MASS LOSS INDUCTION ON PHYSICAL AND CHEMICAL QUALITIES OF 'MURCOTT' TANGOR DURING COLD STORAGE

INDUÇÃO DE PERDA DE MASSA NAS QUALIDADES FÍSICAS E QUÍMICAS DE TANGOR 'MURCOTT' DURANTE O ARMAZENAMENTO REFRIGERADO

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ABSTRACT: In order to obtain more consumers approval, fruit require high quality during commercialization, making the improvement of new storage technologies necessary. Thus, the aim of this study was to evaluate the best mass loss level on 'Murcott' tangor quality maintenance after cold storage during 10 weeks. The treatments evaluated were: [1] 0% of mass loss (100 % of relative humidity); [2] 3% of mass loss; [3] 6% of mass loss and [4] 9% of mass loss, with 5 replicates of 18 fruits each treatment. The storage temperature was maintained at 4.0°C (±0.2°C). The experiment was conducted in a completely randomized design. After 10 weeks of storage plus seven days of shelf life at 20°C it was verified that with the mass loss increase, the decay incidence and the succulence are suppressed, mass loss also increased the soluble solids and titratable acidity. The best mass loss level for 'Murcott' tangor storage stay between 3 up to 6% because it reduces the decay incidence and turgor loss and maintain chemical qualities, such as ascorbic acid, soluble solids and titratable acidity.

KEYWORDS: Postharvest. Decay incidence. Ascorbic acid.

INTRODUCTION

'Murcott' tangor have a high demand by the consumers market, mainly, for in nature consumption. Thus, the fruit needs a high quality standard, but this quality is not always achieved due to inappropriate storage conditions (HENDGES et al., 2011). This fact indicated the necessity of storage technologies improve, with low cost and high postharvest quality maintenance.

Storage temperature reduction, during storage, is one of the most inexpensive and efficient mechanisms to increase the postharvest life of fruit (CHITARRA; CHITARRA, 2005; BRACKMANN et al., 2010). With its reduction, the biochemical reactions rate decrease, such as respiration rate (ASIF et al., 2009). The 'Murcott' tangor storage must be performed in a correct temperature level; because high temperature decrease storage time (high respiration rate) and excessive low temperature increase the physiological disorders, such as chilling. In fact, the temperature for cold storage must be stay between 2 and 10°C (TAVARES et al., 2003).

In addition to temperature control, the mass loss play a fundamental role during 'Murcott' tangor storage. The mass loss is regulated by the relative humidity (RH) (MAGUIRE et al., 2000), whereas a low RH condition result in shriveling and high mass loss, on the other hand, elevated RH can increase the decay incidence, making the fruit useless for commercialization (KADER, 1986; SCHWARZ, 1994; CHITARRA; CHITARRA, 2005). However, not all mass loss is in function of water vapor loss, whereas part is in function of fruit respiration (CO_2 losses) (MAGUIRE et al., 2000; BRACKMANN et al., 2014). The same authors reported that than higher the RH higher is the mass loss in function of respiration and, than lower the RH higher mass loss in function of water vapor loss.

During postharvest life, the mass loss in function of water vapor loss assist on quality maintenance, because we can control exactly and constantly the fruit transpiration during storage (PINTO et al., 2012). The mass loss benefits on quality are demonstrate in apples (MAGUIRE et al., 2000; BRACKMANN et al., 2007), peaches (PINTO et al., 2012) and persimmons (BRACKMANN et al., 2014). Nevertheless, there are not studies about the correct mass loss level for 'Murcott' tangor during storage, showing the necessity of studies to improve the storage.

Thus, the objective of the present study was to evaluate the best mass loss level on post-storage quality of 'Murcott' tangor stored during 10 weeks in cold storage at 4.0°C.

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MATERIAL AND METHODS

Fruit utilized in the experiment were obtained from an orchard located at the Polytechnic School of the Federal University of Santa Maria (UFSM). Right after harvest, fruit were transported to the Postharvest Research Center (NPP) and a selection was carried out. After, the samples were placed into storage chambers ($0.233m^3$) localized into a cold room with $45m^3$.

The experiment was conducted in a completely randomized design with five replicates of 18 fruit each. Four mass loss levels were evaluated: [1] 0% mass loss (100 % of relative humidity); [2] 3% mass loss; [3] 6% mass loss and [4] 9% mass loss. Fruit were stored during 10 weeks at 4.0°C (±0.2°C). The mass loss induction was performed daily, through the passage of air from the chamber by a hermetically bottle that contained silica gel, which absorbed the humidity of air. This form of air humidity absorption was executed until the fruit to reach the pre-established mass loss, according to Brackmann et al. (2007).

After storage plus seven days of shelf life at 20°C, a form to simulate the commercialization time, the variables measured were the following:

a) Succulence: determined by the relation between the juice mass and total fruit mass, expressed in percentage (%);

b) Decay incidence: obtained by the number of fruit with fungal lesions (higher than 0,5cm) in relation to total fruit, data expressed in percentage (%);

c) Turgor loss: evaluated subjectively, where the fruit were compressed among the fingers and visualization of pulp consistence, expressed in percentage of turgid fruit (%);

d) Shriveling: determined by count of fruit that presented any typical shriveling symptom in the skin, expressed in percentage (%);

e) Titratable acidity: obtained by titration of a solution that contained 10 mL of juice diluted in 100 mL of distillable water, with a solution of NaOH 0.1N until pH 8.1, results expressed in meq 100 mL^{-1};

f) Soluble solids; determined with a refractometer, data expressed in °Brix;

g) Respiration rate: determined by placing of approximately 1.5 kg of fruit in a container with volume of 5 liters, that was hermetically sealed for approximately two hours. The air from the container was circulated through a gas analyzer that measured the CO_2 concentration within the container. The data were expressed in mL CO_2 kg^{-1} h^{-1};

h) Skin thickness: evaluated by cutting the skin from the equatorial region and it thickness measured with a pachymeter, results expressed in millimeters (mm);

i) Skin and juice color: determined with an electronic colorimeter (Minolta, model CR310) that uses a tridimensional color system, data expressed in L, C and H;

j) Ascorbic acid: determined by titration, with a 0.01N potassium iodate solution, in a solution with 12g of juice, 1mL of potassium iodide 10%, 20ml of 20% sulfuric acid and 1ml of starch, results expressed in mg 100 g^{-1}.

An analysis of variance (ANOVA) was carried out for all the parameters evaluated. The parameters averages in which the ANOVA was significant were submitted to regression analysis at a 5% probability of error ($p < 0.05$). The data expressed in percentage were transformed by the formula $\text{arc.sin}\sqrt{x/100}$, before the analysis of variance. The software programs, Sisvar and Action for Excel, were used to run the statistical analysis.

RESULTS AND DISCUSSION

Before storage, an initial analysis to determine the maturity stage of fruit was carried out (Table 1). Fruit showed high titratable acidity (19.50 meq $100mL^{-1}$) and soluble solids (12.80 °Brix), and the values were analogous to the ones found in 'Montenegrina' mandarin and 'Murcott' tangor (TAVARES et al., 2003; BRACKMANN et al., 2008). The respiration rate was low and the skin color similar to other studies with 'Murcott' tangor (TAVARES et al., 2003).

Today there is high demand for fruit with significant vitamin levels, among which stay the ascorbic acid. Ascorbic acid is a very important substance present in the citric fruit, such as 'Murcott' tangor (KLUGE et al., 2007; COUTO; CANNIATTI-BRAZACA, 2010). In the present study, the ascorbic acid showed a negative linear response to the mass loss (Figure 1A), decreasing with mass loss increase. The ascorbic acid levels changed from 39.27 up to 46.14 mg 100 g^1, these values are analogous to another research with 'Murcott' tangor (KLUGE et al., 2007). Because ascorbic acid is an antioxidant (PELLEGRINI et al., 2007) its lower concentration in fruits stored under 9% of mass loss may be related with any type of stress triggered by the high water vapor loss of fruit of this treatment. This fact is evidenced by the positive *Pearson* correlation between succulence and ascorbic acid content (Table 2).

Table 1. Physical and chemical characteristics of 'Murcott' tangor before storage (initial analysis). UFSM, Santa Maria, 2015.

Characters	Unit	Mean*	Standart deviation
Titratable acidity	meq $100mL^{-1}$	19.50	±0.3741
Soluble solids	°Brix	12.80	±0.2828
Ascorbic acid	mg $100g^{-1}$	56.65	±0.8302
Skin thickness	mm	2.26	±0.1274
Respiratory rate	mL CO_2 kg^{-1} h^{-1}	8.65	±1.215
Skin color	Luminosity (L)	64.91	±0.2381
Skin color	Intensity (C)	64.69	±0.9142
Skin color	°Hue	68.24	±0.3642

*Mean values obtained from the analysis of three replicates of 18 fruits each.

Table 2. Correlation values of physical and chemical qualities of 'Murcortt' tangor after 10 weeks of storage at different mass loss levels. UFSM, Santa Maria, 2015.

-	AA	SS	TA	SC	DI	TL	RR	JL	JC	JH
AA	1									
SS	ns	1								
TA	-0.57	0.63	1							
SC	0.64	ns	-0.48	1						
DI	0.56	-0.62	ns	ns	1					
TL	0.66	-0.70	-0.59	0.59	0.57	1				
RR	ns	-0.59	-0.64	ns	0.54	0.63	1			
JL	-0.54	0.66	0.57	-0.53	-0.51	-0.72	-0.48	1		
JC	-0.55	0.74	0.61	-0.48	-0.61	-0.78	-0.58	0.96	1	
JH	ns	-0.77	-0.58	ns	0.52	0.77	0.57	-0.86	-0.86	1

AA: Ascorbic acid; SS: Soluble solids; TA: Titratable acidity; SC: succulence; DI: Decay incidence; TL: Turgor loss; RR: Respiratory rate; JL: Luminosity of juice color; JC: Intensity of juice color; JH: Hue angle of juice color. Pearson correlation values ($p < 0.05$).

Mass loss of fruit is a factor of considerable influence on its succulence. Figure 1B shows succulence has a significant reduction with the mass loss increase. Brackmann et al. (2008) also verified lower succulence in 'Montenegrina' mandarin stored under low relative humidity (fruit with high mass loss). The low relative humidity induces high mass loss (water loss), by the different vapor pressure inside and outside of fruit, resulting in higher transpiration and consequently reducing fruit succulence (HARDENBURG et al., 1986). However, compared to results found by other authors, the succulence at this research was high, even when fruit were stored at the highest mass loss level (9%), ranging from 69.16 up to 78.07%, in contrast with 58% in 'Murcott' tangor (TAVARES et al., 2003) and 54.2% in 'Valencia' orange (LATADO et al., 2008).

Soluble solids and titratable acidity, together, are widely used for fruit flavor evaluation, especially, citric fruit (CHITARRA; CHITARRA, 2005). For the present study, both soluble solids and titratable acidity showed a positive linear response with the mass loss increase (Figures 1C e 1D). Acidity and soluble solids increased with the mass loss increase, corroborating the results obtained in 'Royal Gala' apples (BRACKMANN et al., 2007) and 'Eragil' peaches (PINTO et al., 2012). At the present study, than higher the respiration rate lower were the soluble solids and titratable acidity, due the negative correlation between these two parameters (Table 2). Corroborating results of Sweetman et al. (2009) that affirmed titratable acidity reduction have relation with the organic acid metabolism in tricarboxylic acid cycle (respiration rate). However, the titratable acidity reduction, with decrease of mass loss, can be explained because the dilution of the solids according the negative correlation between succulence and titratable acidity (Table 2).

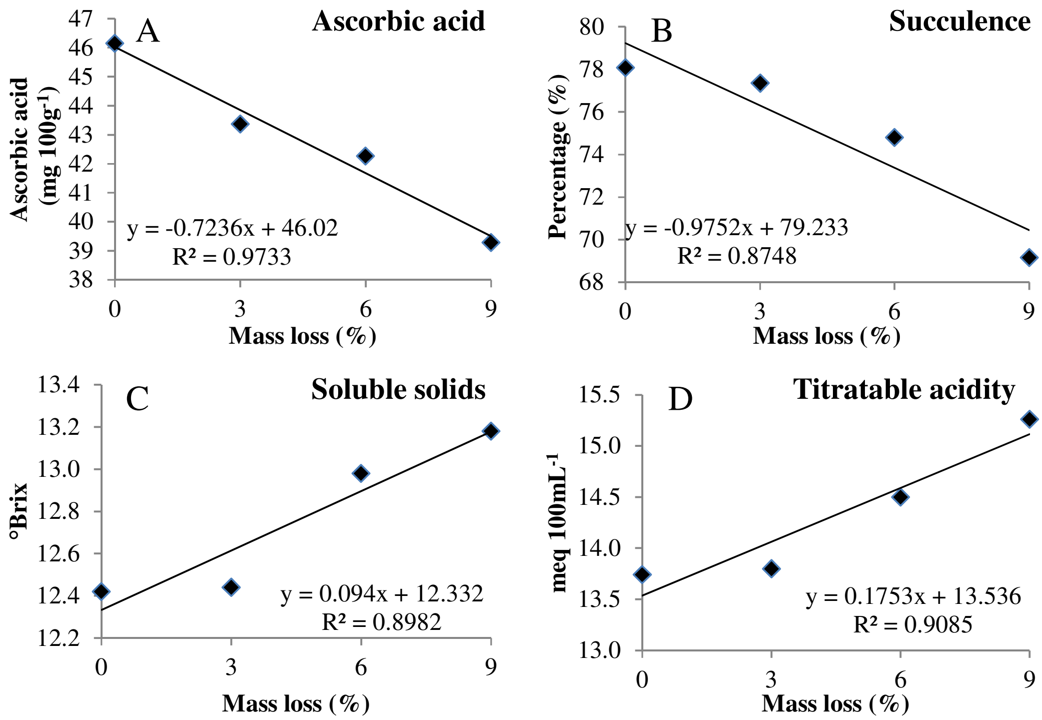

Figure 1: Ascorbic acid, succulence, soluble solids and titratable acidity of 'Murcott' tangor after cold storage at temperature of 4.0°C during 10 weeks plus seven days of shelf life at 20°C. UFSM, Santa Maria, 2015.

The correct mass loss level (by fruit transpiration) is essential for high quality maintenance, mainly, because RH and mass loss has relation with decay incidence (SCHWARS, 1994; BRACKMANN et al., 2007; BRACKMANN et al., 2008). Decay incidence reduced according increase of mass loss level in the storage chamber, changing from 7.4%, at 9% of mass loss, up to 18.11% at lowest mass loss level (Figure 2A).

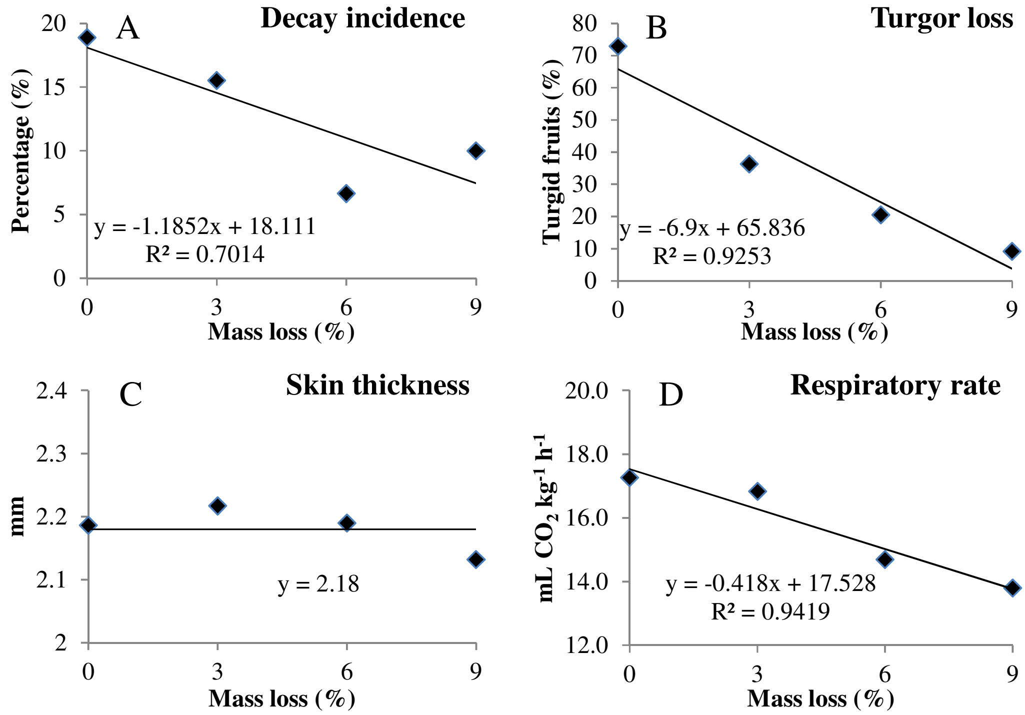

Figure 2. Decay incidence, turgor loss, skin thickness and respiratory rate of 'Murcott' tangor after cold storage at temperature of 4.0°C during 10 weeks plus seven days of shelf life at 20°C. UFSM, Santa Maria, 2015.

The lower decay incidence at the highest mass loss level (lowest humidity) is due to the fact that fungal spores need free water for its germination, and in this storage condition had low free water in the fruit surface, because the relative humidity absorption. Another author reported in ‘Satsuma’ mandarin that the low relative humidity (80%) reduced the decay incidence in relation to the high relative humidity (93%) (ARTÉS et al., 1995).

One of most important problem of high transpiration of fruit is the turgor loss. The factor with greatest influence on fruit turgor is its succulence, because than higher the succulence higher is the turgid fruit level according *Pearson* correlation (Table 2). Observing the figure 2B, a reduction in turgid fruit percentage according the increase of mass loss was verified. This result agree with the literature, which show that the fruit stored in low relative humidity (high mass loss) presented lower percentage of turgid fruit in relation to fruit stored in high relative humidity (BRACKMANN et al., 2008).

Skin color is a very important external characteristic, mainly, because consumers choose the fruit according its outside quality. Nevertheless, at this study the mass loss not influenced the skin color (Figures 3D, 3E and 3F), being the values similar to the initial analysis (Table 1). Regarding the juice color, a significantly effect of mass loss during storage was verified (Figures 3A, 3B and 3C).

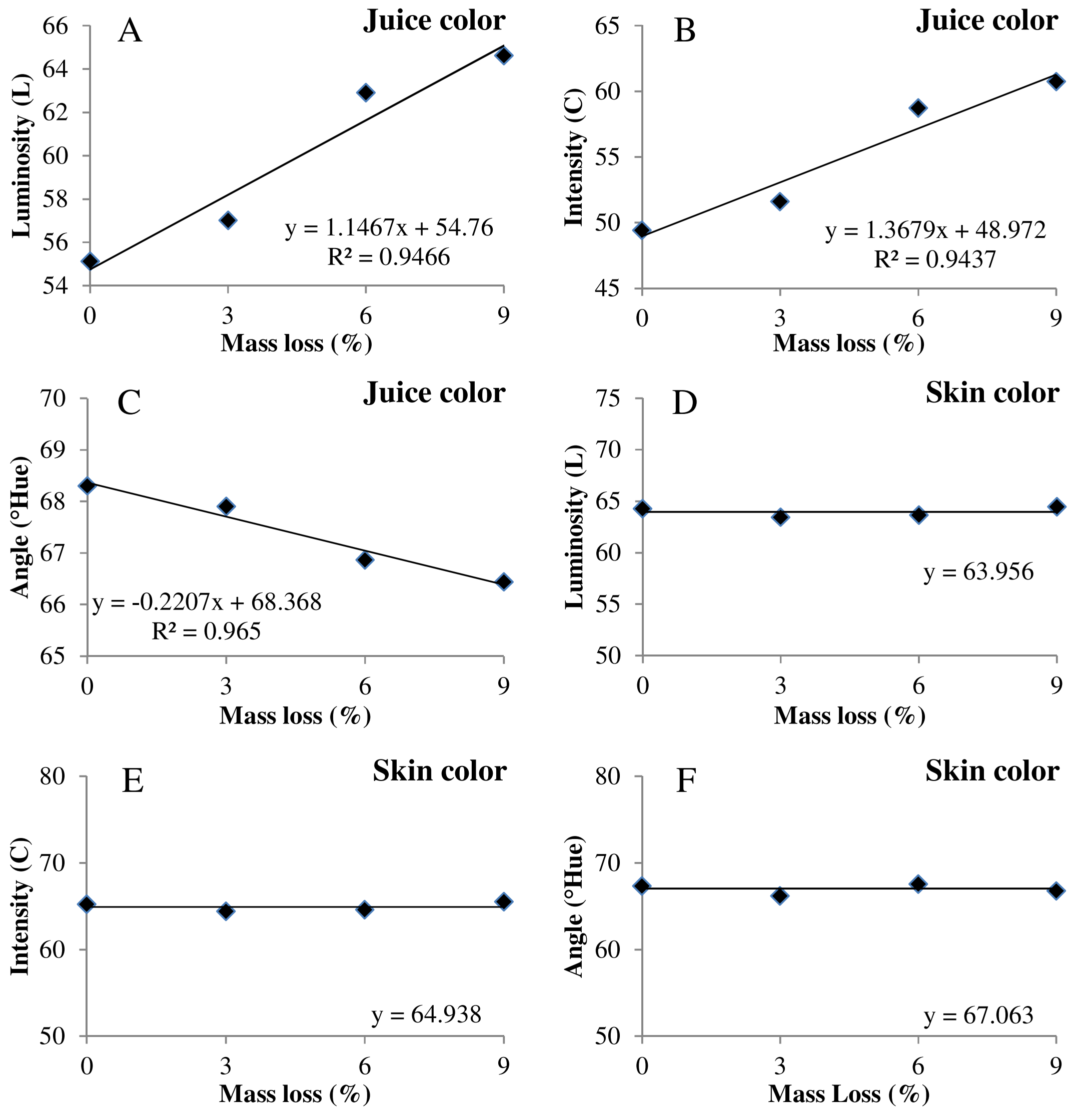

Figure 3. Juice and skin color of ‘Murcott’ tangor after cold storage at temperature of 4.0°C during 10 weeks plus seven days of shelf life at 20°C. UFSM, Santa Maria, 2015.

The luminosity and intensity of juice color increased with the mass loss increase (Figures 3A and B), showing that juice of fruit stored at 9% of mass loss had more intense color, due to the fact that C values close to zero representing neutral color and values close to 60 representing intense color (MENDONÇA et al., 2003). The increase of juice color intensity and luminosity with mass loss is a result of the solids and acids concentration in juice, presented by the positive correlation between these characteristics (Table 2). Already the hue angle (Figure 3C) decreased with mass loss, showing redder juice color on the highest mass loss level.

Respiration rate is closely related with the storage time, so than lower the respiratory rate higher the storage time (CHITARRA; CHITARRA, 2005; STEFFENS et al., 2007). The respiration rate decrease with the rise of mass loss during storage (Figure 2D). The highest respiration rate, at the lowest mass loss level, is a result of decay incidence on fruit submitted to this storage condition (Figure 2A). Other authors also reported increase of the respiration with the RH increase (lower mass loss) in storage environment (PRANGE et al., 2005; BRACKMANN et al., 2007).

On the Table 2 are exposed the *Pearson* correlation of the variable evaluated at the present study. There are no significant correlation between ascorbic acid and soluble solids, soluble solids and succulence, titratable acidity and decay incidence, among some others according to the Table 2. However, the major part of correlations was significant, evidencing that the variables have a relationship and, this relation is than higher than high is the *Person* correlation value. The correlation values ranging from 0.48 up to 0.96 (Table 2).

CONCLUSIONS

The best mass loss level for ‘Murcott’ tangor storage stay between 3 up to 6% because it reduces the decay incidence and turgor loss and maintains chemical qualities, such as ascorbic acid, soluble solids and titratable acidity.

Skin color and thickness not varies according mass loss level during storage and the values remain similar to the harvest.

The succulence has an inverse correlation with the titratable acidity and a direct (positive) correlation with the turgor loss.

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RESUMO: Para obter uma grande aceitação pelo consumidor, os frutos necessitam de uma elevada qualidade na comercialização, tornando necessário o aperfeiçoamento de técnicas de armazenamento. Assim, o objetivo do presente estudo foi avaliar o efeito da perda de massa sobre a manutenção da qualidade durante o armazenamento refrigerado (AR) de tangor ‘Murcott’ durante 10 semanas. Os tratamentos avaliados foram: [1] 0% de perda de massa (umidade relativa de 100%); [2] 3% de perda de massa; [3] 6% de perda de massa; [4] 9% de perda de massa, com cinco repetições de 18 frutos para cada tratamento. A temperatura de armazenamento foi de 4,0°C (±0,2°C). O experimento foi conduzido em delineamento inteiramente casualizado. Após 10 semanas de armazenamento mais sete dias de exposição a 20°C verifica-se que com o aumento da perda de massa diminuiu a incidência de podridões e suculência, aumentou o teor de sólidos solúveis e acidez titulável. O melhor nível de perda de massa para o armazenamento de tangor ‘Murcott’ está entre 3 e 6%, por diminuir a ocorrência de podridões, perda de turgor e manutenção das qualidades químicas como ácido ascórbico, sólidos solúveis e acidez titulável.

PALAVRAS-CHAVE: Pós-colheita. Incidência de podridões. Ácido ascórbico.

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