestireno recubierta con película de PVC (BPE + PVC) resultó en una menor pérdida de masa fresca, mantenimiento de la firmeza y menos degradación de los sólidos solubles, y asegurando la preservación de las características sensoriales durante 12 días de almacenamiento a 10 ° C.

Palabras clave: *Curcubita Moschata* Duch., atmósfera modificada, procesamiento mínimo.

Introduction

Belonging to the Curcurbitaceae family, the squash (*Curcubita moschata* Duch.) is a vegetable with a center of origin in central Mexico and South America (WILSON et al., 1992; ALMEIDA, 2014). It is a fruit with high nutritional value, being a good source of vitamins A and B complex, minerals such as calcium, iron, phosphorus and zinc, as well as antioxidant compounds such as α-carotene, β-carotene and carotenoids (TACO, 2011; DAIUTO et al., 2012; RIBEIRO et al., 2013).

Squash are generally large vegetables, and therefore have difficulties in marketing, storage and handling, which leads to many losses (SASAKI et al., 2006; COSTA et al., 2011). In this sense, the minimum processing is presented as an alternative to reduce these problems and to add value to the product. According Russo et al. (2012), the minimum processing (MP) of fruits and vegetables is a booming market trend and the products subject to the MP become convenient by reducing the time of preparation, better standardization and reduction of post-harvest losses.

However, processed products are more perishable than when intact because they are subjected to severe physical stress mainly coming from peeling and cutting leading to an increase in respiration rate and ethylene production, water loss and enzyme activity due to rupture of cells (DURIGAN e CASSARO, 2000; CHITARRA e CHITARRA, 2005). In this sense, the use of conservation technologies is fundamental for maintaining the quality of these products.

An example is the use of packages as they function as the fruit peels, which were removed during processing and used as a supplement to the refrigeration. To Wiley (1994), Cisnero-Zevallos e Krochta (2002) the containers are able to modify the conservation atmosphere of the vegetal product, given the action of the respiration inside, with increase in CO2 concentration and decrease in O2, besides preserving the appearance and reducing the microbial development, the loss of water and biochemical deterioration during storage.

Currently the market has several materials for the packaging of minimally processed products, such as: polypropylene plastic bag, polyethylene terephthalate (PET), expanded polystyrene with polyvinyl chloride (PVC) film, among others, and considering that the knowledge of the physicochemical and sensory characteristics of the plants varied according to cultivar, stage of maturation and cultivation practices, the objective of this work was to evaluate the efficiency of packaging for the storage of minimally processed squash.

Material and methods

Plant material

Physiologically mature squash (*Cucurbita moschata* Duch.) Were obtained from the local trade in Altamira - PA, selected for the size, shape and color of the bark and transported to the Product Technology Laboratory of the Federal University of Pará, Campus Altamira - PA, where were washed in running water followed by sanitization in chlorinated water (5 $mg.L^{-1}$) for one minute and then subjected to the minimum processing steps.

Minimal processing

Initially, the fruits were cut into 3.0 cm thick slices and peeled with a previously sterilized stainless steel knife and the seeds removed with the help of a spoon. The slices were cut into cubes of 3.0 x 3.0 x 3.0 cm and immersed in distilled water to remove excess cell juice. Afterwards, the cubes were sanitized in chlorinated solution (5 $mg.L^{-1}$) for one minute followed by rinsing in distilled water and left on sieve to drain excess water, before being weighed and packaged.

Packaging and storage

After drying the cubes were weighed (~ 200 g) and packed in the following packages:

i) Plastic sachet of polypropylene 48 microns (SPP), material commonly used by local retailers representing the control treatment;

ii) Expanded polystyrene tray coated with 14 micron PVC plastic film (BPE + PVC);

Polyethylene terephthalate (PET).

The packaged cubes were stored in refrigerator (10 ± 2 ° C) and 85% RH for a period of 12 days and evaluated every three days for physico-chemical and sensory characteristics.

Physical-chemical and sensory analyzes

The determinations were performed for: Weight loss, determined by weighing the packages in an accuracy scale of 0.01 g, and the results expressed as a percentage (%), estimated from the differences in mass of the experimental units between zero storage day and the day of evaluation.

Total soluble solids (TSS): determined through the cell phone was extracted from about 200 g of the sample after processing in a domestic centrifuge. The levels of SST were obtained with the aid of a digital refractometer with automatic temperature compensation and the results expressed in ºBrix (AOAC, 2012).

Titratable total acidity (TTA): determined by titrator, using 5 mL of the juice extracted for SST and homogenized in 45 mL of distilled water, plus 3 drops of 1% alcoholic phenolphthalein as indicator, using sodium hydroxide solution (NaOH) 0.1N until reaching the turning point for the rosy color. The results were expressed as percent citric acid equivalent to the amount of NaOH spent in the titration (AOAC, 2012).

Hydrogen ionic potential (pH): determined with the aid of a digital calibrated benchmark in buffer solution 4.0 and 7.0 by direct immersion of the electrode in the extracted SST juice (AOAC, 2012).

Total soluble solids and total titratable acidity (SST / ATT): obtained by the ratio between the content of SST and ATT and the results expressed by means of the absolute value found.

The sensorial quality was determined by the descriptive method through the assignment of notes based on a hedonic scale of five points on the following variables: firmness (5 = firm, 4 = moderately firm, 3 = slightly firm, 2 = weak firm 1 = soft) (Meezes et al., 2017) For pulp staining, occurrence of whiteness and general quality followed the methodology described by Dutcosky (2011) with modifications (9 = I liked it a lot; 7 = I liked it moderately; 5 = I did not like it I did not dislike it, I did not like it very much.

Experimental design and Statistical analysis

The experimental design was a completely randomized design (DIC) and a 3x5 factorial arrangement that corresponded to three packages (polypropylene plastic bag, expanded polystyrene tray covered with PVC plastic film and polyethylene terephthalate) and five days of evaluation (0, 3, 6 , 9 and 12 days), with three replicates and the experimental plot composed of 200 g samples.

The data were submitted to analysis of variance (ANAVA) followed by the Tukey test for multiple comparison between means at 0.05% significance level using statistical software Sisvar 5.6 (FERREIRA, 2011).

Results and discussion

The weight of loss is a very important factor in the storage of vegetables. According to Figure 1, it was observed that the loss of mass was constant throughout the 12 days of storage, being significantly higher ($p<0.05$) when packed in polyethylene terephthalate (PET) trays (5.21%) in relation to the squash kept in expanded polystyrene trays covered with PVC film (BPE+PVC) and polypropylene plastic bag (SPP), whose loss was 4.15 and 4.68%, respectively.

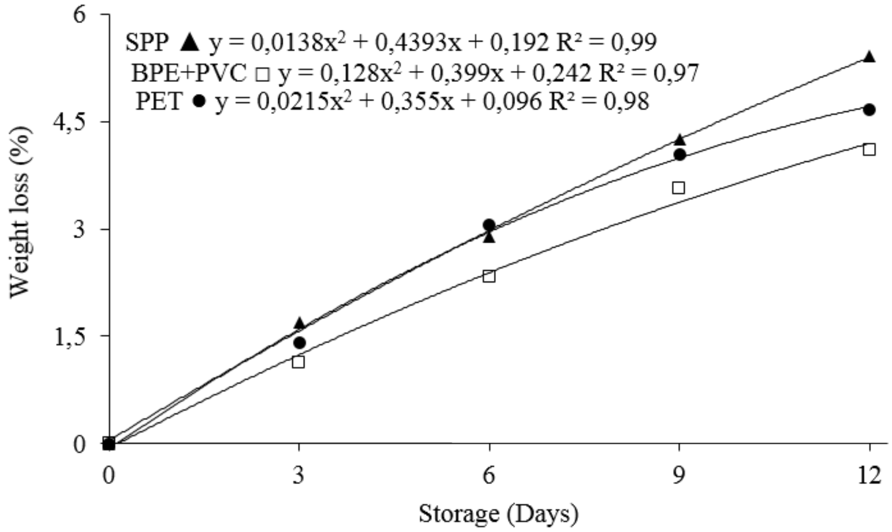

Figure 1. Weight loss (%) in minimally processed squash wrapped in different packages and stored under refrigeration (10ºC) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. SPP= polypropylene plastic bag; BPE+PVC= expanded polystyrene styrofoam tray + polyvinyl chloride film; PET= polyethylene terephthalate.

The weight loss is occurs due to storage time, respiration and the transpiration rate of the products leading to the loss of water, which is the main cause of the deterioration resulting in quantitative and qualitative losses (ARAÚJO e SHIRAI, 2016). In this sense, the lower mass loss observed in the BPE+PVC and SPP packages can be a reflection of the permeability control to water vapor and, thus, the gas exchanges with the environment.

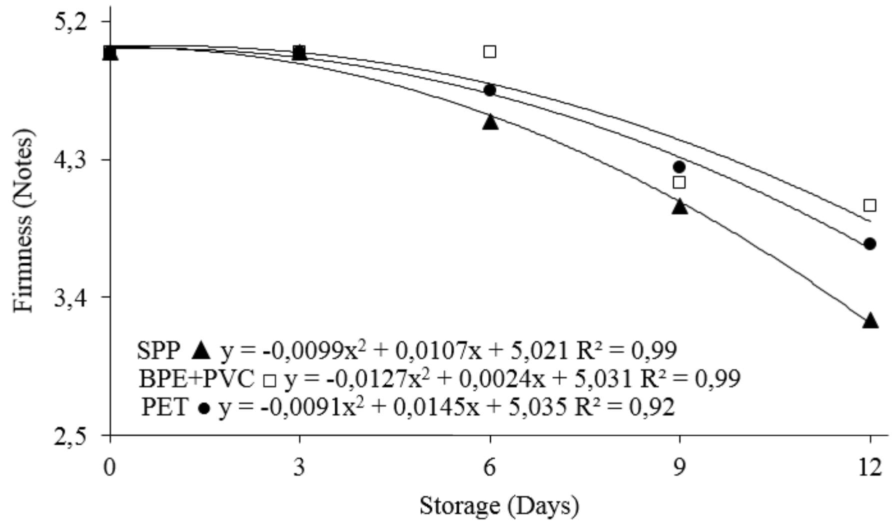

Figure 2. Firmness (notes) in minimally processed squash wrapped in different packages and stored under refrigeration (10 ºC) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. SPP = polypropylene plastic bag; BPE+PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

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A similar result was observed in yellow melon cubes packed in a polypropylene plastic bag and a styrofoam tray covered with PVC film whose mass loss was less than 3% in relation to the control (>5%) at the end of eight days of storage at 10 °C (ANTUNES et al., 2017).

The firmness was compromised with storage time ($p<0.05$) and in the different packages evaluated (Figure 2). The packing in both BPE + PVC and SP were efficient in preserving the firmness of the squash at the end of 12 days when they were characterized with a note 4 (moderately firm) differing ($p<0.05$) from the samples packaged in the PET packaging. the same period was 3.25 (slightly steady).

According to Chitarra and Chitarra (2005) the loss of firmness in plants occurs both by enzymes that degrade the structural carbohydrates that make up the cell wall and by the water content, since it is responsible for turgor and, consequently, for firmness. In this context, the preservation of firmness in the pumpkin cubes conditioned in BPE+PVC and SPP may be associated to the lower loss of fresh mass observed in these packages (Figure 1).

These results corroborate with those obtained by Sanches et al. (2015) in a study with minimally processed red pepper and by Silva et al. (2015) with radishes, whose packaging in plastic bag type and polystyrene styrofoam tray coated with PVC film were efficient in maintaining firmness during storage, respectively.

The content of total soluble solids (TSS) varied between day zero and day 12 between 3.40 and 2.55 ° Brix, respectively, with significant difference ($p<0.05$) in relation to the storage time and the packages used (Figure 3).

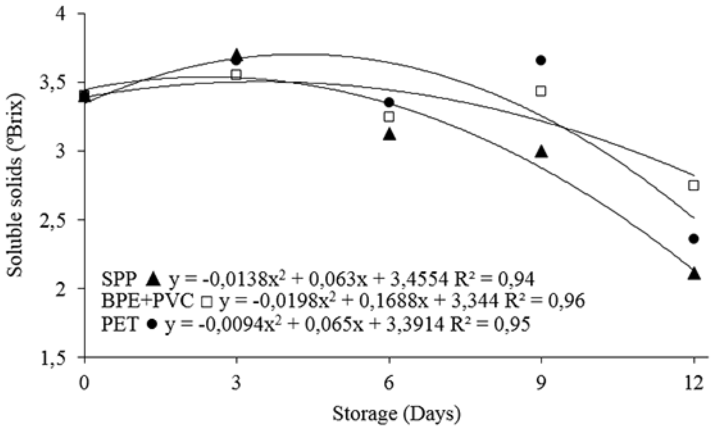

Figure 3. Soluble solids (ºBrix) in minimally processed squash packed in different packages and stored under refrigeration (10 ºC) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. SPP = polypropylene plastic bag; BPE+PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

According to Chitarra and Chitarra (2005), TSS are responsible for the taste of the vegetables, because they correspond to the sugars that are dissolved in the cellular environment, thus, the increase in their concentration is associated with the degradation of the carbohydrates whereas the reduction must the use of sugars in the respiratory and fermentative processes associated with the storage period.

In this study, stability in the content of SST over nine days may be a reflection of the control of factors such as storage temperature, relative humidity and the conservation packaging itself in the control of the metabolic activity of the samples. On the other hand, the reduction of TSS at the end of 12 days is due to the use of sugars as an energy substrate for respiration as a function of the advance in storage time.

Despite the decline in SST content at the end of storage, the squash cubes packed in BPE+PVC showed higher content, average of 2.75 ºBrix, differing significantly ($p<0.05$) from the samples kept in SPP type packages (2.36 ºBrix) and PET (2,11 °Brix), that is, this packaging delayed the degradation of the SST implying a longer shelf life.

The titratable total acidity (TTA) was only significantly affected ($p <0.05$) by the storage time factor. In general, there is a reduction in their contents over 12 days, regardless of the packaging used (Figure 4).

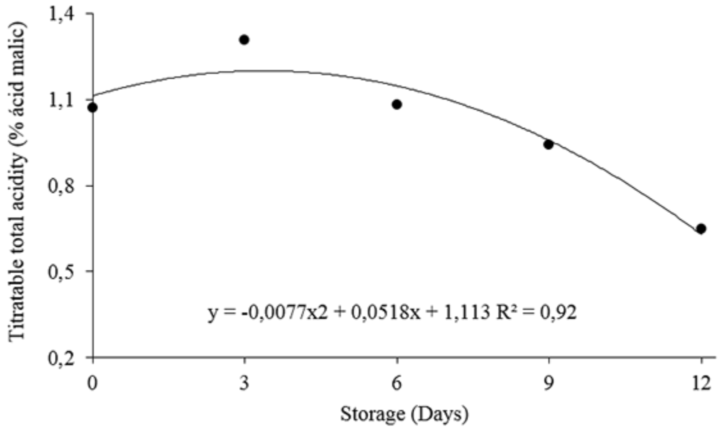

Figure 4. Titratable total acidity in minimally processed squash packed in different packs and stored under refrigeration (10 °C) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. SPP = polypropylene plastic bag; BPE+PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

According to Kluge et al. (2002) during the storage of plant products it becomes natural to reduce acidity, since organic acids are important sources of energy for vegetables. This fact allows to infer that the decrease in TTA content observed in this study may be related to the use of organic acids in the respiratory metabolism of squash.

The stress caused by the minimum processing also resulted in the decrease of ATT during the storage of sweet pepper (VILAS BOAS et al., 2012; SANCHES et al., 2015), cabbage (MORENO et al., 2016), pepper young finger (SOETHE et al., 2017), regardless of the packaging used.

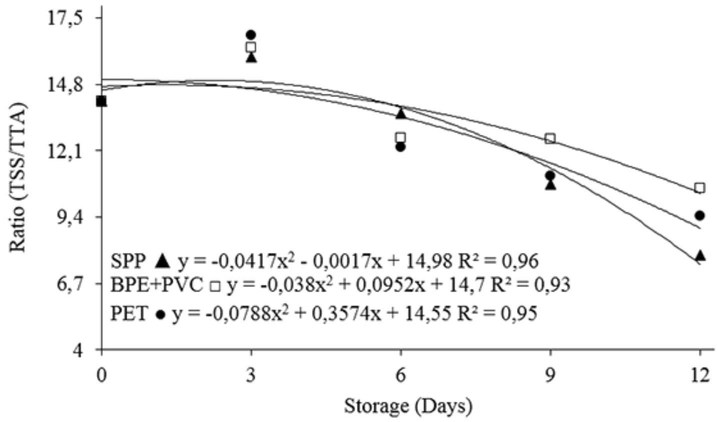

Figure 5. TSS/TTA ratio in minimally processed squach wrapped in different packages and stored under refrigeration ( ) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. SPP = polypropylene plastic bag; BPE+PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

The TSS/TTA ratio is an important indicative of flavor through the balance between sugars and acids (CHITARRA and CHITARRA, 2005). According to Figure 5, it was observed that there was a significant difference over the storage time and the packages used ($p < 0.05$).

In this work, there was a tendency to reduce the values of the TSS/TTA ratio, going from 13.8 on day zero to a mean value of 9.5 at the end of 12 days of storage. Similarly, Russo et al. (2012) also observed a decrease in the SST / ATT ratio of processed squash whose values went from 13.2 (day zero) and 8.0 (day 12) storage at 5 ºC.

The packaging of pumpkin cubes in BPE+PVC and SP packaging had a significantly higher average value ($p<0.05$) 10.16 and 9.83, respectively, when compared to the samples kept in PET packaging (8.16) at the end of 12 days of storage, that is, they are more efficient in the preservation of the attributes of quality TSS and TTA related to the flavor.

The pH was affected only by storage time ($p<0.05$). In general, values ranged from day zero to day 12 of 7.09 and 6.99, respectively.

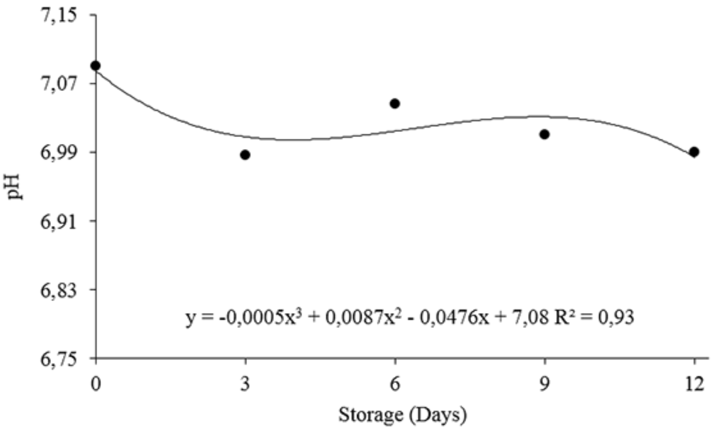

Figure 6. pH in minimally processed squash packed in different packages and stored under refrigeration (10 ºC) for 12 days. Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. ns = not significant. SPP = polypropylene plastic bag; BPE+PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

According to Rinaldi et al. (2009) high values of pH during storage is indicative of the presence of microorganisms, so the maintenance of this variable in this study may be a reflection of the steps of sanitization and refrigerated storage. Vilas Boas et al. (2012), working with chilies found that the mean pH values were not affected by the packaging package.

There was a significant effect ($p<0.05$) on storage time and packing on pulp color, occurrence of whitening and overall quality of squash.

The color of pulp in processed products is an important attribute of quality for the consumer. With the storage time, the color of the pulp was degraded due to the oxidation of carotenoids in all packages, observing note 9 (I liked it a lot) on day zero and an average grade of 6 after 12 days. Samples packed in BPE+PVC packages were characterized with note 7 (moderately liked) differing significantly ($p<0.05$) from the squash kept in the SPP and PET packages (5, neither liked nor disliked) after 12 days.

The whitening of the tissues is a result of the injured surface and includes physical responses due to the color change due to the loss of water and physiological through the activation of phenolic compounds and lignin synthesis (BOLIN e HUXSOLL, 1991; CISNEROS-ZEVALLOS et al., 1995). The formation of this whitish layer on the cut surface gives the product an aged appearance compromising consumer acceptance.

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Table 1. Pulp color, occurrence of whiteness and general quality of minimally processed pumpkins conditioned in different packages and stored under refrigeration (10 ºC) for 12 days.

Days	Pulp color			Whiteness			Quality general		
	SPP	BPE+PVC	PET	SPP	BPE+PVC	PET	SPP	BPE+PVC	PET
0	9 aA	9 aA	9 aA	9 aA	9 aA	9 aA	9 aA	9 aA	9 aA
3	7 bA	9 aA	7 bA	7 bA	9 aA	7 bA	7 bA	9 aA	7 bA
6	7 aA	7 aA	7 aA	7 aA	7 aA	7 aA	7 aA	7 aA	7 aA
9	7 aA	7 aA	5,65 bB	5,25 bB	7 aA	5,75 bB	7 aA	7 aA	5 bB
12	5,65 bB	7 aA	5 bB	5 bB	7 aA	4,75 bB	5 bB	7 aA	5 bB

Lowercase letters (caps) and uppercase letters (days) do not differ by Tukey test at 0.05% probability. ns = not significant. SPP = polypropylene plastic bag; BPE + PVC = expanded polystyrene styrofoam tray + polyvinyl chloride film; PET = polyethylene terephthalate.

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The highest occurrence of whitening occurred after the sixth day of storage, so that at day 12, the squash conditioned in BPE+PVC were characterized with a higher grade (7, moderately liked) differing significantly ($p<0.05$) from the samples kept in plastic bag and PET that received an average grade of 5 (neither liked nor disliked).

To Jedermann et al. (2014) the quality of the vegetable product depends on both the consumer market and the consumer's view through properties such as: color, firmness, presence of microorganisms, appearance, texture and taste. In this sense, the loss of quality observed over 12 days is due to factors associated with loss of fresh mass (Figure 1).

Regarding the effect of the packages, the BPE+PVC preservation preserved the general quality of the squash after 12 days, differing significantly ($p <0.05$) from the samples kept in SPP and PET, observing scores of 7 (moderately liked) and 5 (neither liked nor disliked).

Packaging of minimally processed jambu in polystyrene tray coated with PVC film also ensured better overall quality of the samples after 12 days of storage at 10 ° C (OLIVEIRA et al., 2017).

Conclusion

The packaging of minimally processed squash in polystyrene polystyrene tray coated with PVC film (BPE+PVC) guarantees the preservation of the physical-chemical and sensorial quality during 12 days of storage at 10 ºC.

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