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Revestimentos com filme PVC promovem a conservação pós-colheita de frutos abobrinhas italiana (*Cucurbita pepo* L.)

PVC film coatings promote post-harvest conservation of Italian zucchini fruits (Cucurbita pepo L.)

Los recubrimientos de película de PVC promueven la conservación poscosecha de las frutas italianas de calabacín (Cucurbita pepo L.)

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Resumo

O objetivo do estudo foi avaliar a influência das condições de armazenamento sobre a vida útil pós-colheita de frutos de abobrinhas italianas. Foram avaliadas as abobrinhas sem revestimento e recobertos com filme PVC nas temperaturas de armazenamento de 10 e 25 ºC. As avaliações foram realizadas aos 0, 5, 10, 15 e 20 dias consecutivos. Aos 20 dias as abobrinhas acondicionadas com filme PVC à 10°C apresentaram as menores perdas de massa fresca (0,84%), mostrando-se como sendo a condição mais eficiente na redução de perda de massa e manutenção dos aspectos visuais dos frutos. A 10 ºC independente de embalagem, foi a condição que ocasionou menores perdas de firmeza dos frutos. No acondicionamento com PVC à 25 ºC verificou-se o menor teor de sólidos aos 20 dias e incrementos até os 15 dias para com posterior declínio aos 20 dias para a acidez total titulável, entretanto, para os frutos sem embalagem e independente da temperatura os aumentos foram verificados até o final do período de armazenamento. Também ao longo dos dias de armazenamento, constatou-se variações no pH dos frutos armazenados sem embalagem, e uma redução acentuada no pH das abobrinhas acondicionadas com filme PVC, independente da temperatura de armazenamento, até os 20 dias. Assim, os frutos acondicionados a 10 ºC com ou sem embalagens apresentaram menor perda de biomassa. Armazenar frutos de abobrinha italiana, primeiramente, sob baixa temperatura, apenas, ou revestidos com PVC, porém sob baixa temperatura, são condições que diminuem a atividade das enzimas de solubilização de componentes de parede, com manutenção da turgescência dos tecidos, prolongando sua vida útil.

Palavras-chave: Baixa temperatura; Enzimas; Metabolismo; Perda de massa; Respiração.

Abstract

We evaluated the influence of storage conditions on the postharvest life of Italian zucchini fruits. Zucchinis with and without PVC coating film were evaluated at storage temperatures of

10 and 25 ºC. Evaluations were carried out at 0, 5, 10, 15 and 20 consecutive days. Zucchinis packed with PVC film at 10 °C showed the lowest losses of fresh mass (0.84%), being the most efficient condition in reducing mass loss and maintaining the good aspects of the fruits. The treatments using 10 ºC resulted in less loss of fruit firmness, regardless of packaging. Packaging with PVC at 25 ºC presented the lowest solids content at 20 days and increments up to 15 days of tritatable total acidity, with a subsequent decline at 20 days. Tritatable acidity increased until the end of the storage period in fruits without packaging. We found a variable pH in fruits without packing and a pH reduction in fruits with PCV packing regardless of temperature. Fruits stored at 10 ºC with or without packing showed smaller biomass loss. Storing Italian zucchini fruits at low temperature or coated with PVC at low temperature decrease the activity of the enzymes of solubilization of the wall components, maintaining the turgor of the tissues and extending their useful life.

Keyword: Low temperature; Enzymes; Metabolism; Weight loss; Respiration.

Resumen

El objetivo del estudio fue evaluar la influencia de las condiciones de almacenamiento en la vida poscosecha de las frutas del calabacín italiano. Fueron evaluados como calabacines sin recubrimiento y cubiertos con películas de PVC a temperaturas de almacenamiento de 10 y 25 ºC. Las evaluaciones se realizaron a los 0, 5, 10, 15 y 20 días consecutivos. A los 20 días, como los calabacines están empacados con películas de PVC a 10 °C, aparecen como una menor pérdida de masa fresca (0,84%), lo que demuestra ser una condición más eficiente para reducir la pérdida de masa y mantener los aspectos visuales. de las frutas A 10 ºC, independientemente del embalaje, era una condición que causaba menos daño a la firmeza de las frutas. Sin embargo, ningún empaque con PVC a 25 ºC es menor o menor que 20 días e incrementa hasta 15 días para una disminución adicional de hasta 20 días para una acidez titulable total, sin embargo, para las frutas sin empaque e independientemente de la temperatura o los aumentos se verificaron hasta el final de periodo de almacenamiento. También durante los días de almacenamiento, manteniendo el pH de las frutas sin embalaje, y una marcada reducción en el pH de los calabacines condicionados con películas de PVC, independientemente de la temperatura de almacenamiento, hasta 20 días. Por lo tanto, las frutas empacadas a 10 ºC con o sin empaque tienen menos pérdida de biomasa. El almacenamiento de las frutas italianas de calabacín, el almacenamiento, solo a baja temperatura o recubierto con PVC, pero a baja temperatura, son condiciones que disminuyen

la actividad de las enzimas solubilizantes de los componentes de la pared, mantienen la turbulencia de los tejidos y prolongan su vida útil.

Palabras clave: Baja temperatura; Enzimas Metabolismo; Pérdida de peso; Respiración.

1. Introduction

Italian zucchini (*Cucurbita pepo*), also known as clump, trunk, or tree zucchini in Brazil, belongs to the Cucurbitaceae family with an erect growth habit, short stem, and typical clump shape. The fruits have an elongated cylindrical shapes with soft buds, the average weight of 0.5 kg, and are consumed "green", in the intermediate stage of maturation (Filgueira, 2013).

In Brazil, zucchini is one of the ten most produced vegetables and have high economic value, also stood out for its great potential for commercialization and good acceptance by consumers, therefore, having great economic importance (Azambuja et al., 2015).

Italian zucchini is well accepted by consumers, among immature harvested pumpkins, because they are harvested 45-60 days after sowing, presenting between 15 to 25 cm in length and 4 to 6 cm in diameter, the pulp is tender, and seeds are in formation, making them prone to injuries and skinning. They are packed mainly in "K" boxes with a net weight of around 24 kg (Filgueira, 2013).

Post-harvest losses of zucchinis are enhanced by the packaging adopted. Besides, bulk storage and at ambient conditions contribute to severe injuries to the fruit due to compression and cutting, given the poor arrangement and heaping in the boxes.

Much of post-harvest losses are due to the transport and distribution from the field to the marketing center, resulting from excessive handling and inadequate packaging. Still, the poor maintenance of the highways increasing the vibration and, as a consequence, mechanical injuries, exacerbate the problem.

The vegetable quality depends on the technology used from the field to commercialization. Among the techniques used after harvest, the packaging and cold storage have as main objective the reduction of the metabolic activity of vegetables, which consequently prolongs the post-harvest life of these products.

Mechanical damage during transport is enhanced by the lack of protection, which could be avoided if packed. Knocks and cuts can lead to microbial infections, accentuating losses, especially when the storage time is long and under environmental conditions of temperature (Ishii et al., 1993).

Injuries to the fruits increase the release of CO_2, given the intense respiration of the cells near the damaged site. The increase in respiratory rate triggers an increase in ethylene concentration, accelerating the ripening and senescence process, decreasing the quality and useful life of the fruit (Chitarra; Chitarra, 2005).

Refrigeration during the storage of fruits and vegetables reduces the respiratory rate, ethylene production, microbial activity and senescence intensity (Hardenburg, et al., 1986; Kalbasi-Ashtari, 2004; Wang, 1994). On the other hand, packaging promotes the modification of the atmosphere, changing the concentration of carbon dioxide, oxygen and ethylene, causing a reduction in respiratory rate, water loss, and delaying the maturation and deterioration of vegetables. Besides, packaging can reduce economic losses, facilitate the handling and distribution of products without compromising quality (Brunini et al., 2004).

The literature indicates that the combination of packaging and storage temperatures can provide a more extended postharvest conservation period for fruits and vegetables. We infer that the search for reductions in losses may be more important than increases in production since the product is lost close to the point of consumption, and the resources involved in the production process are completely wasted.

Although there is innumerable information on losses in vegetables and the application of techniques aimed at minimizing the loss and maintaining the postharvest quality of vegetables, there is scarce information about the postharvest conservation of cucurbits. Therefore, our objective was to evaluate the influence of storage conditions on the postharvest shelf life of Italian zucchini fruits.

2. Material and Methods

The experiment was conducted in the multidisciplinary laboratory of the Universidade Federal do Oeste da Bahia, Campus de Barra – BA, Brazil. The Italian zucchinis, from the variety Brenda, were produced in the area of vegetable production of the Campus de Barra, during 60 days, according to the methodology given by Filgueira (2013). Subsequently, they were collected and taken to the laboratory to carry out the experiments.

In the laboratory, the fruits were selected and standardized to eliminate those with mechanical, physiological, and microbiological damage. Zucchinis were sanitized by immersion in sodium hypochlorite solution at 100ppm for 20 minutes, dried at room temperature, and again standardized. For dry, the fruits were placed in plastic trays lined with paper towels at room temperature and then were packed, according to each treatment.

The experiment consisted of a completely randomized design of 4x5 factorial scheme, with four replications each. The factors were the storage conditions (which involved packaging and temperatures) and the storage period. The storage conditions were: without packaging and stored at 10 ºC, without packaging and stored at 25 ºC, coated with PVC (polyvinyl chloride) and stored at 10 ºC and coated with PVC and stored at 25 ºC. The storage periods were 0, 5, 10, 15 and 20 consecutive days. Each experimental unit was composed of 2 fruits. The relative humidity (RH) was 80%, monitored with Thermo Hygrometer.

To analyze the accumulated fresh weight loss and fruit firmness during storage, we weigh the fruits at the time of installing the experiment (time 0) and at each evaluation period, establishing the end of the experiment as the shelf life period through visual analysis. The results were expressed as a percentage of fresh weight loss, according to Moretti (2006).

The firmness of the fruits was evaluated by the applanation technique according to Calbo and Calbo (1989), Calbo and Nery (1995) and Calbo et al. (1995).

The visual analysis was carried out evaluating the external appearance of the fruits, assigning scores according to Durigan and MTTAiuz (2007), with adaptations. The grade 5 (excellent) was attributed to the fruits in perfect conditions of commercialization, considering light green peel, smooth and shiny, apparently immature, juicy and soft, absence of rot, clear and soft pulp. In grade 4 (good) the fruits have good commercial conditions, but with darker green skin, less shiny, without rot and clear and soft pulp. The Grade 3 (regular) was assigned to fruits with dark, wrinkled, slightly withered skin, hard or soft fruits, without rot and characteristic pulp. For grade 2 (bad), the fruits had dark, wrinkled, very withered skin, fruits that were too hard or soft, the beginning of rot and hard or darkened pulp. Grade 1 (very bad) was attributed to fruits with too dark coloring or blackish spots, apparent rot, very withered, wrinkled skin, lesions, and darkened pulp, consisting of no consumption conditions. We arrenged the fruits graded of two and one, as they were unfit for commercialization, determining the end of the experiment.

For chemical analysis, 100 g of previously processed fruits were used until obtaining pasty juice. From which the analyses of total soluble solids, pH, and titratable acidity content were performed.

The concentration of total soluble solids (TSS) was determined using a digital refractometer with automatic temperature compensation and precision of 0.1% at 25 ºC. Five to six drops of the homogenized juice were added to the reader, the results were expressed in °Brix (IAL, 2008).

Total titratable acidity was determined by neutralization titrometry, adding 50 mL of water in 10 g of pulp, and two to three drops of 1% phenolphthalein. Titration was performed with 0.1 N NaOH until the solution was completely pink. The results were expressed as a percentage of citric acid (g citric acid/100 g leaves) (IAL, 2008).

The pH was measured with a bench-top digital pHmeter standardized with standard solutions of pH 4 and pH 7, directly by immersing the pHmeter electrode in 10 mL of fruit juice (IAL, 2008).

For the determination of TSS/TTA ratio, we used the contents of total soluble solids and total titratable acidity of the same sample.

The data was analyzed using an analysis of variance for each day of evaluation, and the averages of the treatments were compared with each other using the Tukey test at the level of 5% probability. We used the software Sisvar version 5.6 (Ferreira, 2011).

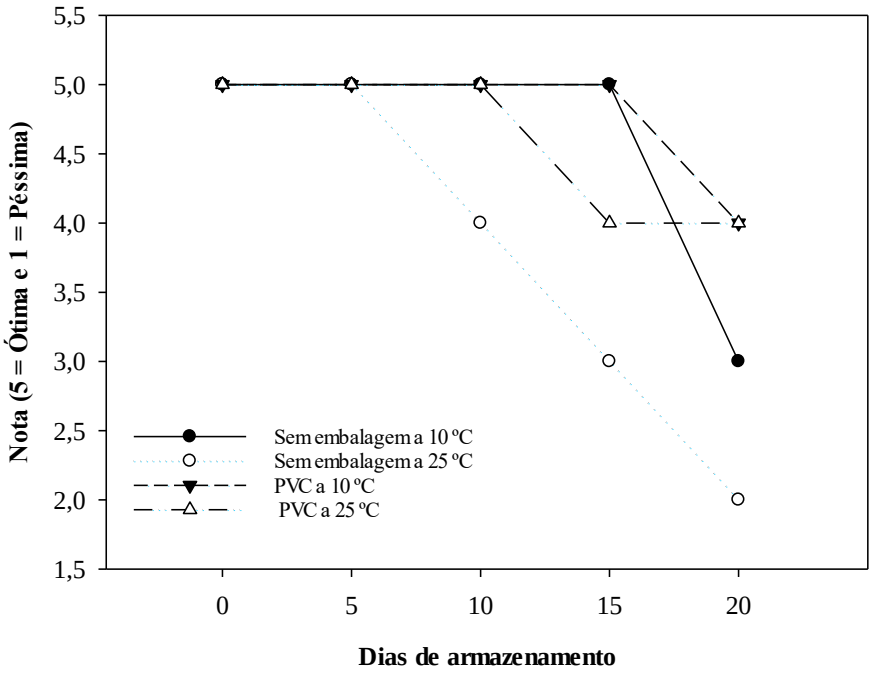
3. Results and Discussion

We verified that zucchini fruits had a 20-day durability. However, the visual aspect of fruits at the end of the experiment was different among treatments, depending on the storage conditions (Figure 1).

Fruits packed with PVC at 10ºC remained with excellent appearance (note 5) until the 15th day and reached the end of the evaluation period in good commercial condition (note 4), according to the analysis of the visual aspect. The fruits packaged and stored at 25 ºC showed good appearance (grade 4) from 15 to 20 days of storage (Figure 1). Therefore, it is possible to extend the period of storage, as the fruits are in perfect condition for consumption. These results show the effectiveness of the use of packaging in the post-harvest conservation of Italian zucchini fruits since packaging protect the fruit against abrasion, cuts and water loss.

Zucchinis stored without packaging at 25 ºC showed a rapid decline in fruit quality during storage (note 2), and at the end of the storage the fruits were wrinkled, very withered and with rotting beginnings, unfit for consumption, thus, this condition should not be recommended for conservation (Figure 1). The ideal storage conditions for Italian zucchinis are between 5° and 10° C and 95% relative humidity (EMBRAPA, 2011). As it is a very perishable product, zucchinis can be stored for periods less than 10 days, since the fruits begin to show wilting, yellowing, and rotting after two weeks of storage, even when in ideal temperature conditions (Suslow; Cantwell, 2009; EMBRAPA, 2011).

Figure 1. Effect of storage conditions (packaging and temperature) on the visual evaluation grades of Italian zucchini fruits (*Cucurbita pepo*).



Source: Authors.

We found an interaction between storage conditions and evaluation time for all variables analyzed (Tables 1 and 2).

Table 1. Effect of storage conditions (packaging and temperature) on fresh weight loss and pulp firmness (N) of zucchini fruits (*Cucurbita pepo*).

Storage conditions	Fresh weight loss (%)**				
	Storage time (days)				
	0	5	10	15	20
Without packing 10 ºC	0.0 Ac	1.6 Abc	3.5 Abc	4.2 Ab	14.2 Aa
Without packing 25 ºC	0.0 Aa	4.3 Aa	7.7 Aa	6.5 Aa	13.0 Aa
PVC packing 10 ºC	0.0 Ab	0.6 Ab	1.5 Aab	0.9 Aab	0.8 Ba
PVC packing 25 ºC	0.0 Ab	3.0 Ab	4.6 Ab	8.2 Ab	17.4 Aa
MSD column			7.6		
MSD line			8.0		
CV (%)			18.7		
	Firmness (N)**				
	Storage time (days)				
	0	5	10	15	20
Without packing 10 ºC	1.53 Aa	1.24 Ab	1.05 Ac	0.63Ad	0.56 Ad
Without packing 25 ºC	1.11 Ba	1.10 Ba	0.82 Bb	0.60 Ac	0.21 Bd
PVC packing 10 ºC	1.64 Aa	1.30 Ab	0.62 Cc	0.52 Bc	0.19 Bd
PVC packing 25 ºC	0.88 Ca	0.48 Cb	0.40 Db	0.29 Cc	0.25 Bc
MSD column			0.13		
MSD line			0.13		
CV (%)			16.30		

Means followed by the same letter, uppercase in the column and lowercase in the row, do not differ by the Tukey test at the 5% probability level. **: significant at the level of 1% probability by the F test. MSD test: minimum significant difference. CV (%): coefficient of variation. Source: Authors.

Fruit weight loss increased in all storage conditions throughout the storage period. However, at 20 days, zucchinis packed with PVC film at 10 °C showed the lowest losses of fresh mass (0.84%), being most efficient in reducing mass loss and maintaining the visual aspects of fruits (Table 1 and Figure 1).

Storage at a lower temperature, which reduces the respiratory rate, and the coating with PVC film, acting as a physical barrier reducing transpiration, both minimized the loss of mass and prolonged the quality and shelf life of cabbages (Guerra et al., 2019). Mota et al. (2010) also found similar result using PVC film at temperatures of 5 ºC and 10 ºC in controlling the loss of fresh matter of okra fruit due to the formation of a mechanical barrier to water loss, abrasions and injuries to the fruits, resulting in reductions in respiratory activity and deterioration.

All treatments reduced the fruit firmness during storage. However, the PVC coating at 25 ºC caused more significant loss of firmness. On the other hand, at 10 ºC regardless of packing showed the lowest loss of fruit firmness (Table 1). These results show the effect of low temperature in delaying the metabolic activity of ripening, decreasing the respiratory rate and the consumption of organic reserve substrates, maintaining the firmness of the fruits.

The post-harvest quality of Italian zucchini is related, among other factors, to the degree of fruit ripeness, since zucchinis are harvested and consumed immature (Suslow; Cantwell, 2009; EMBRAPA, 2011). Therefore, ripening is undesirable, as it implies softening the tissues, hardening the seed coat, reducing the acceptability of the product by consumers.

During the ripening, changes occur, such as degradation of celluloses, hemicelluloses and pectins that make up cell walls (Hopkins; Huner, 2009; Paixão, 2016) leading to the softening of tissues.

To ensure the durability of Italian zucchini fruits, ensuring pulp firmness and meeting the consumer's preference, it is preferable to store them under low-temperature conditions. We also emphasize the care when handling to avoid shocks, injuries and abrasions, to decrease the metabolic rate with the postponement of cell wall degradation and tissue softening.

We found an interaction between the conditions and storage time on the chemical parameters of zucchini fruits (Table 2). The levels of soluble solids fluctuated according to conditions throughout the storage period. A successive decline in the levels of solids occurred up to 15 days in all storage conditions, with a subtle increase at 20 days. The lowest solid content was found in packaging with PVC at 25 ºC at 20 days (Table 2).

Fruits coated with PVC at 10 and 25 ºC, showed an increment of total titratable acidity up to 15 days, with subsequent decline at 20 days, however, for fruits without packaging and regardless of temperature, the increases occurred until the end of the storage period (Table 2). We found variations in the pH of the fruits stored without packaging, and a marked reduction in the pH of the zucchinis packed with PVC film, regardless of the storage temperature, until 20 days (Table 2). Thus, fruits stored at 10 ºC with or without packaging showed less biomass loss (Tables 1 and 2). TSS/TTA ratio varied according to the storage conditions. Fruits covered with PVC and stored at 10 ºC experienced a decrease of TSS/TTA ratio until 15 days and a subsequent increase at 20 days, indicating the intensification and subsequent reduction in respiratory activity (Table 2).

We infer that this behavior is a result of the increase in metabolic activity, because the increases in citric acid contents that occurred parallel to the reduction in soluble solids and pH

levels, therefore are an indicative of the intensification in respiratory activity and consumption of available organic acids and solids which act as substrates for the respiratory process. This observation is stronger in fruits packed at 25 ºC regardless of packaging. Thus, the elevated temperature causes a proportional increase in the respiratory rate and the consequent consumption of organic reserve substrates such as reducing and non-reducing sugars (Paull, 1999; Lee; Kader, 2000).

Table 2. Effect of storage conditions (packaging and temperature) on Total Soluble Solids - TSS (ºBrix), pH, Total Titratable Acidity - TTA (% - g citric acid/100 g of fruit) and Total Soluble Solids/Total Titratable Ratio (TSS/TTA) in fruits of Italian zucchini (*Cucurbita pepo*).

	Total Soluble Solids (ºBrix)**				
	Storage time (days)				
	0	**5**	**10**	**15**	**20**
Without packing 10 ºC	4.1 ABab	3.7 Ab	2.6 Bc	3.4 Abc	4.7 Aa
Without packing 25 ºC	5.1 Aa	4.3 Aab	3.6 Abc	3.1 Ac	4.0 Ab
PVC packing 10 ºC	3.7 Bab	3.9 Aab	3.3 ABbc	2.8 Ac	4.5 Aa
PVC packing 25 ºC	4.4 Ba	3.9 Ab	3.6 Abc	3.0 Ac	3.0 Bc
MSD column			0.8		
MSD line			1.0		
CV (%)			11.7		
	pH**				
	Storage time (days)				
	0	**5**	**10**	**15**	**20**
Without packing 10 ºC	7.4 BCab	7.1 Bb	7.1 Cc	7.2 Aab	7.3 Aa
Without packing 25 ºC	7.0 Cb	6.1 Cc	5.8 Bc	7.2 Aab	7.6 Aa
PVC packing 10 ºC	8.1 Aa	7.9 Aa	7.8 Aa	5.9 Bb	5.7 Bb
PVC packing 25 ºC	7.5 Ba	7.7 Aa	7.9 Aa	5.6 Bb	6.0 Bb
MSD column			0.4		
MSD line			0.4		
CV (%)			3.3		
	TTA (% Citric acid) **				
	Storage time (days)				
	0	**5**	**10**	**15**	**20**
Without packing 10 ºC	0.06 Cd	0.08 Cc	0.11 Bb	0.10 Cb	0.17 Aa
Without packing 25 ºC	0.13 Ab	0.19 Aa	0.10 BCc	0.11 Cc	0.18 Aa
PVC packing 10 ºC	0.03 Dd	0.07 Cc	0.08 Cc	0.29 Aa	0.11 Bb
PVC packing 25 ºC	0.08 Bd	0.11 Bc	0.13 Ab	0.25 Ba	0.11 Bc
MSD column			0.02		
MSD line			0.02		

CV (%)	11.50				
	TSS/TTA**				
	Storage time (days)				
	0	**5**	**10**	**15**	**20**
Without packing 10 ºC	4.41 Ba	3.11 ABab	1.60 Ac	2.16 Abc	1.77 Ac
Without packing 25 ºC	2.63 Ca	1.49 Ca	2.34 Aa	1.81 ABa	1.44 Aa
PVC packing 10 ºC	7.30 Aa	3.88 Ab	2.54 Ac	0.62 Bd	2.51 Ac
PVC packing 25 ºC	3.64 BCa	2.37 BCab	1.77 Abc	0.78 Bc	1.84 Abc
MSD column	1.24				
MSD line	1.32				
CV (%)	26.10				

Means followed by the same letter, uppercase in the column and lowercase in the row, do not differ by the Tukey test at the 5% probability level. **: significant at the level of 1% probability by the F test. MSD test: minimum significant difference. CV (%): coefficient of variation.Source: Authors.

The TSS values indicate a tendency to increase with maturity due to the mass loss that agglomerates and concentrates the solids, also, due to biosynthesis, degradation of the polysaccharides or, even, by the great loss of water by the plants, which causes their accumulation (Oshiro et al., 2012). Besides, the loss of firmness is directly associated with the solubilization of pectic substances, that during maturation, the insoluble pectin transforms into soluble pectin, softening and reducing the resistance of tissues (Russo et al., 2013). On the other hand, the decrease in acids may be related to the ripening of vegetables during storage because of their use in the Krebs cycle, during the respiratory process of fruits or to the solubilization of pectins, which makes the medium more acidic (Durigan; Mttaiuz, 2007).

Storing Italian zucchini fruits at low temperatures alone or coated with PVC at low temperature are conditions that decrease the activity of solubilizing enzymes of wall components, maintaining the tissue turgor. Therefore, using this conditions, it is possible to prolong the firmness and useful life of those fruits.

Confirming our results, similar results were found using cabbages stored at 20 ºC with or without PVC (Guerra et al., 2019). Guerra et al. (2019) observed that the amount of organic acids decreased with the increase in pH, causing increases in the TSS/TTA ratio (GUERRA et al., 2019). Also, when packing and storing 'SASSY F1' cucumber fruits in LDPE and PVC packaging at 13 ± 2 ° C, lower levels of solids and pH were verified (Antoniali, 2012).

Therefore, we infer that the associated adoption of lower temperatures with PVC coating on Italian zucchinis decrease the respiratory, deteriorative and senescence processes, favoring the deceleration of biochemical metabolism, leading to a slower consumption of

organic acids and reserves and the prolongation of post-harvest life and adequate conditions for fruit consumption.

4. Conclusions

The association between the PVC film packaging and the temperature at 10 ° C provided less biomass loss in the zucchini fruits during the storage period.

Refrigerated storage is efficient in maintaining the firmness of fruits packed or not with PVC.

PVC film maintained the good appearance of the fruits for up to 20 days at the two temperatures studied.

Packaging provided a physical barrier preventing abrasions and injuries that trigger intense respiratory activity. However, the best way to store with packaging is at 10 ºC.

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