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SCIENTIFIC ARTICLE

Use of post-harvest films for the maintenance of the visual attributes and ethylene production of ornamental mini-pumpkins

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Abstract

In recent years, consumers have shown interest in the ornamental use of some fruits that were previously used mainly for food purposes. However, the use of 'mini-pumpkins' for ornamentation can be limited by post-harvest aspects, such as skin depigmentation, fresh mass losses, ethylene production and respiration, which compromise the visual quality of the product, resulting in the loss of its ornamental value. The objective was to evaluate the effect of films application (control, carnauba wax, cassava starch and corn starch) in post-harvest of ornamental mini-pumpkins, aiming the shelf life prolongation (experiment 1) and reduction of ethylene production and respiration (experiment 2). The results obtained in experiment 1 pointed to lower mass loss and maintenance of the ornamental mini-pumpkins epidermis color with the application of carnauba wax film. In experiment 2, the application of carnauba wax and the ethylene action inhibitor (1-MCP) did not and respiration production of mini-pumpkins, suggesting that ethylene is not involved in the modifications that occur in the product during the time of exposure to the environment.

Keywords: Cucubitaceae; carnauba wax; pigments; fresh mass loss; 1-methylcyclopropene.

Resumo

Uso de películas pós-colheita para a manutenção dos atributos visuais e produção de etileno em mini-abóboras ornamentais

Nos últimos anos, o mercado consumidor tem mostrado interesse no uso ornamental de alguns frutos que anteriormente eram empregados principalmente para fins alimentares. No entanto, o uso das chamadas 'mini-abóboras' para ornamentação pode ser limitado por aspectos ligados à pós-colheita, como despigmentação da casca, perda de massa fresca, produção de etileno e respiração dos tecidos, que comprometem a qualidade visual do produto, resultando na perda de seu valor ornamental. O objetivo do trabalho foi avaliar o efeito da aplicação de películas (testemunha, cera de carnaúba, fécula de mandioca e amido de milho) em pós-colheita de mini-abóboras ornamentais no prolongamento da vida de prateleira, através da conservação dos pigmentos da casca, manutenção da massa (experimento 1) e redução da produção de etileno e respiração (experimento 2). Os resultados obtidos no experimento 1 apontaram para menor perda de massa e manutenção da cor da epiderme de mini-abóboras ornamentais com a aplicação de película de cera de carnaúba. No experimento 2, a aplicação de cera de carnaúba e o inibidor da ação do etileno (1-MCP) não afetaram a produção de etileno e respiração das mini-abóboras, sugerindo que o etileno não está envolvido nas modificações que ocorrem no produto durante o tempo de exposição ao ambiente.

Palavras-chave: Cucubitaceae; cera de carnaúba; pigmentos; perda de massa, 1-metilciclopropeno.

Introduction

Over the last years, researchers have studied the ornamental use of plants traditionally exploited for food, especially those that produce fruits, such as peppers (Neitzke et al., 2010), pumpkins (Boiteux et al., 2007; Fischer et al., 2015; Fischer et al., 2016), pineapples (Souza et al., 2007) and tomatoes (Embrapa, 2014). Despite the recent interest in the research, the ornamental use of fruits has been reported since the period of navigations, when Europeans took the tomato fruit from the Americas to Europe in the 16th century for decorative purposes and later began to explore it as food (Razdan and Mattoo, 2006).

The pumpkins, which were also widespread in Europe in the 16th century (Paris et al., 2006), show consolidated ornamental use in North America, especially in the central and northern regions of the United States and in the southern region of Canada, with harvest in October and November (Wien et al., 2004), reaching high market values, both for decorative and food purposes (Waterer, 2000). In Brazil, especially in the state of Rio Grande do Sul, Fischer et al. (2015) found excellent acceptance of ornamental

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pumpkins by final consumers and floral decorators, and also highlighted the great potential of use and value of this species. Due to the potential of exploring new high value-added market niches (Boiteux et al., 2007), the production of ornamental mini-pumpkins can be seen as an alternative source of income, especially in family farming.

The ornamental mini-pumpkins (*Cucurbita maxima*, *C. moschata* e *C. pepo*), belong to the Cucurbitaceae family and originate from Americas (Fischer et al., 2016). They are annual plants, with herbaceous stem, prostrate growth habit and provided with tendrils. The fruits are extremely diverse with respect to size, shape, color and texture (Fischer et al., 2012).

However, the ornamental use of these fruits can be limited especially by changes in the color of the skin (depigmentation) (Boiteux et al., 2007). According to Waterer (2000), the fruit pigmentation is crucial for the ornamental use of pumpkins, and also mass loss during the post-harvest period depreciates the quality (Baldwin et al., 1999, Jacomino et al., 2003; Boiteux et al., 2007). In this sense, the application of films on the fruits can be an alternative to avoid or reduce the problems mentioned above.

According to Blum et al. (2008), some fruits naturally have waxes that reduce water loss, thus avoiding the mass loss. This effect can be further enhanced by the application of post-harvest films, which will modify the internal composition of the gases, thus reducing tissue senescence (Awad, 1993). The films represent low-cost alternatives that improve the conservation and presentation of fruits, reducing transpiration, wilting and wrinkling of the skin, increasing the brightness (Blum et al., 2008).

Carnauba wax, a Brazilian palm tree, has been used as a coating on fruits, vegetables (Blum et al., 2008) and ornamentals, such as citrus (Malgarim et al., 2007), papaya (Fernades et al., 2010), ornamental pineapple (Oliveira et al., 2014), avocado (Santos et al., 2015), and melon (Batista et al., 2007). Studies with mango fruit (Baldwin et al., 1999) and guava fruit (Jacomino et al., 2003) treated with carnauba wax at concentrations of 50 and 30%, respectively, revealed a decrease in mass loss, and reduction of rot. Boiteux et al. (2007) observed mass losses in fruits of *Cucurbita moschata* bicolor in the post-harvest period (9 days), which varied from 4.8 to 13.6% in relation to the original mass when stored in natural environment conditions (dry winter). The mass loss results in fruit wilting (Azzolini et al., 2004) and, consequently, loss or reduction of its aesthetic value.

In climacteric fruits, during ripening, occurs a drastic increase in ethylene production, which results in high respiratory activity (Chitarra and Chitarra, 2005). Although some studies have shown that the ‘Menina Brasileira’ zucchini is considered non-climacteric, it has some sensitivity to ethylene (Araújo et al., 2017). Thus, it is also important to understand the sensitivity of ornamental mini-pumpkins to this phytohormone, by evaluating the ethylene production and respiration, in response to the application of compounds that inhibit the ethylene action, such as 1-methylcyclopropene (1-MCP). According to Watkins (2006), this compound can be used to study the action of ethylene in the process of fruit and vegetable maturation and senescence. Increased respiratory activity reduces the post-harvest life of the products.

The objective was to evaluate the effect of post-harvest films on the shelf life of ornamental mini-pumpkins, by preserving skin pigments, maintaining mass (experiment 1) and reducing the ethylene production and respiration (experiment 2).

Material and Methods

In order to obtain the data analyzed and discussed in this work, two experiments were performed. For Experiment 1, ornamental mini-pumpkins were obtained from seedlings produced in trays of 128 cells, obtained through commercial seeds, and grown in previously fertilized beds. The mini-pumpkins were harvested on 12/21/2016, selected and grouped according to the shape and color of the skin, being described by codes as light yellow rough (ACR); bicolor (BiC), rough white (BR); and dark green (VE) (Figure 1).

Figure 1. Varieties of ornamental mini-pumpkins analyzed. From left to right: rough yellow light (ACR); bicolor (BiC), rough white (BR); and dark green (VE).

For these varieties were applied, on 12/21/16, four treatments (films): control (without application); 15% carnauba wax (1:1, i.e. one part of the product diluted to one part of water); cassava starch (120 g / 3L H_2O); and corn starch (120 g / 3 L H_2O). The mini-pumpkins were immersed individually, for 30 seconds, in the respective treatments. The units that composed the control were immersed, for the same period of time, in pure water. For each treatment eight ornamental mini-pumpkins were evaluated, each fruit being considered a repetition, totaling 32 fruits. Considering the four varieties, 128 fruits were evaluated in the experiment.

After treated, the mini-pumpkins were laid on pallets to drain excess film and waited until the films were dry. On the same day, mass determination (by digital scale Marte, model AS 5500C) and determination of the coloration with Minolta colorimeter (model CR-310) were carried out using the following parameters: brightness (L), which varies from white (L = 100) to black (L = 0); chromaticity or color intensity (C) and hue angle (Hº), where 0º pure red, 90º pure yellow and 180º pure green.

After application of the treatments, the mini-pumpkins were kept at room temperature on a bench, avoiding direct exposure to solar radiation. At 48 (02/07/2017) and at 75 (03/06/2017) days after harvest (D.A.H.), mass loss (%) was evaluated in relation to the initial mass (obtained on harvest day) and changes in coloration, observing the variations in relation to the analysis performed on harvest day (12/21/2016). The data obtained in Experiment 1 were submitted to analysis of variance and Tukey's test (5%) using SiSvar® software, considering a two-factor scheme where factor A was composed of treatments (control, carnauba wax, cassava starch and corn starch) and factor B the analyzes over time (at 48 and 75 D.A.H. in relation to the initial reading). The varieties, because they presented distinct morphological characteristics, were analyzed independently (they were not considered as factors in the construction of the experimental design).

For Experiment 2, the ornamental mini-pumpkins were obtained as in Experiment 1, were collected and selected on 12/14/2017, discarding those that presented some damage. In this experiment, different varieties (mix) were used to compose the experimental units of each treatment, due to the high heterogeneity of fruits obtained in the cultivation, and the mix composition was the same for all treatments.

The mini-pumpkins were taken to the laboratory on 12/14/2017, where three treatments were applied: control (without application, only immersion in pure water); 15% carnauba wax (1:1), repeating the protocol performed in experiment 1, but in 2 immersions and application of 1-methylcyclopropene (1-MCP). Carnauba wax was selected from the films tested in experiment 1, as it showed a trend towards better results. For the application of 1-MCP, the commercial product SmartFresh® (0.14% of a.i.) was used, which was weighed and diluted in 20 mL of distilled water in a hermetic bottle, which was opened inside a mini-chamber where the mini-pumpkins were previously allocated. The concentration of the product in the atmosphere of this mini-chamber was 1 $\mu L\ L^{-1}$, applied at a temperature of 20 °C, for 24 h. After the mini-chamber was opened and the mini-pumpkins of the 1-MCP treatment were arranged with the others, at room temperature, on a bench, avoiding direct exposure to solar radiation.

The objective of this experiment was to evaluate the physiological parameters (ethylene production and respiration) in response to the application of carnauba wax and the ethylene action inhibitor (1-MCP). The first determination of ethylene and respiration was carried out on 12/15/2017 (1 D.A.H.) and, on 10/01/2018 (27 D.A.H.), the second determination was carried out. For these determinations, 10 mini-pumpkins were placed in a 5-liter glass bottle (three bottles per treatment) and hermetically sealed for approximately 15 hours. After this period, the air in the bottle was circulated by a gas analyzer (Siemens, Ultramat 23) to record the percentage of CO_2 from the pumpkin's respiration. Due to the free space in the container, the mass of 10 pumpkins, the closing time and the CO_2 concentration, it was possible to calculate the respiration, expressed in mL CO_2 kg^{-1} h^{-1}. Likewise, it was possible to determine the ethylene production, except that to obtain the internal concentration in the bottles, 1mL of the air from each container was withdrawn with a syringe, and injected immediately into the injector of a gas chromatograph (Varian, Star 3400 CX), equipped with a flame ionization detector (FID) and Porapak N80 /100 column. The temperature of the oven, the injector, and the detector were 90, 140 and 200 °C, respectively. Ethylene synthesis was expressed in μL C_2H_4 kg^{-1} h^{-1}.

The data obtained in Experiment 2 were submitted to analysis of variance and comparison of means by Tukey's test (5%), with the SiSvar® software.

Results and Discussion

The results of experiment 1, related to mass loss (%), showed that there was no significant interaction between the treatments (control, carnauba wax, cassava starch and corn starch) versus the days after harvest (48 and 75 D.A.H.) (Table 1). Therefore, the averages were considered separately for the analysis and discussion of the results.

Table 1. Mass loss (%) in relation to the initial mass, at 48 and 75 days after harvest (D.A.H.) in ornamental mini-pumpkins, for treatments: control (without application); 15% carnauba wax (1:1); cassava starch (120 g / 3 L H_2O) and corn starch (120 g / 3 L H_2O).

Treatment	***Mass loss (%) in relation to the initial mass***		
	48 D.A.H.	**75 D.A.H.**	**Average**
	BR variety		
control	9.92 ± 1.90	13.25 ± 2.85	11.59 ± 2.91 b
15% carnauba wax	7.67 ± 1.03	10.51 ± 1.35	8.91 ± 1.73 a
cassava starch	14.72 ± 4.09	17.92 ± 4.76	16.32 ± 4.60 c
corn starch	9.51 ± 1.54	12.38 ± 2.12	10.94 ± 2.32 ab
Average	10.47 ± 3.52 A*	13.42 ± 4.08 B	
CV (%)	23.11		
Treatment	**BiC variety**		
control	8.93 ± 2.51	12.41 ± 3.03	10.67 ± 2.98 ab
15% carnauba wax	6.41 ± 0.91	8.36 ± 0.49	7.39 ± 1.28 a
cassava starch	12.52 ± 3.06	16.18 ± 2.01	14.35 ± 2.82 b
corn starch	10.12 ± 3.04	13.56 ± 4.33	11.84 ± 3.79 b
Average	9.70 ± 3.55 A	12.91 ± 3.82 B	
CV (%)	24.07		
Treatment	**ACR variety**		
control	9.55 ± 1.96	12.04 ± 2.34	10.80 ± 2.44 a
15% carnauba wax	9.60 ± 1.36	12.61 ± 1.74	11.11 ± 2.17 a
cassava starch	19.59 ± 7.24	23.69 ± 7.65	21.64 ± 7.50 b
corn starch	11.33 ± 2.28	14.32 ± 2.78	12.82 ± 2.90 a
Average	12.61 ± 5.71 A	15.78 ± 6.36 B	
CV (%)	29.64		
Treatment	**VE variety**		
control	8.52 ± 2.69	10.92 ± 3.64	9.72 ± 3.31 a
15% carnauba wax	7.52 ± 3.01	10.06 ± 4.13	8.79 ± 3.60 a
cassava starch	16.14 ± 4.32	20.56 ± 5.68	18.35 ± 5.36 c
corn starch	11.99 ± 2.02	15.86 ± 2.89	13.93 ± 3.13 b
Average	11.04 ± 4.42 A	14.35 ± 5.85 B	
CV (%)	29.07		

*Averages followed by the same letter do not differ statistically from each other, uppercase in the row and lowercase in the column by the Tukey test at 5% probability.

For the BR variety, the 15% carnauba wax provided lower mass loss, not statistically different from corn starch. For this variety, the worst treatment was cassava starch, with mass loss of 16.32% in relation to the initial mass. For the BiC variety, the lowest mass loss was obtained in 15% carnauba wax, not statistically different from control. For ACR variety, there was a statistical difference only for cassava starch, in which there was the highest percentage of mass loss. For VE variety, control and 15% carnauba wax presented no statistical difference, with cassava starch being the worst treatment. Regarding the evaluations performed at 48 and 75 D.A.H., it can be seen that, for all ornamental mini-pumpkin varieties, there was a greater mass loss (%) at 75 D.A.H. In general, there is a trend of lower mass loss in fruits that received the application of carnauba wax, and its efficiency can be increased by use the product in a higher concentration. This result corroborates that obtained by Baldwin et al. (1999) and Jacomino et al. (2003), who studied mango and guava treated at concentrations of 50% and 30%, respectively, showed a decrease in mass loss.

Exposure to temperature and ambient light conditions results in changes in the original color of the fruits, and these changes intensify over time (Chitarra and Chitarra, 2005). Thus, an electronic colorimeter was used to evaluate the alteration of different color parameters in relation to the harvest evaluation. The data obtained from Experiment 1 of the BR, ACR and VE varieties are presented in Table 2.

For the BR variety there was no interaction between the post-harvest films and days after harvest and, therefore, the statistical evaluations were performed only with the means of the treatments. For the parameters luminosity (L) and hue angle (H°), there was no difference between the treatments, meaning that there was no darkening or alteration of the color tone, even with the advance of the period of exposure (75 D.A.H.). For chromaticity (C), the variation was greater with 75 D.A.H., compared to 48 D.A.H., meaning that it increases the brightness and intensity of the color with time. The result for an increase of brightness with the use of films corroborates with those obtained by Baldwin et al. (1999), in mango, Blum et al. (2008) in persimmon, and by Jacomino et al. (2003) in guava. This variety of mini pumpkins, in particular, has a good potential for ornamentation, since it practically did not change coloration, even in the control (without application).

The L and C parameters showed no significant difference between the treatments and time of exposure in the ACR variety (Table 2). As for the hue angle (Hº), the initial value was 89.12º (90º representing the yellow color). In the variation of Hº, negative values were recorded for treatments 15% carnauba wax) and cassava starch, that is, they kept the color very close to yellow (original color of the variety). These treatments differed only statistically from the control, which presented positive values, tending to reddish-yellow.

The VE variety did not show a variation of the color parameters C and Hº (Table 2). The parameter L, which varies from 0 (black) to 100 (white), presented an initial value of 29.7 (at the harvest date), that is, tending to the dark tone. At 48 D.A.H. there was an increase of 21.8 points on this scale towards the light color, which intensified even more at 75 days, differing significantly from the previous period. Therefore, for this variety, the main problem is the loss of the dark coloration and none of the applied films was efficient to contain this variation since there was no difference in relation to the control.

The BiC variety has good potential for the ornamental use because it presents the peduncular half of the fruit with a completely yellow coloring and the opposite half of a completely green coloring (Figure 1). It is desirable, therefore, that this coloring characteristic is maintained over time. The main attributes described by floral decorators in ornamental pumpkins are shape and color, while for final consumers, color is the most important (Fischer et al., 2015). According to these authors, the final consumers report the orange color as the most attractive. In the present work, the data of both colors' variation of the BiC variety are arranged in the same table (Table 3), in order to facilitate the understanding of this alteration.

In the green half, the luminosity (L) varied more in the evaluation at 75 D.A.H. than to at 48 D.A.H., indicating that the green half becomes less dark with time. Regarding the post-harvest films, there was no significant difference, despite a tendency of less alteration with an application of 15% carnauba wax. In the yellow half, there was no effect of time on this parameter, however, cassava starch avoided darkening (smaller variation), but did not differ significantly from 15% carnauba wax and control (Table 3).

The brightness or intensity of the skin color was greater on the green half of the BiC variety with the increase of the time of exposure to the environment, evidenced by the higher values of chromaticity (C) at 75 D.A.H. Among the films applied, the corn starch showed less variation, that is, a lower color intensity, but only differed significantly from the control. In the yellow half, the variation was small and there was no influence by the films and it was also maintained in time.

For H°, in the green half, a greater change was observed with storage time at 75 D.A.H., indicating that the tonality has become yellowish. According to Chitarra and Chitarra (2005), changes occur in the coloration of fruit epidermis as a function of chlorophyll degradation and new pigment synthesis. Again, no significant effect of the films was observed on the green color loss, despite a slight tendency of less variation for the three films in relation to the control. In the statistical analysis of the yellow half for the Hº, there was interaction among the factors, but in none of the films applied there was a significant difference between the evaluation periods. At 48 D.A.H. there were slight changes in H°, with no effect of post-harvest films. At 75 D.A.H., cassava starch presented a small positive variation, that is, it presented a reddish-yellow tone, differing significantly from the control and 15% carnauba wax, which presented negative variations, tending to pure yellow (Table 3). From these analyses, it is possible to verify that the great coloration change in the BiC variety occurs in the green half, that is acquiring a clearer tone, until reaching the yellow color, depreciating its ornamental value. In contrast, Boiteux et al. (2007), investigating a bicolor cultivar of *Cucurbita moschata*, found that the portion of the fruit with green pigmentation did not present significant alterations of any of the color attributes during storage, but the portion of the yellow pigmentation underwent significant changes of all the attributes.

Although the post-harvest films did not differ significantly from the control in many evaluated parameters, there is a trend of improvement with these treatments, especially with the use of carnauba wax, suggesting that future work should be performed with different concentrations of this film.

The results of experiment 2 are presented in Figure 2. Ethylene production and respiration (evaluated by CO_2 production) of ornamental mini-pumpkins was evaluated as a function of the carnauba wax and of 1-MCP, an inhibitor of ethylene action (Watkins, 2006). According to the results of the analysis, there was no significant difference for the ethylene production between the treatments at 27 D.A.H., with very low values and close to the production recorded at the harvest date (Figure 2A). This result proves that ornamental mini-pumpkins produce very low amounts of ethylene, ruling out the hypothesis that ethylene could be responsible for color changes and mass loss during the post-harvest period. For the 'Menina Brasileira', Araújo et al. (2017) observed sensitivity to ethylene with increasing doses of exogenous ethylene. In the present study, ornamental mini-pumpkins were not exposed to the exogenous ethylene application, so it is not possible to state that they are also not sensitive to ethylene. However, the most important is to evaluate the autocatalytic production of ethylene by the mini-pumpkins, because in the ornamental use, only this form of ethylene could be acting, since the product is not exogenously applied.

Table 2. Variation of luminosity (L), chromaticity (C) and hue angle (Hº) at 48 and 75 days after harvest (D.A.H.) in ornamental mini-pumpkins (BR, ACR and VE varieties), for treatments: control (without application); 15% carnauba wax (1:1); cassava starch (120 g/3 L H_2O) and corn starch (120 g/3 L H_2O).

BR variety									
Treatment	**Luminosity variation (L)***			**Chromaticity variation (C)****			**Hue angle variation (Hº)*****		
	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average
control	2.56 ± 1.6	2.98 ± 1.5	2.77 ± 1.5a	2.92 ± 1.2	4.27 ± 1.2	3.59 ± 1.3a	6.57 ± 3.0	5.96 ± 2.6	6.26 ± 2.8a
15% carnauba w.	2.07 ± 1.2	2.29 ± 1.0	2.18 ± 1.1a	2.89 ± 0.6	3.95 ± 0.6	3.42 ± 0.8a	6.66 ± 3.4	6.35 ± 3.3	6.50 ± 3.2a
cassava starch	1.67 ± 0.5	1.77 ± 0.9	1.72 ± 0.7a	3.58 ± 1.1	4.64 ± 1.1	4.11 ± 1.2a	3.94 ± 3.2	4.60 ± 3.9	4.27 ± 3.5a
corn starch	2.46 ± 1.0	2.60 ± 1.0	2.53 ± 0.9a	3.24 ± 0.9	4.91 ± 1.7	4.08 ± 1.6a	6.12 ± 3.0	7.12 ± 4.6	6.62 ± 3.8a
Average	2.19 ± 1.1 A	2.41 ± 1.1A		3.16 ± 0.9 B	4.44 ±1.2 A		5.82 ± 3.2 A	6.00 ± 3.6 A	
CV (%)	49.5			29.2			58.3		
ACR variety									
	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average
control	1.32 ± 1.8	1.84 ± 1.6	1.58 ± 1.7a	2.93 ± 4.0	1.40 ± 4.6	2.17 ± 4.2a	0.92 ± 1.4	0.65 ± 1.3	0.79 ± 1.3a
15% carnauba w.	2.06 ± 0.9	1.81 ± 0.9	1.93 ± 0.9a	2.05 ± 1.9	0.69 ± 2.7	1.36 ± 2.4a	-0.24 ± 0.5	-0.54 ± 0.4	-0.39 ± 0.5b
cassava starch	1.35 ± 0.8	1.71 ± 1.0	1.53 ± 0.9a	1.77 ± 2.8	0.51 ± 3.3	1.14 ± 3.0a	-0.24 ± 0.9	-0.44 ± 0.9	-0.34 ± 0.9b
corn starch	1.88 ± 1.1	1.98 ± 1.0	1.93 ± 1.0a	2.13 ± 1.9	2.72 ± 2.2	2.43 ± 2.0a	0.41 ± 1.4	0.37 ± 1.5	0.39 ± 1.4ab
Average	1.65 ± 1.2A	1.84 ± 1.1A		2.22 ± 2.7A	1.33 ± 3.2A		0.22 ± 1.2A	0.01 ± 1.2A	
CV (%)	69.5			173.4			995		
VE variety									
	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average	48 D.A.H.	75 D.A.H.	Average
control	17.6 ± 14.7	24.5 ± 12.9	21.1 ± 13.8a	29.3 ± 24.3	37.9 ± 21.4	33.6 ± 22.6a	10.9 ± 21.9	15.8 ± 20.6	13.4 ± 20.7a
15% carnauba w.	27.9 ± 13.2	24.3 ± 13.9	26.1 ± 13.2a	42.7 ± 21.1	42.0 ± 23.8	42.4 ± 21.7a	22.3 ± 21.0	18.7 ± 24.6	20.5 ± 22.2a
cassava starch	19.2 ± 11.5	27.9 ± 12.0	23.6 ± 12.2a	25.0 ± 15.6	32.1 ± 14.9	28.6 ± 15.2a	9.1 ± 15.1	13.9 ± 18.3	11.5 ± 16.4a
corn starch	22.7 ± 10.9	36.7 ± 11.7	29.7 ± 13.1a	31.9 ± 14.9	39.9 ± 13.0	35.9 ± 14.1a	16.8 ± 15.7	28.4 ± 13.0	22.6 ± 15.1a
Average	21.8 ±12.7B	28.4 ±13.1A		32.2 ±19.6A	38.0 ±18.3A		14.8 ±18.5A	19.2 ±19.5A	
CV (%)	50.5			54.4			112.7		

Averages followed by the same letter do not differ statistically from each other, uppercase in the row and lowercase in the column, by the Tukey test at 5% probability.
*L final – L initial. L inital (average): BR = 82.94; ACR = 70.65; VE = 29.7.
**C final – C initial. C initial (average): BR = 15.76; ACR (C initial - C final) = 47.64; VE = 6.13.
***Hº initial - Hº final. Hº initial (average): BR = 91.14; ACR = 89.12; VE = 124.4.

Table 3. Variation of luminosity (L), chromaticity (C) and hue angle (Hº) at 48 and 75 days after harvest (D.A.H.), in BiC variety (green half and yellow half) for treatments: control (without application); 15% carnauba wax (1:1); cassava starch (120 g / 3 L H_2O) and corn starch (120 g / 3 L H_2O).

Treatment	**Luminosity variation (L)***					
	Green half			***Yellow half***		
	48 D.A.H.	**75 D.A.H.**	**Average**	**48 D.A.H.**	**75 D.A.H.**	**Average**
control	36.9 ± 2.6	38.0 ± 2.5	37.5 ± 2.4a	2.06 ± 1.2	1.65 ± 1.0	1.85 ± 1.0ab
15% carnauba	33.5 ± 1.0	35.7 ± 1.6	34.6 ± 1.7a	1.90 ± 1.0	1.30 ± 0.7	1.60 ± 0.8ab
cassava starch	35.3 ± 3.8	38.4 ± 1.2	36.8 ± 3.1a	1.34 ± 2.2	-0.31 ± 2.3	0.52 ± 2.3b
corn starch	34.1 ± 2.8	37.5 ± 2.8	35.8 ± 3.2a	2.84 ± 1.4	2.56 ± 2.0	2.70 ± 1.6a
Average	35.0 ± 2.9B	37.4 ± 2.2A		2.04 ± 1.5A	1.30 ± 1.8A	
CV (%)	6.81			95.4		
Treatment	**Chromaticity variation (C)****					
	Green half			***Yellow half***		
	48 D.A.H.	**75 D.A.H.**	**Average**	**48 D.A.H.**	**75 D.A.H.**	**Average**
control	60.5 ± 4.2	62.1 ± 3.1	61.3 ± 3.6a	1.32 ± 1.6	0.80 ± 1.7	1.06 ± 1.6a
15% carnauba	55.2 ± 1.7	61.0 ± 1.5	58.1 ± 3.5ab	1.08 ± 1.4	-0.07 ± 2.2	0.50 ± 1.9a
cassava starch	55.2 ± 6.4	60.2 ± 1.0	57.7 ± 5.0ab	0.13 ± 2.7	-1.65 ± 3.1	-0.76 ± 2.9a
corn starch	52.7 ± 5.2	58.3 ± 3.3	55.5 ± 5.1b	1.88 ± 1.7	0.21 ± 1.5	1.05 ± 1.7a
Average	55.9 ± 5.2B	60.4 ± 2.7A		1.10 ± 1.9A	-0.18 ± 2.2A	
CV (%)	6.45			451		
Treatment	**Hue angle variation (Hº)*****					
	Green half			***Yellow half***		
	48 D.A.H.	**75 D.A.H.**	**Average**	**48 D.A.H.**	**75 D.A.H.**	**Average**
control	39.9 ± 3.4	40.9 ± 1.7	40.4 ± 2.6a	-0.28 ± 0.6aA	-0.86 ± 0.6bA	-0.57 ± 0.6
15% carnauba	37.9 ± 1.7	39.8 ± 1.2	38.8 ± 1.7a	-0.69 ± 0.4aA	-1.52 ± 0.4bA	-1.10 ± 0.6
cassava starch	37.4 ± 2.5	38.6 ± 1.3	38.0 ± 2.0a	-0.01 ± 1.1aA	0.73 ± 1.9aA	0.36 ± 1.5
corn starch	36.3 ± 4.0	38.9 ± 2.7	37.6 ± 3.5a	-0.06 ± 0.7aA	-0.49 ±0.5abA	-0.27 ± 0.6
Average	37.8 ± 3.1B	39.6 ± 1.9A		-0.26 ± 0.7	-0.53 ± 1.3	
CV (%)	*6.51*			*231*		

Averages followed by the same letter do not differ statistically from each other, uppercase in the row and lowercase in the column, by the Tukey test at 5% probability.

*L final – L initial. L initial (average) = 31.7 (green half) and 67.7 (yellow half)

**C final – C initial. C initial (average) = 8.22 (green half) and 71.7 (yellow half)

***Hº initial - Hº final. Hº initial (average) = 120.2 (green half) and 78.6 (yellow half)

After 27 D.A.H., ornamental mini-pumpkins respiration also did not differ between treatments (Figure 2B). At harvest, respiration was high (29.2 mL CO_2 kg^{-1} h^{-1}), reducing to approximately 8 mL of CO_2 kg^{-1} h^{-1}, at 27 D.A.H. in all treatments. The respiration is directly related to the catalytic metabolism of fruits, and the higher respiration after harvest results in faster physical-chemical changes in the fruits. In climacteric fruits, respiration increases due to the increase of ethylene production (Chitarra and Chitarra, 2005). Again, there was no effect of the 1-MCP on respiration reduction, as reported for the ethylene production. In addition, carnauba wax also had no effect on respiration and ethylene production of ornamental mini-pumpkins.

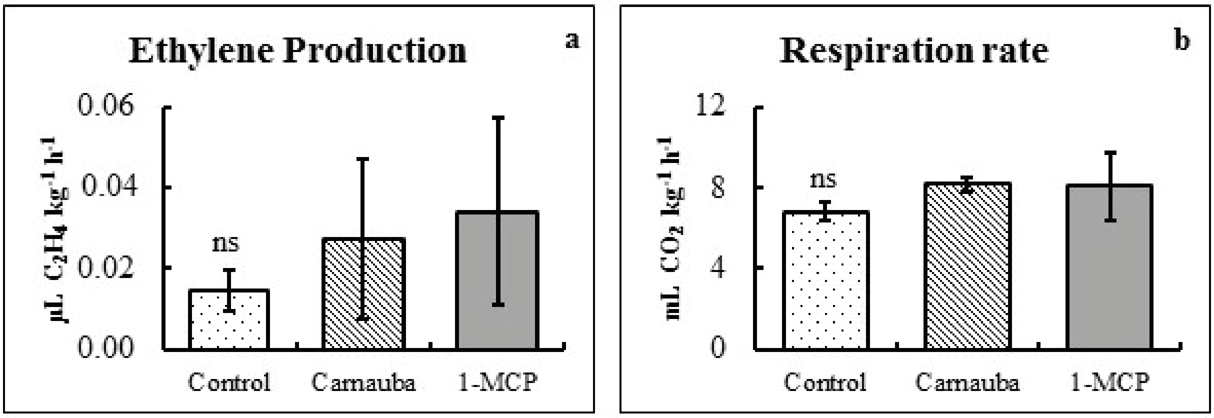

Figure 2. Ethylene production and respiration of ornamental mini-pumpkins at 27 days post-harvest. The initial production of ethylene (at harvest) was 0.048 μL C_2H_4 kg^{-1} h^{-1} and the respiration was 29.21 mL CO_2 kg^{-1} h^{-1}.

Conclusions

The use of cassava starch and corn starch to reduce mass loss in ornamental mini-pumpkin is not recommended. In some situations, it was observed lower mass loss and better maintenance of the skin color with carnauba wax application, suggesting future work with different doses of this film. The application of carnauba wax and the ethylene action inhibitor (1-MCP) did not affect the ethylene production and respiration of the mini-pumpkins, suggesting that ethylene is not involved with the modifications that occur in fruit during the post-harvest.

Author Contribution

N.T.S. $^{0000-0003-4767-2907}$: work conception, data collection, analysis and interpretation, writing and, critical review of the article. V. B. 0$^{000-0003-1056-6887}$: collection, analysis and interpretation of data, writing and, critical review of the article. P.A.B. $^{0000-0002-5293-7597:}$ data collection and analysis. A.F. $^{0000-0002-0255-4723}$: data collection and analysis. M.C.B. $^{0000-0001-5353-2754}$: data collection and analysis.

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