Original

Quality of yellow passion fruit stored under refrigeration and controlled atmosphere

Qualidade do maracujá-amarelo armazenado sob refrigeração em atmosfera controlada

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Resumo

Neste trabalho, avaliou-se a qualidade dos maracujás-amarelos armazenados sob refrigeração em diferentes composições de atmosfera, visando aumentar a vida útil dos frutos. Determinaram-se as características de coloração da casca, aparência, perda de massa, além da qualidade química do suco dos maracujás-amarelos armazenados em: 21% O_2 e 0,03% CO_2; 1% O_2 e 0,03% CO_2; 5% O_2 e 0,03% CO_2; 12% O_2 e 5% CO_2; 5% O_2 e 15% CO_2, com 1 tratamento de controle (refrigeração a 13 °C e 90%UR). As análises foram conduzidas antes e após 30 dias de armazenamento dos frutos, e após serem retirados das atmosferas e mantidos por 9 dias sob refrigeração em atmosfera ambiente. Os dados foram interpretados por análise simples estatística, utilizando-se o teste por intervalo de confiança com 95% de probabilidade. Concluiu-se que a utilização de atmosferas com baixas concentrações de oxigênio e com altas concentrações de dióxido de carbono reduziu a perda de qualidade dos frutos. Na atmosfera com 5% O_2 e 15% CO_2 foram encontrados os menores índices de mudança de cor e perda de massa, além de mínima redução de acidez titulável, conteúdo de sólidos solúveis, vitamina C, açúcares redutores e açúcares solúveis totais.

Palavras-chave: *Passiflora edulis; estocagem; composição química da fruta; composição da atmosfera.*

Abstract

In this study, it was evaluated the quality of yellow passion fruits stored under refrigeration and controlled atmospheres of different composition aiming to extend the postharvest life of the fruits. The characteristics of skin color, appearance, mass loss, as well as the chemical quality of the juice of yellow passion fruits stored at: 21% O_2 plus 0.03% CO_2; 1% O_2 plus 0.03% CO_2; 5% O_2 plus 0.03% CO_2; 12% O_2 plus 5% CO_2; and 5% O_2 plus 15% CO_2, with 1 control treatment (refrigeration at 13 °C and 90% UR) were determined. The analyses were performed before and after 30 days of storage and after removing the controlled atmospheres and storage for 9 days under refrigeration at ambient atmosphere. The data were interpreted by simple statistical analysis using the test by confidence intervals with 95% of probability. It was concluded that the application of atmospheres with low oxygen concentration and high carbon dioxide level minimized quality losses. At atmosphere with 5% O_2 and 15% CO_2 it was observed the lowest color change indexes and mass loss, and also the smallest decrease in acidity, soluble solids content, vitamin C, reducing sugars, and total soluble sugars.

Keywords: *Passiflora edulis; storage; chemical composition of fruits; atmosphere composition.*

1 Introduction

There are more than 150 native cultivars of passion fruit in Brazil, and the most known and useful to the industry is the yellow passion fruit (NEGREIROS et al., 2006). According to the Instituto Brasileiro de Geografia e Estatística – IBGE (2009), the production of yellow passion fruit in 2007 was 664,286.00 t in an area of 46,866 ha, with the average production yield of 14,174 kg.ha^{-1}. The major producing states are Bahia, Espírito Santo, São Paulo, Minas Gerais, Sergipe, and Rio de Janeiro.

The North of Rio de Janeiro State, Brazil, presents the higher production in this state. During the years from 1990 to 2005 19,770 t were planted per year representing 71.81% of the total production (PONCIANO; SOUZA; GOLYNSKI, 2006).

Approximately 60% of the total production of yellow passion fruits in Brazil is used by consumers of fresh fruits besides supermarkets, free markets, and retailers (ROSSI, 2001). Passion fruit is generally appreciated because of its especial taste and flavor as well as its vitamins and mineral contents in the juice (SANDI et al., 2003). The main economic importance of the fruit is related to concentrated juice processing, but other products can be prepared using the pulp in confectionery and candy making such as nectar, syrup, ice cream, and jelly (CAVALCANTE, 1974; MELETTI; MOLINA, 1999; MODESTA, 1990).

The technological quality of the juice required by consumers of fresh fruits or by industrial processing must be assured by the titratable acidity from 3.2 to 4.5% , soluble solids content from 15 to 16 °Brix, juice yield around 40% , vitamin C content from 13 to 20 mg.100 mL^{-1}, and average fruit weight above 120 g (RUGGIERO et al., 1996; SÃO JOSÉ et al., 1999). Sjostrom and Rosa (1978) observed that the changes in the chemical composition of ripe yellow passion fruit occurs depending on

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the harvest season in the North region of Bahia State, where the juice presents titratable acidity of 4.54% , soluble solids content (SS) of 16% , juice yield of 30.1% and SS/Acidity ratio of 3.55 in the summer. In the winter, the respective values were 4.95%, 16.1% , 29.4% , and 3.28. According to Vianna-Silva et al. (2008), the yellow passion fruit harvested in the North of Rio de Janeiro state should show at least 30% of yellowish skin color when growing in the winter. However, in the summer the fruits need to have almost 60% of yellow skin color to reach an adequate ripening stage and also to assure the better juice quality.

Refrigeration is one of the most efficient techniques that allows the reduction of the metabolic process of ripening and extend the postharvest life of fruits, and it can be used in combination with other methods such as controlled atmosphere (SEYMOUR; JOHN; THOMPSON, 1987), modified atmosphere by plastic film (TAN; ALI; SOON, 1990), and ethylene scrubbers (SATYAN; SCOTT; GRAHAM, 1992). The control of atmospheres has the main objective to reduce respiration rate to a minimum level. Therefore, under low concentrations of O_2 and high CO_2 levels in the atmosphere, the ethylene synthesis reduces thus reducing its action on the fruit metabolism (CHITARRA, 1998). Normally, the control of atmospheres is employed associated with refrigeration with the aim to get a synergic effect on quality preservation and extend the postharvest life of the fruit (LANA; FINGER, 2000).

In studies with apple, Brackmann and Steffens (2002) observed that controlled atmospheres increase the storage time in 50 to 80%. For the 'Gala' apple, Saquet (1997) verified that refrigeration combined with controlled humidity preserves the fruits as longer as 4 months. However, when this technique is applied associated with controlled atmosphere with low oxygen and CO_2 levels, the storage time may reach up to 8 months.

The yellow passion fruits loose their quality quickly after harvest when stored under ambient conditions. Usually, they present shriveling and diseases before ten days after harvest. The aim of this work is to investigate the fruit quality and postharvest life of yellow passion fruits stored under refrigeration in atmospheres with controlled oxygen (O_2) and carbon dioxide (CO_2) levels and also ethylene (C_2H_4) scrubbers.

2 Materials and methods

The yellow passion fruits (*Passiflora edulis* Sims) were harvested in a commercial orchard located in Campos dos Goytacazes (RJ) during the months of November and December, 2008. In this season, the weather is characterized by temperatures of 23.8 ± 2.7 °C, relative humidity of 84.2 ± 12.2% and precipitation of 456.7 ± 49.7 mm. Fruits with 250 g approximately and with the yellow skin color were selected. The harvest occurred in the morning and the fruits were taken to the laboratory to be washed, sanitized with hypochlorite at 100 ppm for 15 minutes, and dried under ambient air temperature.

Firstly, the fruits were weighed to determine the mass loss after some days of storage A sample of 15 fruits was used for physical and chemical characterization, as well for fruit appearance and skin color, before storage.

In small chambers (70 × 50 × 40 cm) inside the cold room (13 ± 1.0 °C and 90 ± 5.0% RH), 60 fruits were stored and the doors were sealed. The atmospheres were set up by flushing N_2 and CO_2 at the beginning of the storage until required gas levels were reached: 21% O_2 and 0.03% CO_2; 1% O_2 and 0.03% CO_2; 5% O_2 and 0.03% CO_2; 12% O_2 and 5% CO_2; 5% O_2 and 15% CO_2, and also scrubbing ethylene through a potassium permanganate column. The fruits in the control sample were kept in the cold room at 13 ± 1.0 °C and 90 ± 5.0% RH. The oxygen and CO_2 concentrations were controlled by flushing with nitrogen gas and adding CO_2. The chosen levels were kept constant by scrubbing the excess CO_2 resulting from the fruits' respiration and adding air for the O_2. Gas concentrations were monitored daily using computerized analyzers with paramagnetic (O_2) and infrared (CO_2) detection.

After 30 days of storage in controlled atmosphere, a sample of 15 fruits from each treatment was evaluated immediately and the other sample was stored inside the cold room for nine days to achieve complete ripening.

The skin colour was determined using a Spectrophotometer (Hunterlab MiniScan XE Plus, USA) calibrated to a standard white and black reflective plate. A D65 illuminant and a 10° standard observer were used. The measurements were taken at two equidistant points in the equatorial region of sun-exposed and non-exposed side of the fruit. The results were expressed as the amount of the skin yellowness (%) defined by the ratio of the change in the Hunter *b* parameter with respect to the total range of the yellowness after the complete fruit ripening, according to Silva et al. (2008).

The fruit mass loss after the storage period was quantified using a semi-analytical electronic balance (Gehaca, model BC 2000, Brazil) and the results were calculated based on the difference between the initial weight and the weight recorded after the storage, and normalized by 100 g. The change in appearance was registered by pictures taken of the sun-exposed and non-exposed fruit faces.

For the analysis of soluble solids content, measurements were taken using a hand-held digital refractometer (Model PR 201, ATAGO Co. Ltd, Japan) with automatic compensation of temperature and expressed as °Brix.

Titratable acidity was quantified by titrating 2 mL of juice diluted with 25 mL of distilled water with 0.1 mol.L^{-1} of NaOH solution to an endpoint of pH 8.2 and expressed as the percentage of citric acid. The pH measurements were taken using a pH meter (WTW, Model 330, Brazil) through the direct immersion of the electrode in the juice.

The ascorbic acid (vitamin C) content in the juice was determined according to the 2.6-dicloroindophenol titrimetric method (ASSOCIATION..., 1997) by using 2 mL of juice, and the results were expressed as mg.100 mL^{-1} of juice.

For the determination of reducing sugars (RS), the method recommended by Eynon-Lane, according to AOAC (ASSOCIATION..., 1997) was used. A sample of 10 mL of juice diluted in 40 mL of distilled water was used. The results were expressed as g.100 mL^{-1} of juice. For measuring the total soluble sugars (TSS), an acidic hydrolysis of 10 mL of juice with 2 mL HCl 2 mol.L^{-1} was promoted. The determinations were done

using the Eynon-Lane method, and the results were expressed as g.100 mL^{-1} of juice.

The results were interpreted by simple statistical analysis, and the medium values were compared by confidence intervals applying the Tuckey Test with 5% of significance. The samples were taken from infinite population of yellow passion fruits considering $p \leq 0.05$ and 10% of deviation of each parameter

3 Results and discussion

Samplings of 15 fruits were representative of an infinite population when used to analyze the Hunter *b* parameter. In the quantification of yellow skin color and fruit mass loss, the sampling was insufficient to represent an infinite population when some atmosphere treatments were evaluating. For the juice chemical analysis, the sampling was representative when the titratable acidity, pH, soluble solids contents, and vitamin C were evaluated However, for evaluating reducing sugars and total soluble sugars, it was necessary to use a greater number of fruits in some atmosphere treatments (CERQUEIRA, 2009).

The fruits used in this experiment presented an average mass of 275.75 ±17.30 g, which is equivalent to that used by Coelho et al. (2011) and classified as Extra 3A. The sampling of 15 fruits was representative of an infinite population with $p \leq 0.05$.

3.1 Appearance of the fruits

Pictures the fruits taken of at the harvest time show the occurrence of a major proportion of green color in both fruit faces. According to Coelho et al. (2010), in the winter (May to August) the fruits from the North of Rio de Janeiro State become physiologically ripe when they show at least 30% of yellowish skin color. However,Vianna-Silva et al. (2008) verified that, in the summer (October to December), the fruits present better quality when they get approximately 60% of yellowish skin color. The higher rain fall regime during the months of November to December of 2008 in the North of Rio de Janeiro State promoted excessive soil moisture that caused brownish areas in the skin and pathogen's attack on fruits, making difficult the selection to a good quality pattern at the harvest point.

Fruits in the control sample and those stored for 30 days in small chambers with 21% O_2 and 0.03% CO_2 and kept during 9 days at 13 °C and 90% RH presented an excessively damaged appearance by diseases, softening, and wrinkling wasting up to 75% . In atmospheres with low levels of oxygen and carbon dioxide (1% O_2 and 0.03% CO_2, 5% O_2 and 0.03% CO_2) there was less damages in the fruits, but at least 60% of the total sample were wasted. However, at 1% O_2 and 0.03% CO_2 the fruits were greener indicating a slowdown in the ripening pattern. The increase in CO_2 level reduced the quality losses minimizing the greenness color change and avoiding the softening and wrinkling, but also reaching almost 50% of waste losses from the total samples stored under 5% O_2 and 15% CO_2. This can be explained by the poor quality of fruits before storage.

3.2 Mass loss of the fruits

Fruits in the control sample stored for 30 days at 13 °C and 90% RH presented 10% of mass loss (Figure 1). For the fruits stored at 21% O_2 and 0.03% CO_2 with ethylene scrubby, the mass loss decreased (5.22%). In both treatments at high oxygen concentration, there were some damages in the fruits that impaired the determination of mass loss after their removal from the atmosphere chamber and storage for 9 days under refrigeration.

At 30 days of storage, the lowest mass loss occurred in fruits stored at 5% O_2 and 15% CO_2. In atmospheres with traces of CO_2, there was a tendency to reduce mass loss in fruits stored at 1% O_2 (Figure 1). Therefore, the lower O_2 levels caused a tendency to minimize the mass loss, but it was effectively minimized with the increase in the CO_2 level, even at higher O_2 concentrations

There was an increase in the mass loss in the fruits evaluated after their removal from the atmosphere chamber and storage for 9 days under refrigeration, but the values were proportional to those observed at 30 days of storage. Again, the lowest mass loss was observed in fruits stored under atmosphere with 5% O_2 and 15% CO_2. This is because the metabolism rate was affected by the atmosphere composition, even after the fruits' removal from the chambers.

3.3 Skin color of the fruits

Fruits in the control sample presented a tendency for increasing the skin yellowness from the beginning until 30 days of storage with values of 40.11 ± 5.84% and 60.28 ± 14.93%, respectively (Figure 2). This small difference between the measurements was affected by expressive brownish spot area on the fruits stored in the cold room that caused high variance coefficient.

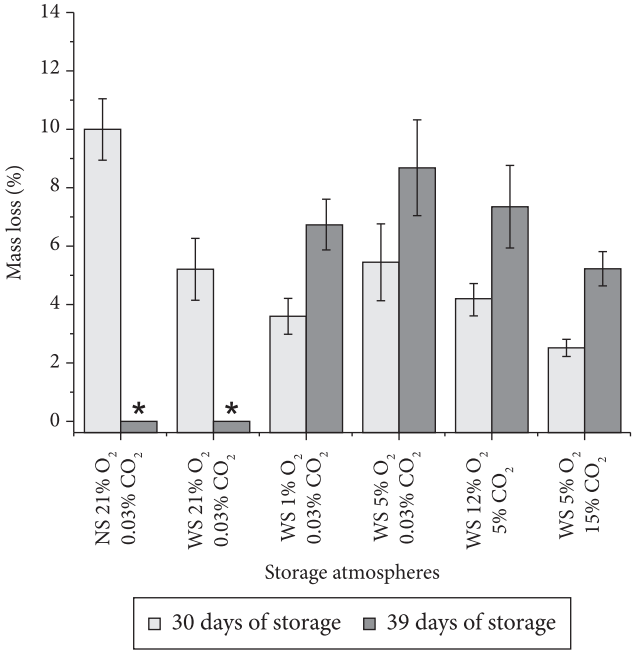

Figure 1. Mass loss (%) of yellow passion fruits stored under different controlled atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits' removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at $p \leq 0.05$ (*damaged samples).

The harvest point of the fruits in the beginning of the experiment was characterized by 40.11 ± 5.84% of skin yellowness. Thus, they shown a more advanced ripening stage than that found by Coelho et al. (2010), which was considered as adequate in the winter (30% of skin yellowness). However, this maturation pattern is insufficient to complete adequately the ripening, as observed by Vianna-Silva et al. (2008) for summer harvests, when the fruits must have approximately 60% of skin yellowness. Hence, the fruits used in this study did not present a complete mature stage, which is necessary to maintain the ripening process after harvest.

At 30 days of storage, an increase in skin yellowness in all atmospheres of storage occurred (Figure 2). Except for the atmosphere containing 5% O_2 and 15% CO_2, the others presented the same average yellowness measurements, reaching 71.8 ± 5.8%, matching the value of 74% in the color scale described by Silva et al. (2008) for yellow passion fruit. The fruits stored at higher CO_2 concentration reached 55.23 ± 7.29%, which matches the color scale pattern of 55% yellowness described by Silva et al. (2008). This treatment with high content of CO_2 and low level of O_2 promoted the slowest change in skin yellowness.

The skin yellowness measurements decreased in the fruits evaluated after removal from the atmosphere chamber and storage for 9 days under refrigeration due to incidence of a significant brownish spot area with direct effect on Hunter *b* measures. Nevertheless, this effect was less profound in fruits stored at 5% O_2 and 15% CO_2.

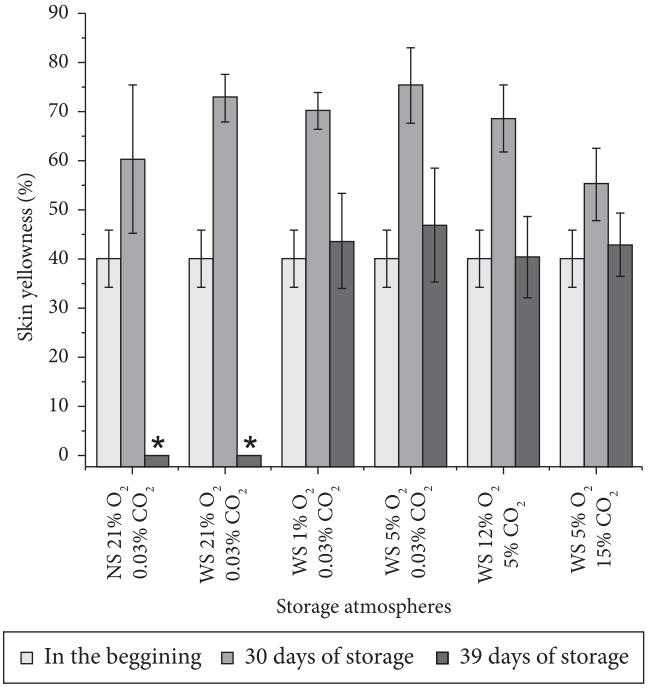

Figure 2. Skin yellowness (%) of yellow passion fruits stored under different controlled atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits' removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at p ≤ 0.05 (*damaged samples).

3.4 Soluble solids (SS) content

As can be seen in Figure 3, the SS content for the control treatment does not change from the beginning to 30 days of storage, maintaining 10.9 ± 1.2 °Brix. This value was found by Coelho et al. (2010) in immature fruits. According to this author, the SS content remained unchanged during the fruits ripening since they were harvested at adequate physiological stage. According to Azzolini (2002), the SS content depends on the maturity stage, and it generally increases progressively during the ripening process due to the hydrolysis of polysaccharides to maintain the respiration rate.

After 30 days of storage in controlled atmosphere, it was verified that, considering the atmospheres with lower CO_2 level, the SS content was higher at atmosphere with 1% O_2 and 0.03% CO_2 (Figure 3). However, it did not differ from the fruits stored at 5% O_2 and 15% CO_2.

The SS content decreased intensively in all atmosphere treatments in the fruits evaluated after removal from the atmosphere chamber and storage during 9 days under refrigeration; excepted for the fruits stored at 5% O_2 and 15% CO_2 (Figure 3). In this atmosphere, it was observed a tendency of higher values compared to those of fruits stored at 1% O_2 and 5% O_2 with traces of CO_2, and the value remained at the same level of that observed for the control sample after 30 days of storage. This indicates that the application of higher concentration of CO_2 combined with low levels of oxygen reduced the decrease of SS after removal of atmospheres.

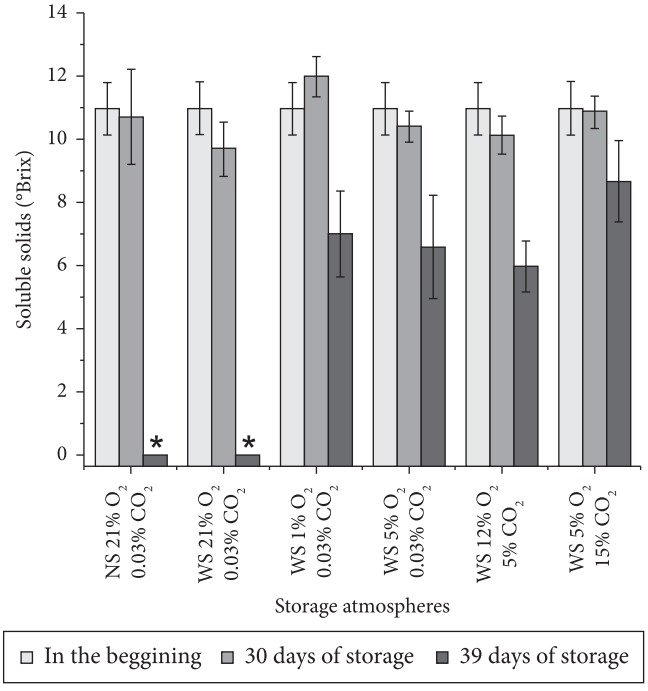

Figure 3. Soluble solids content (°Brix) in juice of yellow passion fruits stored under different controlled atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits' removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at p ≤ 0.05 (*damaged samples).

3.5 Titratable acidity (TA) and pH

The TA of fruits in the control treatment showed tendency for decreasing their values from the beginning to 30 days of storage, with average of 4.59 ± 0.28% and 4.11 ± 0.39%, respectively (Figure 4). Coelho et al. (2010) reported values of 4.93 ± 0.36% for totally green fruits and 1.83 ± 0.21% after storage during 30 days at 22 °C e 90% RH. In immature fruits, with 5.1% skin yellowness, the measurements of TA before and after storage were 4.83 ± 0.46% and 3.19 ± 0.25% , respectively. For the fruits harvested at an adequate maturity stage, the author observed a decrease in TA during the storage, but it was slight for the fruits harvested in more advanced maturity stages.

After 30 days of storage, the fruits kept at 21% O_2 and 0.03% CO_2 presented lower TA, and those stored at 5% O_2 and 15% CO_2 did not show a decrease in the acidity after 30 days of storage, which was also found for the fruits in the control sample (Figure 4). According to Nava (2001), the degradation of acids in controlled atmosphere may be associated with the action of CO_2 on the inhibition of the enzymes aconitase, isocitrate dehydrogenase, and succinate dehydrogenase in the Krebs cycle.

In the fruits evaluated after removal from the atmosphere chamber and storage during 9 days under refrigeration, there was an accentuated decrease in TA for those stored at 5% O_2 plus 0.03% CO_2, and 12% O_2 plus 5% CO_2 (Figure 4). TA measurements of high values were found in fruits stored at higher level of CO_2, but within the same level of TA determined for the control fruits in 30 days of storage. This shows the efficiency of this atmosphere in preserving the TA during storage in controlled atmosphere.

Conversely, the TA and pH of the juice from the fruits in the control sample presented a tendency for increasing the values from the beginning to 30 days of storage in cold room showing values of 2.90 ± 0.03% and 2.99 ± 0.08, respectively (Figure 4).

After 30 days of storage at different atmospheres, it was verified that the fruits presented higher values in the atmosphere with 21% O_2 and 0.03% CO_2 (Figure 4). Nevertheless, for the fruits stored at atmosphere with low oxygen level (5%) and higher CO_2 concentration (15%), there was no change in the pH level, which was also found for the fruits in the control sample.

After the fruits removal from the atmosphere chamber and storage during 9 days under refrigeration, there was a slight increase in the pH of yellow passion fruits stored at 5% O_2 plus 0.03% CO_2 and 12% O_2 plus 5% CO_2 (Figure 4). However, pH changes were impaired in atmosphere with the minimum level of O_2 (1% O2 and 0.03% CO_2) and higher level of CO_2 (5% O_2 and 15% CO_2).

3.6 Ascorbic acid (vitamin C) content

The ascorbic acid of the fruits in the control sample decreased from the beginning to 30 days of storage, presenting averages of 27.52 ± 3.32 mg.100 mL^{-1} and 18.15 ± 1.78 mg.100 mL^{-1}, respectively (Figure 5). According to Coelho et al. (2010), the vitamin C content of immature yellow passion fruits is reduced during storage, decreasing from 30.97 ± 3.58 mg.100 mL^{-1} to 18.99 ± 1.97 mg.100 mL^{-1}. However, the vitamin C content

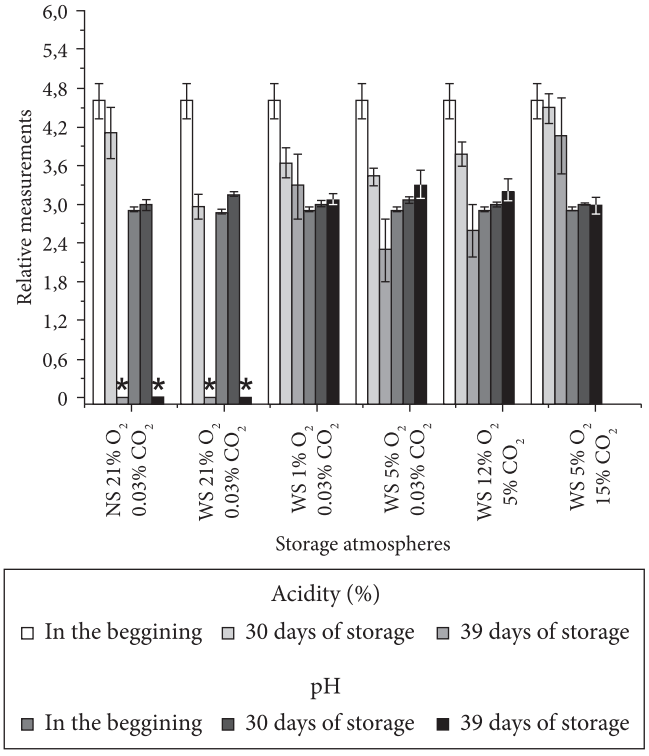

Figure 4. Titratable acidity content (% of citric acid) and pH in juice of yellow passion fruits stored under different atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits` removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at p ≤ 0.05 (*damaged samples).

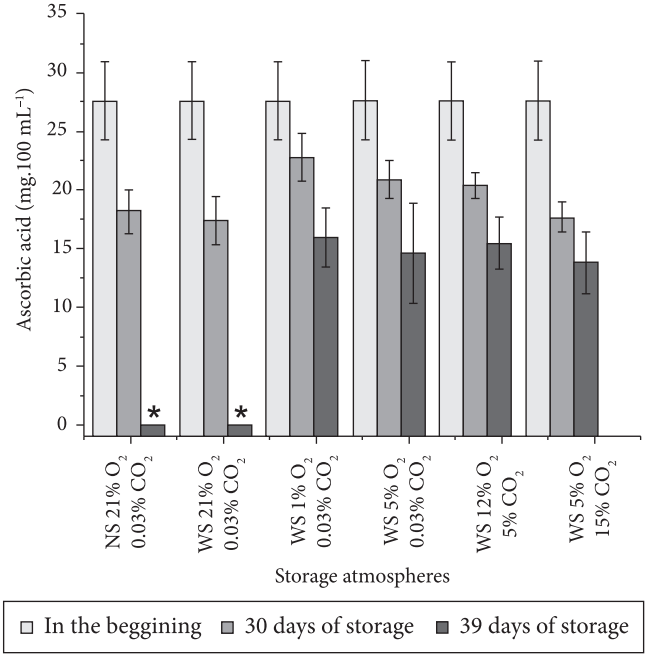

Figure 5. Ascorbic acid content (mg.100 mL^{-1}) in juice of yellow passion fruits stored under different controlled atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits' removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at p ≤ 0.05 (*damaged samples).

did not change when the fruits were harvested at an adequate maturity stage.

At 30 days of storage under refrigeration and controlled atmosphere, the ascorbic acid content decreased in fruits stored at 21% O_2 and 0.03% CO_2 and matched similar levels to the those of the control samples. For the atmosphere with 1% O_2 and 0.03% CO_2, it was only observed a tendency for decreasing the vitamin C content (Figure 5). This evidences the benefit effect of the lower oxygen level on the preservation of ascorbic acid content. However, the fruits stored at 5% O_2 and 15% CO_2 presented higher decrease in vitamin C compared to that of the control sample. Hence, the high concentration of CO_2 promoted a small oxidative activity in the tissue during the fruit storage. According to Fennema (2000), the free oxygen promotes the ascorbic acid oxidation.

After the fruits removal from the atmospheres and storage during 9 days under refrigeration, the vitamin C content dropped in all atmosphere treatments, but this decrease was not significant when compared to that found in fruits in the control sample evaluated at 30 days of cold storage (Figure 5).

3.7 Reducing sugars (RS) and total soluble sugars (TSS) content

For the control treatment, it was noted a tendency of increase in reducing sugars from the beginning to 30 days of storage, with values of 1.76 ± 0.27 g.100 mL^{-1} and 2.47 ± 0.46 g.100 mL^{-1}, respectively (Figure 6). Coelho et al. (2010) verified that immature yellow passion fruits, evaluated before and after the storage, present values of 0.80 ± 0.34 g.100 mL^{-1} and 2.74 ± 0.44 g.100 mL^{-1}, respectively. However, the fruits harvested at adequate maturity stage did not change the reducing sugars content during storage, maintaining values of 5.33 ± 0.34 g.100 mL^{-1}. In immature fruits, a hydrolysis of more complex sugars or synthesis of simple sugars using organic acids from the Krebs cycle may occur promoting an increase in free sugars, which is the source of energy in metabolic processes. For mature fruits, there is a balance in those processes in a way that reducing sugars levels stay constant during the ripening process.

At 30 days of storage at different controlled atmosphere compositions, it was observed a tendency of increase in the reducing sugars of the fruits (Figure 6). Nevertheless, after removal from the atmosphere chamber and storage during 9 days under refrigeration, the RS content tended to drop in fruits stored at atmosphere with low levels of O_2 and traces of CO_2. Fortunately, for the atmosphere with higher level of CO_2, this drop was not so intense, and the final RS content stayed at the same magnitude of the fruits in the control sample evaluated after 30 days of storage. These results indicate that the release of controlled atmosphere stimulates the metabolic activity that results in the consumption of free sugar source.

The total soluble sugars content in fruits in the control sample stayed constant before and after 30 days of storage, with an average level of 4.65 ± 0.68 g.100 mL^{-1} (Figure 6). In the work of Coelho et al. (2010), the TSS content in immature fruits, evaluated before and after the storage, increased from 3.49 ± 0.58 g.100 mL^{-1} to 5.15 ± 0.82 g.100 mL^{-1}. When the fruits were harvested at an adequate maturity stage, the TSS content did not change during the storage, but the fruits harvested at more advanced ripening stages presented higher TSS content, reaching up to 9.62 ± 0.58 g.100 mL^{-1} and revealing the accumulation of energy source.

At 30 days of storage, the fruits in the control sample accumulated TSS when maintained under lower oxygen levels and traces of carbon dioxide (Figure 6). At atmosphere with higher CO_2 level, it was observed only a tendency to increase the TSS content, but the same magnitude of the fruits in the control sample was maintained. Therefore, the accumulation of TSS promoted by the lower oxygen level in the atmosphere was impaired by increasing the CO_2 level in the storage chamber.

After the fruits removal from the atmospheres and storage during 9 days under refrigeration, the TSS content decreased. This drop may be due to the hydrolysis of sugars to maintain the fruit metabolism (Figure 6). In atmospheres with lower oxygen level and traces of CO_2, this drop was less pronounced; however, the TSS values did not differ from those found in fruits stored at 5% O_2 and 15% CO_2. This shows that the application of lower levels of O_2 combined with higher levels of CO_2 minimized the metabolic rate of yellow passion fruits during storage in controlled atmosphere and after their removal.

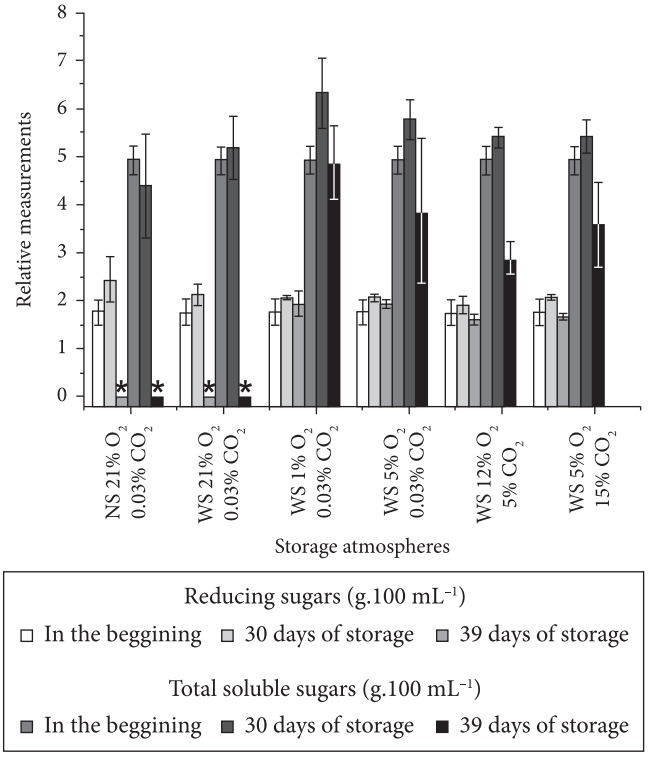

Figure 6. Reducing and total soluble sugars contents (g.100 mL^{-1}) in juice of yellow passion fruits stored under different controlled atmospheres for 30 days, with scrubbing (WS) and non-scrubbing (NS) ethylene, and after the fruits' removal and storage for 9 days at 13 °C and 90% RH. The vertical bars indicate the confidence intervals at $p \leq 0.05$ (*damaged samples).

4 Conclusions

The storage under controlled atmosphere at lower O_2 and higher CO_2 levels was effective to minimize the quality losses of yellow passion fruits and to extend their postharvest life. The reduction in O_2 levels to less than 5% preserved the vitamin C content, but it increased the total soluble sugars and dropped the titratable acidity content during the 30 days of storage. These effects were impaired by increasing the CO_2 levels. The best atmosphere composition was defined at 5% O_2 and 15% CO_2, after the fruits removal from the chamber and storage for 9 days in cold room, when the fruits presented the same chemical compositions compared to those stored under normal atmosphere.

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