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Postharvest quality of grapefruit (C*itrus paradisi* Macf.) produced from initial plantings in Ceará state, Brazil[1]

Qualidade pós-colheita de pomelos (C*itrus paradisi* Macf.) produzidos em plantações iniciais no estado do Ceará, Brasil

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Abstract - Ceará state, northeast Brazil, is gaining attention as the most significant emerging fruit production region in the country. Citrus, including grapefruit, traditionally cultivated in the south, was recently implanted. However, data on postharvest quality of grapefruit grown under local conditions are nonexistent. A study was designed to examine postharvest quality of locally grown 'Star Ruby' and 'Ruby Red' grapefruits. Fruits were assessed for size and shape, pulp color, peel thickness, juice content, soluble solids (SS), titratable acidity (TA), pH, SS/TA ratio, and ascorbic acid at harvest and at the fifteenth day of storage. A second set of fruits were accessed for mass loss and peel color. Results suggested that locally grown grapefruits are of good size and shape, presenting orange peel color and reddish pulp color, and appropriate peel thickness. Fruits yielded a high amount of juice, rich in ascorbic acid, and with values of SS, TA, and pH comparable to those found in traditional grapefruit growing areas. SS to TA ratio was above the least recommended for good flavor. Peel color varied from yellow to pinkish. Mass loss increased, while luminosity and hue angle decreased following the same pattern for the two varieties.

Key words - Grapefruit. Rootstock. Internal and External quality. Postharvest life.

Resumo - O estado do Ceará, nordeste do Brasil, vem ganhando atenção como o mais emergente Estado produtor de frutos no país. Citros, incluindo pomelos, tradicionalmente cultivados no sul, vem sendo plantados no Estado. No entanto, ainda não existem informações sobre qualidade de pomelos cultivados localmente. Este estudo objetivou examinar a qualidade pós-colheita de pomelos 'Star Ruby' e 'Ruby Red' quanto ao tamanho e forma, coloração da polpa, espessura da casca, rendimento do suco, sólidos solúveis (SS), acidez titulável (AT), pH, relação SS/AT e níveis de ácido ascórbico na colheita e após 15 dias de armazenamento. Um segundo lote de frutos foi examinado quanto a perda de massa e coloração externa. Os resultados sugerem que os pomelos apresentam bom tamanho e forma, com coloração externa alaranjada e interna avermelhada e espessura da casca apropriada. Frutos apresentaram um bom rendimento de suco, rico em ácido ascórbico, e com valores de SS, AT e pH comparáveis aos reportados para frutos cultivados em áreas tradicionais do país. A relação SS/AT encontra-se acima do mínimo necessário para um bom sabor. A coloração da casca variou de amarelado a alaranjado. Perda de massa aumentou, enquanto o ângulo de cor hue decresceu, seguindo o mesmo padrão para as duas variedades.

Palavras-chaves - Pomelos. Porta-enxerto. Qualidade externa e interna. Vida útil pós-colheita.

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Introduction

Brazil is a leading world citrus producer. However, traditionally citrus production has focused primarily on the production of fruit for processing, mostly juices, rather than on producing good quality table fruits. In recent years, the grapefruit (*Citrus paradise* Macf.) has received much attention because of its nutritional and antioxidant properties. Besides ascorbic acid, grapefruit also contains abundant flavonoids, which are reported to be the important part of active ingredients. Recently, reporters are focusing on the newly discovered beneficial effects of the grapefruit juice on human health, such as protection against high blood pressure or cholesterol increase (WU; GUAN; YE, 2007), as well as already well known benefits such as antioxidant and anticarcinogenic (KAWAII et al., 1999). Ceará state, located in the northeast Brazil, has been gaining attention as a significant emerging fruit producer in the country. Fruit crops cultivated elsewhere in the country now are heavily produced, placing Ceará state among the greatest fruit producers and exporters in Brazil. Citrus, including grapefruit, traditionally cultivated in the south, mostly São Paulo State, is on the list of recently planted fruit crops in Limoeiro do Norte county, north state. To be considered as high quality for the fresh market, however, grapefruit should meet some quality standards such as color intensity, size, shape, peel thickness, smoothness, and a minimal soluble solids/acid ratio threshold for good flavor (ARPAIA; KADER, 2000) at harvest, as well as after storage. External color might be a concern in areas where fruit reaches internal maturity while the peel is still green. In this case it becomes necessary the development of the customary yellow to orange color through a process called degreening. Besides, favorable climate conditions, it is known that rootstock has a significant effect on fruit quality at the time of harvest (MCCOLLUM; BOWMAN, 2002). Thus, it becomes fundamental that a study be carried out to access quality of locally grown grapefruits at harvest and after storage.

This work aimed at evaluating postharvest quality of locally grown 'Star Ruby' and 'Ruby Red' grapefruits ('Star Ruby' grafted on 'Swingle' citrumelo (*Citrus paradise x Poncirus trifoliata*) rootstock, 'Ruby Red' grafted on 'Swingle' citrumelo (*Citrus paradise x Poncirus trifoliata*) or 'Rangpur' lime (*Citrus limonia*) rootstock.

Material and methods

Plant material

Fruits from 'Star Ruby' grapefruit grafted on 'Swingle' citrumelo rootstock (SR/SC), 'Ruby Red' grapefruit grafted on 'Swingle' citrumelo (RR/SC) or 'Rangpur' lime rootstock (RR/RL) were harvested in August, 2009, from a well-managed orchard located at Taboleiro de Russas, Limoeiro do Norte County (5º13' S, 37º54' E), Ceará state, and transported by road to The Laboratory of Food Quality and Control, Universidade Federal do Ceará, located in Fortaleza.

Sample preparation and condition of storage

Upon arrival, fruit were sorted out for stage of maturity (more than 2/3 of fruit showing yellow color), shape, size, freedom from defects and sunburn. Fruit were washed with water at room temperature, air-dried, and divided into two sets. The first set was composed of 30 fruit, being 10 fruit per grafted variety and was reserved for non destructive analyses such as mass loss and external color. For that, each fruit was numbered and individually analyzed at harvest and every period of three days up to 15 days of storage. The second set was composed of 36 fruit, being 12 fruit per grafted variety and was reserved for destructive analyses such as internal quality, including fruit diameter, thickness of the peel, pulp color, juice content, soluble solids, titratable acidity, pH, and ascorbic acid. For that, fruit were analyzed at harvest and after fifteen days of storage. Both set of fruit were stored at ambient condition (22 ± 2 ºC, 60 ± 5% RH).

Quality assessment

Cumulative mass loss (%) was determined by weighting each numbered fruit during storage and then calculating mass loss in relation to fruit mass at harvest. Peel and pulp color were determined using a Minolta Chroma Meter (Minolta Corporation Instrument Systems). L, a*, b* values were scored from opposite sides of the fruit and results expressed as L, chroma and hue angle (MCGUIRE, 1992). Juice was extracted with an automated squeezer with a rotating red. Juice content (%) was calculated by weighting fruit juice and dividing it by fruit mass. Soluble solids (SS) (Brix) were determined in juice samples with a digital refractometer (0-45 Brix) (Palette 100, Atago, Co., Ltd). Acidity (mg citric acid/100g juice) was determined by titration with 0.1N NaOH, end point pH 8.2; pH was measured with a pHmeter directly in the juice. Ascorbic acid followed methodology reported by Hernádez, Lobo and González (2006).

Statistics

Data from the first set of fruits were analyzed using an entirely randomized model, with ten replications, in a split plot array. The main plot was composed by the combination variety and rootstock ('Star Ruby' grapefruit grafted on 'Swingle' citrumelo rootstock (SR/SC), 'Ruby Red' grapefruit grafted on 'Swingle' citrumelo (RR/SC) or 'Rangpur' lime rootstock (RR/RL)), while the subplot

included 5 durations (0; 3; 6; 9; 12, and 15 days). All data were subjected to analysis of variance (SISVAR 4.3). Tukey´s test ($P \leq 0.05$) was used to compare treatments classification when F values were significant for main effects.

Results and discussion

Fruit Internal Quality

Fruits from the two varieties, regardless of rootstock, were elliptical in shape, showing smooth and healthy peel, with fruit diameter varying from 107 to 129 mm and weighting from 450 to 770 g. Peel thickness from all fruits fell into the range of 0.6 to 0.8 mm. These average weight values are higher than those reported by Lederman et al. (2005) for six grapefruit varieties ('M. Foster', 'Star Ruby', 'Rio Red', 'Red Blusa', 'Triumph', and 'Marsh F. Nucelar') produced under irrigation in a semi-arid area located in Pernambuco State, a neighboring state in the northeastern region in Brazil. Fruit weight and average diameter, reported above, fall within the diameter range for large grapefruits produced in Corsega, France (PAILLY; TISON; AMOUROUX, 2004).

Fruits presented brilliant, vivid crimson pulp color for the two varieties, regardless of rootstock, as indicated by the average values of luminosity, chroma, and hue angle, 45; 32 and 27, respectively.

RR/SC fruit soluble solids averaged 9.33 and was significantly higher than those of RR/NL fruits (7.5 Brix) or SS/SC fruits (7.5 Brix) (TAB. 1). Overall, soluble solids did not differ from harvest to the end of storage for the two varieties grafted on the three rootstocks ($p \leq 0.05$). These SS values are within the range of SS reported by Patil et al. (2004) for late harvested 'Rio Red' grapefruits. Stability of soluble solids of grapefruit during storage (PAILLY; TISON; AMOUROUX, 2004; PATIL; VANAMALA; HALLMAN, 2004), as well as the effect of rootstock on fruit quality, including soluble solids and postharvest behavior (MCCOLLUM; BOWMAN, 2002), are well documented.

Average values of titratable acidity varied from 0.65 to 1.09 mg citric acid/100g juice at harvest and from 0.71 to 1.38 mg citric acid/100g juice after 15 days of room temperature storage (TAB. 1). This pulp quality parameter was influenced by rootstock, as fruits grown on RR/RL produced significantly higher acidity than fruits grown on RR/SC ($p \leq 0.05$). The average values reported above are close to that of 'Flame' grapefruit (1.3 mg citric acid/100g juice) grafted on different rootstocks and produced in Bahia State (FLORI, 2008). pH values averaged 3.83; 3.67, and 3.08; for MRL, DSSC, and MSC, which, in turn, was significantly lower than the first two values ($p \leq 0.05$) (TAB. 1).

The results of SS/TA ratio were converse to those of TA, since SS values at harvest were similar to those measured at the end of storage (TAB. 2). SS/TA ratio average values were 6.3 for SR/SC fruits, 7.8 for RR/SC fruits, and 12 for RR/RL fruits, which is above the minimal value recommended for good flavor (ARPAIA; KADER, 2002). Those values are also higher than the average value reported for 'Star Ruby' (5.26) and 'Red Blush' grapefruits (5.67) produced in Pernambuco State (LEDERMAN et al., 2005).

SR/SC fruits presented a higher amount of vitamin C, 59 mg ascorbic acid/100g juice, than RR/SC fruits, 56 mg ascorbic acid/100g juice, and RR/RL fruits, 53 mg ascorbic acid/100g juice (TAB. 2). These means, however, did not differ statistically. The average values of ascorbic acid of locally grown grape fruits are higher than those reported for orange juice, 36 mg ascorbic acid/100g juice (WU; GUAN; YE, 2007) and 'Rio Red' grapefruit, 20 mg ascorbic acid/100g juice (PATIL; VANAMALA; HALLMAN, 2004). Even though no significant differences were observed from harvest to the end of storage in this study, the contents of ascorbic acid after 15 days of storage were slightly higher than those observed at harvest. Higher content of ascorbic acid after 35 days of storage was observed for late harvested 'Rio Red' grapefruits (PATIL; VANAMALA; HALLMAN, 2004). Considering the benefits brought by

Table 1 - Internal quality (SS, TA, pH) of SR/SC, RR/RL or RR/SC grapefruit from initial plantings in Ceará state, Brazil, at harvest and after 15 days of ambient storage (22 ± 2 ºC, 60 ± 5% RH)

Variety/ Rootstock	----------SS (ºBrix)----------			--------TA (mg /100g juice)-------			----------pH----------		
	Harvest	Storage	Mean	Harvest	Storage	Mean	Harvest	Storage	Mean
RR/RL	7.50	7.50	7.50a	0.65	0.71	0.68a	3.80	3.80	3.83b
RR/SC	8.70	10.0	9.33b	1.09	1.38	1.24b	3.16	3.00	3.08a
SR/SC	6.50	7.33	6.92a	1.02	1.16	1.09b	3.50	3.83	3.67b

Values followed by different letter, in the columns are significantly different at $p \leq 0.05$

Table 2 - Internal quality (SS/TA, ascorbic acid, juice content) of SR/SC, RR/RL or RR/SC grapefruit from initial plantings in Ceará state, Brazil, at harvest or after 15 days of ambient storage (22 ± 2 ºC and 60 ± 5% RH)

Variety/ Rootstock	----------SS/TA----------			-Ascorbic acid (mg /100g juice)-			----------Juice content (%)---------		
	Harvest	Storage	Mean	Harvest	Storage	Mean	Harvest	Storage	Mean
RR/RL	12.00	10.88	11.44 b	52.00	54.20	53.22[a]	37.83	37.83	37.81a
RR/SC	7.88	7.76	7.82a	55.20	57.00	56.11a	36.97	36.86	36.91[a]
SR/SC	6.37	6.21	6.29[a]	57.66	60.00	58.86a	37.90	38.48	38.14b

Values followed by different letter, in the columns, are significantly different at $p \leq 0.05$

ascorbic acid intakes on human health the maintenance of this acid during storage comes as a great advantage for stored grapefruits, as compared with fruits presenting high losses of that acid during storage.

Commercially acceptable juice content was observed for the two grapefruit varieties, and the rootstock did not seem to affect juice content of 'Ruby Red' fruits (TAB. 2). That value was superior to the 36% yielded by 'Star Ruby' grapefruit grown in Corsega, France (PAILLY; TISON; AMOUROUX, 2005).

Cumulative mass loss did not differ among rootstocks ($p = 0.7495$) and increased linearly with storage time ($p = 0.00$), reaching about 12% of the initial value at the end of storage (FIG. 1). Singh and Reddy (2006) reported a loss of about 20% of initial mass in 'Nagpur Mandarin' orange stored for 18 days at ambient condition (28 °C and 58% RH), while Alferez et al. (2010) observed a mass loss of as low as 3% in 'Marsh' grapefruit stored at 20 °C and 95% RH. Discrepancy among results might have been caused by storage conditions, such as relative humidity and temperature which may play a direct role on the magnitude of the loss. Pailly, Tison and Amouroux (2002) associated mass loss, among other factors, to fruit diameter, in a way that the smaller the fruit diameter the higher the mass loss.

Luminosity of the peel was affected by treatments ($p = 0.031$) and storage periods ($p = 0.00$), although independently. Overall, luminosity of the peel decreased over the course of storage following a linear equation, and this decrease was strongly influenced by storage durations ($R^2 = 0.928$) (FIG. 2). SR/SC fruits presented luminosity averaging 56.2, which was significantly higher than that found for 'Ruby Red' fruits, 54.5 and 55.6 for RR/RL and RR/SC fruits, respectively. Suggesting that brightness of the peel of 'Ruby Red' fruits may be influenced by rootstock (TAB. 3). Conversely to brightness, 'Ruby Red' fruits were significantly yellower, with a pinkish blush, while 'Star Ruby' fruits presented a lesser intense yellow color, as indicated by hue angle values (TAB. 3).

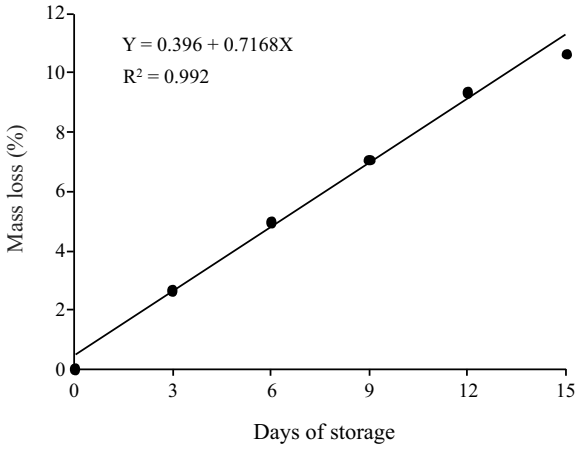

Figure 1 - Cumulative mass loss (%) of SR/SC, RR/rL or RR/SC grapefruit from initial plantings in Ceará State, Brazil, and stored under room temperature for 15 days

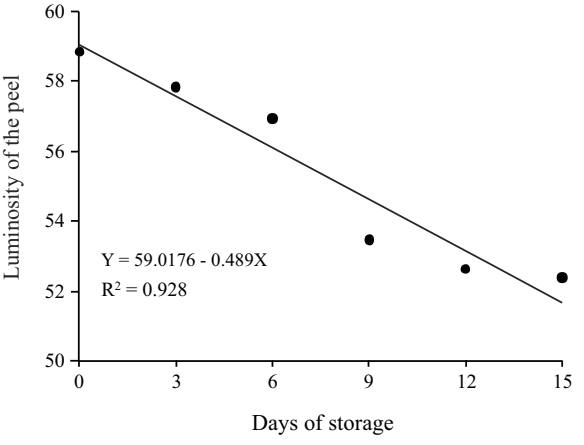

Figure 2 - Luminosity of SR/SC, RR/RL or RR/SC grapefruit during 15 days of storage under ambient condition (22 ± 2 ºC, 60 ± 5% RH)

Table 3 - Luminosity, hue angle and chromaticity of the peel of SR/SC, RR/RL and RR/SC grapefruit from initial plantings in Ceará state, Brazil, at harvest or after 15 days of ambient storage (22 ± 2 ºC, 60 ± 5% RH)

Variety/ Rootstock	Luminosity	Hue angle	Chromaticity
RR/RL	54.5 a	54.5 a	34.2 b
RR/SC	53.3 ab	55.3 ab	31.3 a
SR/SC	56.2 b	56.2 b	31.7 ab

Values followed by different letter, in the columns are significantly different at $p \leq 0.05$

Similarly to luminosity, hue angle of the peel was affected by treatments ($p = 0.002$) and storage periods ($p = 0.00$) independently (FIG. 3). Taken as a whole, hue angle values increased from 58.8º to 60º after six days of storage to decrease thereafter to 56º at the end of storage, indicating the loss of any remaining shade of green.

Chromaticity of the peel was also affected by treatments ($p = 0.008$) and storage periods ($p = 0.00$) independently (FIG. 4). The pattern of change in chroma values indicates that peel color became less vivid, as chroma decreased from harvest to the end of storage (TAB. 3). Corroborating with the results above, 'Ruby Red' fruits, especially RR/RL fruits, presented the highest values of chroma, confirming the vivacity of the yellowish peel (TAB. 3).

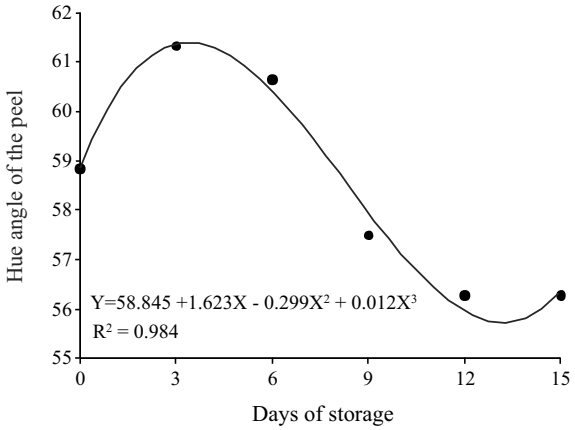

Figure 3 - Hue angle of the peel of SR/SC, RR/RL or RR/SC grapefruit during 15 days of storage under ambient condition (22 ± 2 ºC, 60 ± 5% RH)

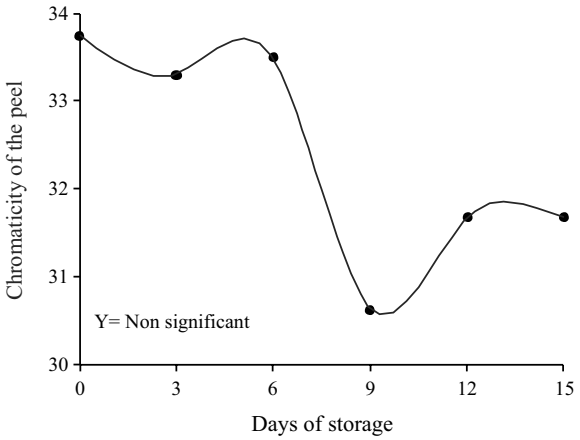

Figure 4 - Chromaticity of the peel of SR/SC, RR/RL or RR/SC grapefruit during 15 days of storage under ambient condition (22 ± 2 ºC, 60 ± 5% RH)

Conclusions

1. Grapefruits from initial plantings in Ceará state, Brazil, present excellent internal quality, comparable to fruit produced in traditional grapefruit producing areas of the Country;
2. Fruit from 'Ruby Red' grapefruit grafted on 'Rangpur' lime rootstock stand out for presenting high equilibrium between SS and acidity, consequently, best flavour;
3. It may be stated that grapefruits produced in Ceará State, Brazil, does not need to undergo degreening process.

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