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Postharvest shelf-life and fruit quality of strawberry grown in different cropping systems

Maria Lucilania Bezerra Almeida[1]*, Carlos Farley Herbster Moura[2], Renato Innecco[1], Aline dos Santos[3] and Fábio Rodrigues de Miranda[2]

[1]Department of Plant Sciences/UFC, Av. Mister Hull, bloco 805, 60.356-000, Fortaleza,CE - Brazil.
[2]Embrapa Tropical Agroindustry, Rua Dra. Sara Mesquita, 2270, 60511-110, Fortaleza, CE - Brazil.
[3]Department of Plant Production/UDESC, Av. Luiz de Camões, 2090, Lages, SC - Brazil.

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The strawberry is highly perishable, has high metabolic activity and considerable levels of favorable substrates for proliferation of pathogenic organisms, such as humidity, organic acids and sugars. These organisms lead to further, therefore reducing post-harvest shelf-life. With this in mind, the research objective was to evaluate the post-harvest shelf life in cooled storage of two cultivars of strawberries (Oso Grande and Festival) in the hydroponic cultivation system in coconut fiber substrate, and then compare them with the quality obtained in conventional farming. The strawberries were stored under refrigeration (2 ± 2°C and 85% ± 10%) using modified atmosphere, with 9 µ PVC film for 14 days. The experiment was conducted in a completely randomized design, distributed in a sub-subdivided plot with the cropping systems in the plot, cultivars in the subplot and in the sub-subplot with storage times of 0, 3, 6, 10 and 14 days with three replicates. The use of cooling associated with modified atmosphere increased the shelf-life of the strawberries of both systems, indicating the potential of this combination to maintain the post-harvest quality of the fruit. Although the shelf life of cultivars of both systems increased, the fruits produced in the conventional system showed better physical-chemical characteristics.

Key word: *Fragaria x ananassa*, cold storage, conservation, modified atmosphere.

INTRODUCTION

In Brazil, the cultivation of the strawberry plant (*Fragaria x ananassa* Duch.) is being carried out in tropical areas, more specifically on small farms in the mountainous region of the state of Ceará. This is feasible due to the fact that the environmental conditions present similarities to those found in the main producing regions. The first crops in the region have shown good adaptation to the climate, reducing the time for the start of the harvest and have a lower incidence of pests and diseases. Since 2009, strawberries have been cultivated in the mountainous region of the state of Ceará, Brazil, predominantly the cv. Oso Grande in the conventional system, which presents some disadvantages. These dis-advantages include leaf wetness, increased susceptibility

*Corresponding author. E-mail: lucilanialmeida@hotmail.com. Tel: + 55 85 9 9714-5801.

to pests and diseases, and the need to rotate its planting areas. The areas need to be rotated since the successive use of the same area culminates in frequent problems like the spread of diseases in the plants causing reduction in crop productivity (Resende et al., 1999), which leads to an increased use of agricultural defense systems, hindering the acceptance and safety of the product for the consumers.

Despite being a non-climacteric fruit (Pineli et al., 2011), the strawberry is highly perishable, with high metabolic activity, greater susceptibility to mechanical injury and considerable levels of substrates favorable to proliferation of pathogenic organisms, such as moisture, organic acids and sugars. These organisms lead to a higher probability of deterioration, and therefore considerably reducing the post-harvest shelf-life. In order to extend the shelf-life through the reduction of the metabolic rate of the fruit and fruit rot control, cooled storage, is the main tool that has proven to be effective. However, for extended storage, it is still not enough to maintain good fruit quality, therefore an addition of other post-harvest preservation techniques, such as modified atmosphere are needed.

The modified atmosphere has had success in many vegetables. This technique consists of an increase in the partial pressure of the CO_2 and a decrease in the O_2 (Silveira et al., 2014), caused by the gas exchanges of the container with the ambient air. The packaging with low partial pressure of oxygen can reduce the breathing rate and maintain the shelf-life for a longer time or with better quality than the package with normal air. However, the extremely low oxygen content may result, in some cases, in fermentation resulting in an accumulation of unpleasant odors and tastes, reducing the aroma biosynthesis and tissue damage (Li et al., 2014). In this type of atmosphere, the partial pressure of O_2 and CO_2 are not controlled, and vary with time, temperature, type of film and the respiratory rate of the product (Chitarra and Chitarra, 2005).

Since the recent strawberry crop in the mountainous region of Ceará, is still adopting conducting techniques from other producing regions, there is a need for studies in the region with other cropping systems and crop cultivars, and the post-harvest shelf-life of the fruit. With this in mind, the objective of the research was to evaluate the post-harvest shelf life of two cultivars of strawberries (Oso Grande and Festival) in the hydroponic cultivation system in coconut fiber substrate, and compare them with the quality obtained in conventional farming, with cooled storage under modified atmosphere.

MATERIALS AND METHODS

Experimental conditions

The experiment was conducted in 2012 in the county of Ibiapina-CE, located in the Serra da Ibiapaba (mountainous region), 360 km from Fortaleza-CE, Brazil. The average temperature and relative humidity in the conventional system were 21.58°C and 61.76% and in the greenhouse 23.38°C and 71.24%, respectively.

The strawberries were stored under refrigeration (2 ± 2°C and 85% ± 10%) using modified atmosphere, with 9 µ PVC film for 14 days. The experiment was conducted in a completely randomized design, distributed in sub-subdivided plots with cropping systems (hydroponic and conventional) in the plot, Oso Grande and Festival cultivars in the subplot and the sub-subplot with storage times of 0, 3, 6, 10 and 14 days, with three replicates, represented by a tray with approximately 200 g of strawberries.

In the treatments in hydroponic crops, two wooden benches were used that were installed under a high tunnel with a tubular structure in galvanized steel, covered with white polyethylene film of 150 µm that was 3 m wide and 2 m high. The Golden Mix Misto type 80 coconut fiber substrate was used. The nutrient solution used presented itself with electrical conductivity ranging from 1.3 to 1.5 dS m^{-1} and a pH ranging from 5.4 to 6.5. The plots in conventional farming followed the technology already used by the farmer, which were installed outside of the tunnel in a garden that was 0.2 m high and 1 m wide, that was covered with black-white plastic (mulching), and before planting, the garden was fertilized with 180 g m^{-2} of simple superphosphate.

Quality evaluation

The fruits were harvested when they appeared to be ripe, meaning they had fully red skin, then transported to the laboratory, where they went through a selection process, where those with cuts or slots and insect attacks were discarded. Initially they were analyzed for the average mass variables (g) of the fruit, obtained by weighing each fruit individually with a semi-analytical scale; including the length (mm) and diameter (mm) of the fruit, determined with the use of a caliper rule. The other physical and physical-chemical variables were determined throughout the course of storage (0, 3, 6, 10 and 14 days). In each storage interval, the fruit samples were removed from the cooled chamber and physically analyzed and then processed using a domestic Walita® centrifuger, with the pulp stored at -20°C for a subsequent completion of the physical-chemical analysis.

The mass loss (%) was obtained through the difference between the initial mass and the mass obtained in each analysis interval and the firmness (N) was determined in the middle region of the whole fruit, with a manual Magness-Taylor model FT 011 penetrometer using a 8 mm tip. For the appearance we used a subjective grading scale, which considered the extra category - grade 4 (absence of serious defects and up to 5% of small defects), I - grade 3 (10% defects, considering up to 3 and 10% severe and mild defects, respectively) II - grade 2 (100% of defects, whereas up to 10 and 100% of severe and mild defects, respectively) (PBMH; PIMo, 2009). The severe defects that were analyzed were: Rot, mechanical damage, deep injury and severe deformation. Mild defects: Slight deformation, presence of foreign material and healed superficial damage. Grade 3, category I, was the minimum grade considered acceptable for consumption.

The titratable acidity (% citric acid) obtained through titration of the pulp with 0.1 M NaOH solution, according to the AOAC methodology (2005). Soluble solids (°Brix), the pulp, was filtered with filter paper and the content was measured with an Atago® model PR-101 Pallete digital refractometer, according to the AOAC (2005). The SS / TA ratio was determined by the ratio between the soluble solids and the titratable acidity values. The vitamin C (mg ascorbic acid 100 g^{-1}) was measured immediately after the processing of the fruit through titration with DFI solution of (2.6-

dichloro-phenol indophenol 0.02%) until it had a permanent pink color (Strohecker and Henning, 1967). Total anthocyanins and Yellow flavonoids (mg 100 g^{-1}) were extracted and determined through the method developed by Francis (1982).

Statistical analysis

Data was subjected to variance analysis (ANOVA) performed with the help of the SISVAR software version 5.3, and for the comparison of means, we used the Tukey test with 0.05 significance. Regression analysis was performed for data in which significant effects occurred.

RESULTS AND DISCUSSION

There were differences ($p<0.05$) between the crops and the crop systems that were isolated for the physical variables of the strawberries that were analyzed before storage. An average mass of 19.95 and 10.95 g, with a diameter of 31.64 and 24.01 mm and length of 40.86 and 36.97 mm for the hydroponic and conventional systems, respectively, was observed. Comparing the cultivars amongst themselves, the average mass of 16.21 and 14.47 g, diameter of 29.00 and 26.65 mm for the cvs. Oso Grande and Festival, respectively, was observed. The length of 39.21 mm for cv. Oso Grande and 38.63 mm for cv. Festival did not differ ($p>0.05$).

Similar results were observed by Resende et al. (2010), while evaluating the influence of different cropping systems on the average mass of strawberries in Guarapuava, in the state of Paraná. They found the highest and lowest values for the cultivar in greenhouses and field, respectively.

The largest fruits were obtained when produced hydroponically. This is probably due to the fact that plants are more healthy and vigorous when grown hydroponically, because of the nutritional and climatic conditions provided by this environment. This allows a greater expression of physiological activities and, consequently, a greater accumulation of carbohydrates which result in the increase of biomass (Taiz and Zeiger, 2013), resulting in larger strawberries. Meanwhile, the plants in the conventional system proved to be less vigorous, perhaps due to edafoclimatic stress conditions, resulting in smaller strawberries.

The storage time did not influence ($p>0.05$) the firmness of the pulp of the strawberries. As for systems and the cultivars, an isolated difference was observed ($p<0.01$), with higher values for the conventional system and the cv. Festival, averaging at 8.80 and 9.75 N respectively. As for the hydroponic system, it was 7.52 N and for the cv. Oso Grande it was 6.57 N.

The maximum firmness in the conventional cultivation system probably occurred due to higher weight loss in these fruits, because when water is lost, a stiffening of the cell walls of the fruit occurs. It may also be the result of the difference in nutrient availability between the systems, the culture management in the systems and the lowest temperature in the conventional, when compared to hydroponics.

A fact that was also confirmed by Pinto et al. (2012) while they studied the induction of weight loss in post-harvest quality of 'Eragil' peaches was an increase in firmness with an increase in mass loss.

Hoppula and Karhu (2006) observed that the low firmness in the strawberry is strongly related to high temperatures. They found a stronger correlation with the average temperature three weeks before the harvest. This indicates that the temperature conditions may affect the properties of the cell wall responsible for the firmness of the strawberry in the initial stages of the development of the fruit.

Time interaction was observed ($p<0.01$) between the systems and between the cultivars (Figure 1A and B) in relation appearance of the strawberries. The systems reduced 20 and 18.25% over time in the hydroponic and conventional systems, respectively, not differing from each other. The cvs. Oso Grande and Festival decreased over time, represented by 26.75 and 11.75%, respectively, showing a difference between them, only in the last storage time, with the highest value for the cv. Festival (average grade 3.53). However, at the end of the storage time, the fruits of both cultivars still had attractive features to consumers, such as firmness, external color and absence of injuries and rot.

The mass loss showed interaction ($p<0.05$) between the time, system and cultivars (Figure 2A). The largest losses were observed in the conventional system with the cv. Festival, which differed from other treatments at 10 and 14 days, presenting on the day 14 a mass loss of 2.1%. For other treatments, similar behavior was observed, not differing from each other at any point. The cv. Festival in the hydroponic system and the cv. Oso Grande in the conventional system showed a growing behavior throughout the storage period, reaching 1.18 and 1.33% at 14 days of mass loss, respectively. As for the cv. Oso Grande in the hydroponic system, it showed an increase up to day 10 (1.19%) followed by a drop until the end of the storage time. It was also observed that the cv. Oso Grande, unlike the cv. Festival was not different in both systems. According to Calegaro et al. (2002), the maximum loss commercially tolerated for strawberries is 6%, being that in this study, lower values were found.

The most massive loss recorded in strawberries in the conventional system may have been influenced by the smaller size of the fruit, which probably has a higher transpiration rate, compared to fruits produced in the hydroponic system. It is assumed that the transpiration rate of vegetables is proportional to its relative surface area / mass. In other words, with the increase in the size of the fruit, there is a reduction in the ratio surface area / mass and consequently a reduction of the transpiration

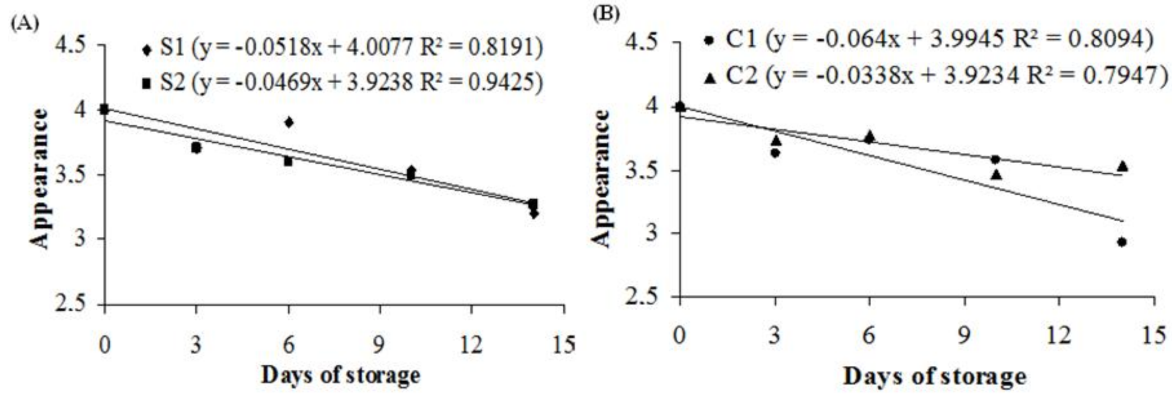

Figure 1. External appearance for system (A) and cultivars (B) of fruits of two strawberry cultivars and in two cropping systems and stored under modified atmosphere at 2 ± 2°C and 85 ± 10% U.R. S1 - hydroponic system; S2 - conventional system; C1 - Oso Grande; C2 - Festival.

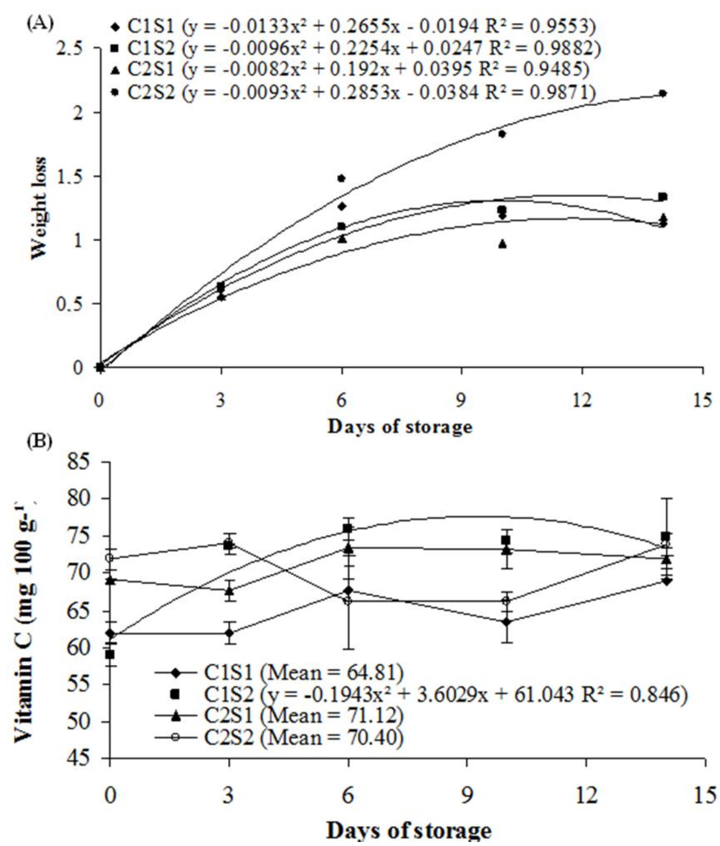

Figure 2. Weight loss (%, A) and Vitamin C (mg ascorbic acid 100 g^1, B) of fruits of two strawberry cultivars and in two cropping systems and stored under modified atmosphere at 2 ± 2 °C and 85 ± 10% U.R. S1 - hydroponic system; S2 - conventional system; C1 - Oso Grande; C2 – Festival.

rate, as shown in eggplants (Pérez, 1998).

In vitamin C, interaction was observed ($p<0.01$) between the storage time, systems and cultivars (Figure 2B). The hydroponic system with the cvs. Oso Grande and Festival and the conventional system with the cv. Festival showed variations over time, but at the end of

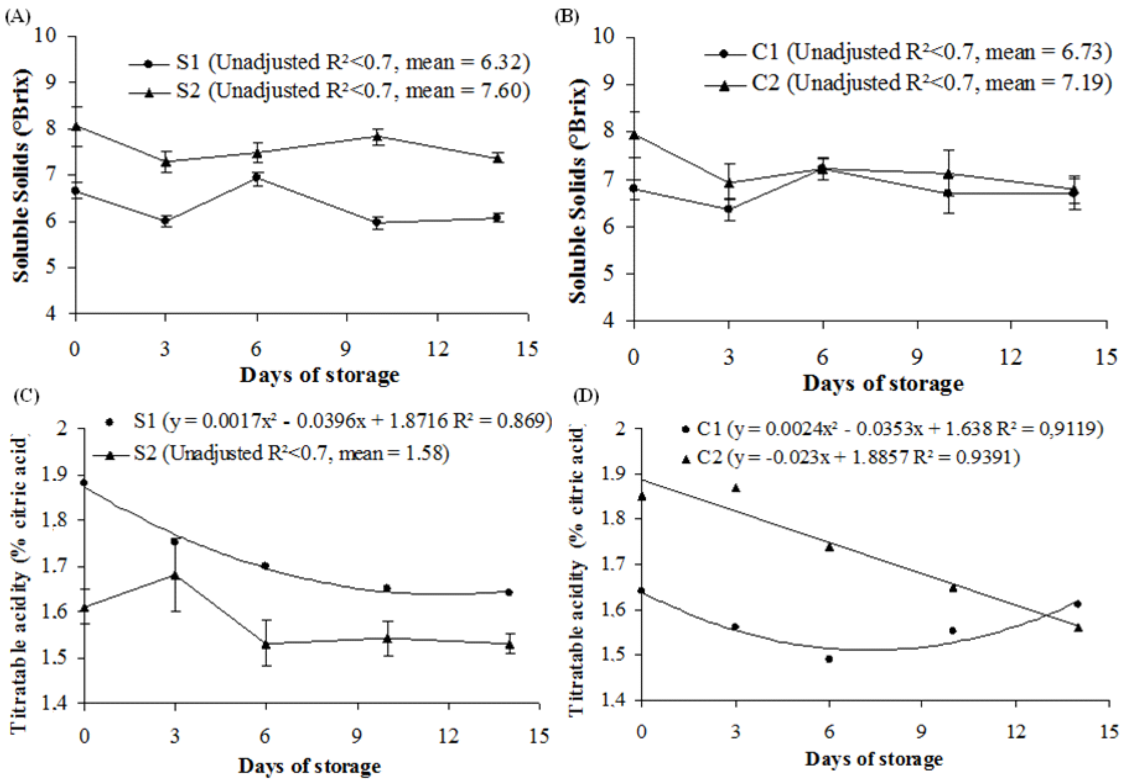

Figure 3. Soluble solids (°Brix, A and B) and Titratable acidity (% citric acid, C and D) of fruits of two strawberry cultivars in two cropping systems and stored under modified atmosphere at 2 ± 2 °C and 85 ± 10% U.R. S1 - hydroponic system; S2 - conventional system; C1 - Oso Grande; C2 – Festival.

the storage time, it maintained values similar to the original ones. For these treatments, there was not an equation that would fit. However, the cv. Oso Grande in the conventional system showed a higher level of variation, starting the storage time with 58.9 mg 100 g^{-1} and ending with 74.8 mg 100 g^{-1}. These variations in the quantification of the vitamin C may have been caused by the determination method that was used, using the titrimetric. With this tool, systematic errors may occur. And example of this is the difficulty in the visualization of the final titration point which presents a pink color, therefore when the strawberry presents an intense red color, it makes this visualization difficult.

The values of this study were higher than those observed by Atress et al. (2010), who while evaluating edible films in the cv. Festival strawberries in Egypt, found variations of approximately 10 to 35 mg 100 g^{-1} during the storage time.

There was interaction (p<0.01) between the storage time and the systems, as well as between the time and the cultivars in relation to the soluble solids content (Figure 3A and B). In both cases, there were fluctuations of soluble solids over time. They did not present an equation that would fit. These soluble solids results are in agreement with those obtained by Borges et al. (2013), who found similar values and also saw variations during the storage time.

The cultivars only differed until the third day, with a greater amount of soluble solids for the cv. Festival, maintaining similar values after this period. As for the systems, there were differences from the beginning to the end of the storage time, with the highest averages presented by the conventional system (Table 1). The highest concentration of SS in the conventional system may be due to direct sunlight, and also, the lowest water absorption by the plant, when compared to the hydroponic system, which has water more frequently. In the conventional system, the amount of water applied does not reflect the absorbed, since various factors affected the absorption of water. Among these is the evapotranspiration. This is influenced by several climatic parameters, the most important being the temperature, relative humidity, wind speed and solar radiation (Valipour, 2014a, b).

According to Kader (1999), the minimum amount recommended for the strawberry flavor to be acceptable is 7°Brix. In this study, lower values were observed when produced in the hydroponic system. These lower values

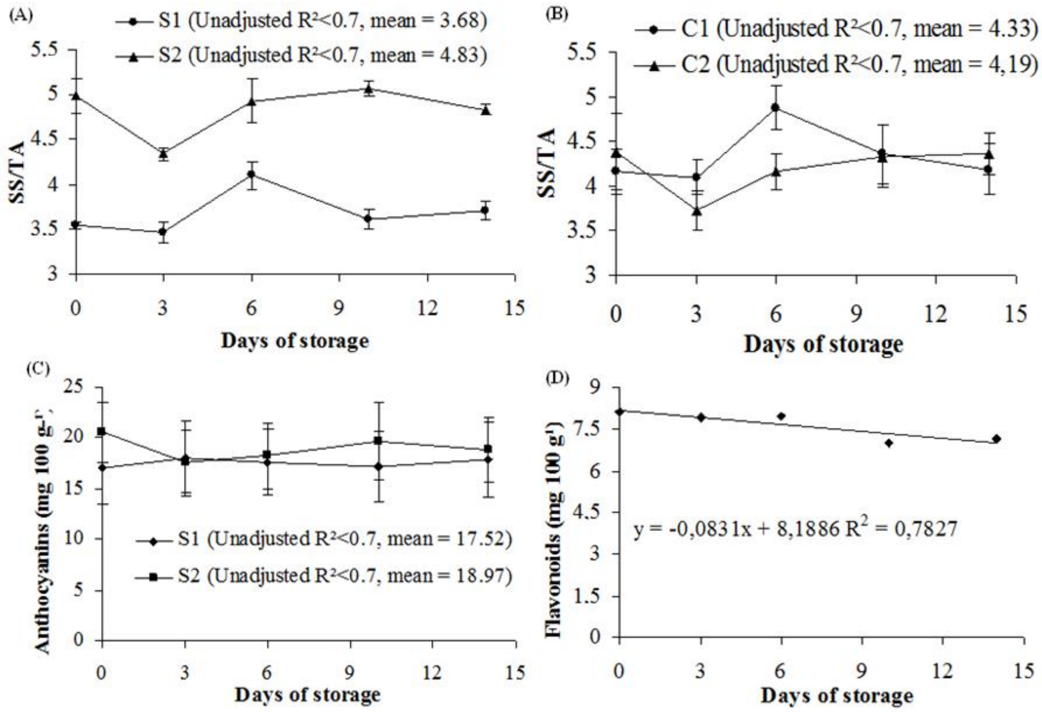

Figure 4. SS/TA ratio (A and B), Total anthocyanins (mg 100 g^{-1}, C) and Flavonoids (mg 100 g^{-1}, D) of fruits of two strawberry cultivars in two cropping systems and stored under modified atmosphere at 2 ± 2°C and 85 ± 10% U.R. S1 - hydroponic system; S2 - conventional system; C1 - Oso Grande; C2 – Festival.

are probably due to weather conditions that are unfavorable to the crop, that are present in the system that was used. The fruit that was produced in the conventional system showed values that fall within the acceptable minimum.

The titratable acidity showed interaction ($p<0.05$) between the storage time and the systems, and between the time and the cultivars (Figure 3C and D). During the study, one could observe that the acidity decreased over time, probably due to the use of organic acids as a substrate in respiratory metabolism during the storage time and /or as carbon skeletons for the synthesis of new compounds (Sólon et al., 2005). The systems differ from each other in all storage time intervals, except for the third day, that has the highest values observed in the hydroponic system, reducing throughout the storage time, presenting on day 14, 1.64% of citric acid (Table 1). For the conventional system, there was not an equation that adjusted over time. While the cultivars differed among themselves until the tenth day, with the cv. Festival presenting the highest rates, which decreased linearly during the storage time; however, the cv. Oso Grande showed a lower value of 1.49% of citric acid for the 6 days (Table 1).

The results of this study were higher than those found by Cunha Júnior et al. (2012), in the municipality of Valinhos-SP, for the cv. Oso Grande, that varied from 0.79 to 0.85% of citric acid during the storage time. The elevated acidity of the fruits can be attributed to the high temperatures of the Ceará region, when compared with traditional cultivation. Since the strawberry plant is a crop that under high temperature, during the day and / or night, may cause the strawberry to become excessively acidic.

As far as the SS / TA, an interaction ($p<0.01$) was observed between the storage time and the systems, and between the time and the cultivars (Figure 4A and B), in which there was no equation that would fit in both cases. Farming systems showed differences in all the storage intervals, with the highest values represented by the conventional system. The cultivars showed variation over time, but only showed a difference on the third and sixth day, and at the end of the storage time the final values were very close to the original ones, represented by a difference of 0.48 and 0.46% for the cvs. Oso Grande and Festival, respectively (Table 1).

The results of this work were inferior to those observed by Borsatti et al. (2009), who found SS /TA values of 6.29 and 7.27 for the cvs. Oso Grande and Festival, respectively, being lower than recommended (8.75) by

Table 1. Soluble solids (°Brix), Titratable acidity (% citric acid) and SS/TA ratio of fruits of two strawberry cultivars in two cropping systems and stored under modified atmosphere at 2 ± 2 °C and 85 ± 10% U.R.

Soluble solids**					
Cultivars	**Days of storage**				
	0	**3**	**6**	**10**	**14**
Oso Grande	6.77[b]	6.35[b]	7.20[a]	6.67[a]	6.68[a]
Festival	7.93[a]	6.93[a]	7.20[a]	7.13[a]	6.77[a]
Systems					
Hydroponic	6.65[b]	6.00[b]	6.92[b]	5.97 [b]	6.08[b]
Conventional	8.05[a]	7.28[a]	7.48[a]	7.83 [a]	7.37[a]
CV(%)-a = 6.42		CV(%)-b=5.58		CV(%)-c=5.15	
Cultivars			**Titratable acidity.**		
Oso Grande	1.64b	1.56b	1.49b	1.55b	1.61[a]
Festival	1.84[a]	1.87[a]	1.74[a]	1.65[a]	1.56[a]
Systems					
Hydroponic	1.88[a]	1.74[a]	1.70[a]	1.66[a]	1.64[a]
Conventional	1.61[b]	1.68[a]	1.53[b]	1.55[b]	1.53[b]
CV(%)-a = 4.66		CV(%)-b=3.17		CV(%)-c=4.65	
Cultivars			**SS/TAratio****		
Oso Grande	4.15[a]	4.08[a]	4.87[a]	4.34[a]	4.17[a]
Festival	4.38[a]	3.71[b]	4.16[b]	4.33[a]	4.36[a]
Systems					
Hydroponic	3.54[b]	3.46[b]	4.10 [b]	3.61[b]	3.71[b]
Conventional	4.99[a]	4.34[a]	4.93 [a]	5.07[a]	4.82[a]
CV(%)-a = 4.81		CV(%)-b=5.51		CV(%)-c=6.24	

Means followed by the same letter in columns do not differ by the Tukey test at 1% (**) and 5% (*) probability.

Kader (1999). Although the soluble solid values were lower than recommended in some treatments, what affected the reduction of the SS / TA relation the most was the acidity of the fruit. However, even with low SS / TA relation, the local consumer market and from the state of Piauí, Brazil, routinely consume these products.

As for the total anthocyanins, there was interaction ($p<0.01$) between the storage time and the cultivation systems (Figure 4C), with variation over time. Differences were noted among the systems at harvest and on day 10, with the highest values in the conventional system, however not very expressive (Table 2). In both systems, there was no equation that would fit, with the averages represented in the chart. The cultivars and the systems differ in an isolated way, with 10.7 and 25.8 mg 100 g^{-1} of anthocyanins for the cvs. Oso Grande and Festival and 17.53 and 18.97 mg 100 g^{-1} of this pigment for the hydroponic and conventional systems, respectively.

The flavonoids showed linear reduction throughout the storage time, represented by 11.96% ($p<0.01$) (Figure 4D). Interaction was observed ($p<0.01$) between the systems and the cultivars, which was the best performance of the hydroponic and conventional systems with the cvs. Festival and Oso Grande, respectively (Table 2).

The contents of anthocyanins and flavonoids were greater in the conventional system, probably due to activation of the biosynthesis of these compounds, as a result of high solar radiation in this system when compared with the hydroponic system, which was conducted in a greenhouse. Corroborating Jaakola et al. (2004), that while studying the activation of flavonoid biosynthesis in *Vaccinium myrtillus* L.*,* observed activation of expression of the flavonoid pathway genes, as a result of high solar radiation. The influence of solar radiation in the phenolic compounds has also been observed by Cortell and Kennedy (2006) who studied *Vitis vinifera*, and noted in a cloudy system, a decrease of some anthocyanins, such as delphinidin, cyanidin, petunidin and malvidin. In studies with strawberries by Josuttis et al. (2010), a decrease in the content of cyanidin 3-glucoside, quercetin 3-glucuronide and Kaempferol 3-glucoside in the fruit cultivated with the blocking of ultraviolet radiation in comparison with the strawberries

Table 2. Total anthocyanins (mg 100 g^{-1}) and Flavonoids (mg 100 g^{-1}) of fruits of two strawberry cultivars in two cropping systems and stored under modified atmosphere at 2 ± 2°C and 85 ± 10% U.R.

Total anthocyanins					
Systems	Days of storage				
	0	3	6	10	14
Hydroponic	16.98[b]	18.01[a]	17.63 [a]	17.20 [b]	17.79 [a]
Conventional	20.58[a]	17.61[a]	18.22 [a]	19.67 [a]	18.77 [a]
CV (%)-a = 8.42		CV(%)-b=8.70		CV(%)-c=5.62	

Flavonoids		
	OsoGrande	Festival
Hydroponic	6.79[bB]	7.30[aA]
Conventional	9.44[aA]	7.09[aB]
CV (%)-a = 8.10	CV (%)-b = 4.99	CV (%)-c = 9.85

Means followed by the same lowercase letters in columns and uppercase letters in rows do not differ by the Tukey test at 1% probability.

cultivated in the open field.

Although the strawberry's exposure to sunlight adds benefits to the quality, such as accumulation of phenolic compounds, the intensity of the sunlight should not be too strong. This is because if sunlight too strong, it results in increased temperature of the fruit, which may cause a decrease in phenolic compounds, such as anthocyanins, as observed in 'Aki Queen' and red-wine by Yamane and Shibayama (2006) and Mori et al. (2007), respectively.

Conclusions

The fruit shelf life was extended by the use of cooling along the modified atmosphere, indicating the good potential of this combination to increase the post-harvest life of the strawberry, with fruit produced in conventional and hydroponic systems with the best physical-chemical quality and greater size, respectively.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

AOAC-Association of official analytical chemists (2005). Official methods of analysis of the association of official analytical chemists. 18.ed. Maryland. P 850.

Atress ASH, El-Mogy MM, Aboul-Anean HE, Alsanius BW (2010). Improving strawberry fruit storability by edible coating as a carrier of thymol or calcium chloride. J. Hortic. Sci. Ornamen. Plant 2(3):88-97.

Borges CD, Mendonça CRB, Zambiazi RC, Nogueira D, Pinto EM, Paiva FF (2013). Conservação de morangos com revestimentos à base de goma xantana e óleo essencial de sálvia. Biosci. J. 29(5):1071-1083.

Borsatti FC, Godoy WI, Farinácio D, Funguetto RF, Simonetti D (2009). Avaliações químicas de dez cultivares de morangueiro produzidos em sistema orgânico na região sudoeste do Paraná. Rev. Bras. Agroec. 4(2):31-34.

Calegaro JM, Pezzi E, Bender RJ (2002). Utilização de atmosfera modificada na conservação de morangos em pós-colheita. Pesq. Agropec. Bras. 37(8):1049-1055.

Chitarra MIF, Chitarra AB (2005). Pós-colheita de frutas e hortaliças: fisiologia e manuseio. 2 ed, UFLA, Lavras, P 785.

Cortell JM, Kennedy JA (2006). Effect of shading on accumulation of flavonoid compounds in (*Vitis vinifera* L.) pinot noir fruit and extraction in a model system. J. Agric. Food Chem. 54(22):8510-8520. http://dx.doi.org/10.1021/jf0616560

Cunha Junior LC, Jacomino AP, Ogassavara FO, Trevisan MJ, Parisi MCM (2012). Armazenamento refrigerado de morango submetido a altas concentrações de CO2. Hortic. Bras. 30(4):688-694. http://dx.doi.org/10.1590/S0102-05362012000400020

Díaz-Pérez JC (1998). Transpiration rates in eggplant fruit as affected by fruit and calyx size. Posth. Biol. Technol. 13:45-49. http://dx.doi.org/ 10.1016/S0925-5214(97)00078-1

Francis FJ (1982). Analysis of Anthocyanins. In: MARKAKIS P. Anthocyanins as food colors. London, UK: Academic Press P 263.

Hoppula KB, Karhu ST (2006). Strawberry fruit quality responses to the production environment. J. Food Agric. Environ. 4(1):166-170.

Jaakola L, Maatta-Riihinen K, Karenlampi S, Hohtola A (2004). Activation of flavonoid biosynthesis by solar radiation in bilberry (Vaccinium myrtillus L.) leaves. Plant 218:721-728. http://dx.doi.org/10.1007/s00425-003-1161-x

Josuttis M, Dietrich H, Treutter D, Will F, Linnemannstöns L, Krüger E (2010). Solar UVB response of bioactives in strawberry (Fragaria × ananassa Duch.): A Comparison of protected and open-field cultivation. J. Agric. Food Chem. 58:12692-12702. http://dx.doi.org/10.1021/jf102937e

Kader AA (1999). Fruit maturity, ripening, and quality relationships. Acta Hortic. 485:203-208. Li Y, Ishikawa Y, Satake T, Kitazawa H, Qiu X, Rungchang S (2014). Effect of active modified atmosphere packaging with different initial gas compositions on nutritional compounds of shiitake mushrooms (*Lentinus edodes*). Posth. Biol. Technol. 92:107-113. http://dx.doi.org/10.1016/j.postharvbio.2013.12.017

Mori K, Goto-Yamamoto N, Kitayama M, Hashizume K (2007). Loss of anthocyanins in red-wine grape under high temperature. J. Exp. Bot. 58:1935-1945. http://dx.doi.org/10.1093/jxb/erm055

Pineli LLO, Moretti CL, Santos MS, Campos AB, Brasileiro AV, Cordova AC, Chiarello MD (2011). Antioxidants and other chemical and physical characteristics of two strawberry cultivars at different

ripeness stages. J. Food Compos. Anal. 24:11-16. http://dx.doi.org/10.1016/j.jfca.2010.05.004
PBMH PIMo (2009). Programa brasileiro para a modernização da horticultura e produção integrada de morango. Normas de Classificação de Morango. São Paulo: CEAGESP, (Documentos, 33).
Pinto JAV, Brackmann A, Schorr MRW, Venturini TL, Thewes FR (2012). Indução de perda de massa na qualidade pós-colheita de pêssegos 'Eragil' em armazenamento refrigerado. Cienc. Rural. 42(6):962-968. http://dx.doi.org/10.1590/S0103-84782012000600002
Resende LMA, Mascarenhas MHT, Paiva BM (1999). Programa de produção e comercialização de morango. Inform. Agropec. 20(198):5-19.
Resende JTV, Morales RGF, Faria MV, Rissini ALL, Camargo LKP, Camargo CK (2010). Produtividade e teor de sólidos solúveis de frutos de cultivares de morangueiro em ambiente protegido. Hortic. Bras. 28(2):185-189.
Silveira AC, Araneda C, Hinojosa A, Escalona VH (2014). Effect of non-conventional modified atmosphere packaging on fresh cut watercress (*Nasturtium officinale* R. Br.) quality. Posth. Biol. Technol. 92:14-120. http://dx.doi.org/10.1016/j.postharvbio.2013.12.012
Solon NK, Menezes JB, Medeiros MKM, Aroucha EMM, Mendes MO (2005). Conservação pós-colheita do mamão formosa produzido no Vale do Assu sob atmosfera modifica¬da. Rev. Caating. 18(2):105-111.
Strohecker R, Henning HM (1967). Analises de vitaminas: métodos comprobados. Madrid: Paz Montalvo, P 428.
Taiz L, Zeiger E (2013). Fisiologia vegetal. 5.ed. Porto Alegre: Artmed, 918p.
Valipour M (2014a). Analysis of potential evapotranspiration using limited weather data. Appl. Water Sci. pp. 1-11. http://dx.doi.org/10.1007/s13201-014-0234-2.
Valipour M (2014b). Application of new mass transfer formulae for computation of evapotranspiration. J. App. Water Eng. Res. 2(1):33-46. http://dx.doi.org/10.1080/23249676.2014.923790.
Yamane T, Shibayama K (2006). Effect of changes in the sensitivity to temperature on skin coloration in `Aki Queen' grape berries. J. Jpn. Soc. Hortic. Sci. 75:458-462.