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Research Note

Influence of different postharvest treatments on nutritional quality of grapefruits

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Abstract

The effects of postharvest treatments and storage periods on ascorbic acid content were evaluated for Rouge La Toma and Ruby Red grapefruit cultivars (*Citrus paradisi* Macf.). The ascorbic acid levels in the beginning and the end of the treatments studied were not significantly different ($P > 0.05$) for most treatments. For both cultivars, at the end of the marketing conditions, the treatments involving low storage temperatures did not affect the ascorbic acid content. At the end of the marketing conditions, Rouge La Toma grapefruit had a decrease ($P < 0.01$) in ascorbic acid levels when temperature conditioning was part of the treatment. On the other hand, Ruby Red presented the same behavior when prolonged storage periods where used. It was concluded that Rouge La Toma grapefruit had a greater susceptibility to postharvest temperature conditioning than Ruby Red grapefruit relative to ascorbic acid degradation.

Keywords: Vitamin C; Nutritional quality; Grapefruit; Postharvest treatments

1. Introduction

Epidemiological evidence inversely relates fruit consumption to the risk of degenerative diseases (Hertog, Feskens, Hollman, Katan, & Kornhout, 1993; Stampfer et al., 1993; Southon, 1998; Benavente-García, Castillo, Marin, Ortuño, & Del Río, 1997; Block, 1992; Block, Patterson, & Subar, 1992). In this sense, the antioxidant properties of many fruits and vegetables are widely recognized (Gey, 1990; Ames, Shigena, & Hagen, 1993; Cao, Sofic, & Prior, 1997). Natural antioxidants found in these products include phenolics and nitrogen compounds, carotenoids and some vitamins (A, C, E and folates). Among antioxidant vitamins, vitamin C plays several roles in human health (Harris, 1996). Updated US daily requirements of vitamin C are 90 mg per day, for young women, and 75 mg per day for men (Levine, Wang, Padayatti, & Morrow, 2001). More than 90% of the vitamin C in human diets is supplied by fruits and vegetables (Wills, Wimalasiri, & Greenfield, 1984), being citrus fruits the most important sources of vitamin C because of the large quantities consumed (Benavente-García, Castillo, & Del Río, 1993; Castillo, Benavente-García, & Del Río, 1993; Del Río, Arcas, Benavente-García, Sabater, & Ortuño, 1998; Ortuño, Arcas, Benavente-García, & Del Río, 1999).

Many investigations have been made in the human health area, however, the effect of postharvest treatments and storage conditions on the vitamin C content of citrus fruit are scarce. Postharvest handling conditions, inherent to citrus's commerce, such as prolonged storage periods, high storage temperatures, low relative humidity, physical damage and chilling injury are known to induce vitamin C destruction in citrus fruits (Kader, 1988; Parviainen & Nyyssonen, 1992). Thus, the effect of these factors should be carefully studied when selecting postharvest treatments in order to preserve as much of the nutritional quality of citrus fruit as possible. Some of these postharvest handling conditions are included in this investigation in relation to Rouge La

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Toma grapefruit, a pigmented variety obtained from a natural mutation selected in Salta (northwestern province of Argentina), which is appreciated for its flavor and general appearance. Therefore, the objective of this research was to evaluate the effect of postharvest treatments and storage periods on vitamin C content in Rouge La Toma and Ruby Red grapefruit cultivars (*Citrus paradisi* Macf.).

2. Materials and methods

2.1. Plant material and postharvest treatments

Two grapefruit cultivars were used in the study: Rouge La Toma and Ruby Red (*Citrus paradisi* Macf.). Fruits were degreened with 3.5 mg/kg ethylene and 1.5 mg/kg CO_2 at 26°C and 90% relative humidity. Then, they were washed, disinfected (with sodium orthophenylphenate, SOPP), rinsed, dried, and coated (wax with 18 g/100 g of solids, and 5000 mg/kg thiabendazole). At this time the grapefruits were packed in boxes and randomly distributed among six different treatments mimicking different postharvest conditions. Treatments were combinations of: (1) conditioning: none or 7 days at 15°C; (2) Temperature during 18 days of cold storage: 2°C or 13°C; (3) Number of days at the shipment period with a temperature of 13°C: 4 or 17 days. For example, treatment 1 (T1) was the result of: (1) no conditioning, (2) 2°C at cold storage, and (3) 17 days at the shipment period, and so on for the remaining treatments listed in Fig. 1.

2.2. Sampling

Three boxes with 40 fruits each were used for the analysis of each of the six treatments. Grapefruits were sampled immediately after transportation, and marketing conditions. Ascorbic acid (AA) determination was performed on fruit juice pools. Each pool was obtained by squeezing six randomly chosen fruits. An aliquot from each pool was kept in a dark glass bottle with minimum headspace to prevent AA oxidation. Samples were kept at -18 ± 1°C until the analysis was performed. Duplicate determinations were made on three replicates from each sampling moment.

2.3. Analytical methodology

AA was determined volumetrically with the 2-6 dichloro-phenol-indophenol reagent (AOAC, 1990).

2.4. Statistical analysis

The response variable was the level of AA in the fruit. The data were analyzed as a $6 \times 4 \times 2$ factorial design. There were three replicates (boxes) on each of the 48 three-way interaction cells. Main effects were treatments (6), times (4) and cultivars (2). All two-way and the three-way interactions were included in the model. Planned linear contrasts were used to test the effects of different linear combinations of main effects and interactions (Weber & Skillings, 2000). All estimates and tests were calculated with PROC GLM procedure using SAS Version 8.0 (Cary, NC, USA).

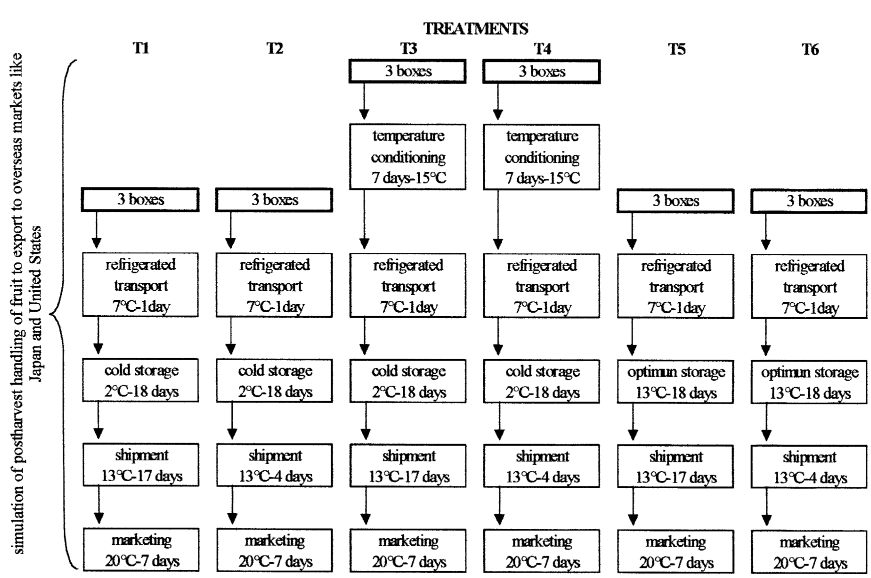

Fig. 1. Treatments simulating temperature conditioning, cold storage, shipment periods, marketing conditions and storage at optimum temperature (control treatments).

3. Results and discussion

Means and standard deviation of AA in Rouge La Toma and Ruby Red grapefruit cultivars, in the beginning and the end of the treatments studied, are shown in Table 1.

Analysis of variance for AA levels in Rouge La Toma and Ruby Red grapefruits showed that all main effects (Treatments, Time and Cultivars) and the Treatment × Time and Treatment × Cultivar interactions were significant ($P<0.001$, $P<0.01$). Therefore, main effects cannot be studied independently of each other, and the only meaningful linear contrasts are those that involve main effects and interactions.

Citrus are known to be susceptible to chilling injury (CI) development during cold storage (Chalutz, Waks, & Schiffmann-Nadel, 1985). Chilling injury causes accelerated losses in AA content of chilling sensitive crops (Lee & Kader, 2000), even before any visible symptoms of chilling injury (Miller & Heilman, 1952).

The comparisons between the treatment without temperature conditioning and the treatment at optimum storage temperature, T1 vs. T5 and T2 vs. T6, revealed no significant differences ($P>0.05$) in AA levels, for cultivars Ruby Red and Rouge La Toma at the end of the marketing conditions. These results are in agreement with those obtained by Miller and Heilman (1952) and Lee and Kader (2000) as treatments with low temperature of storage (T1–T2), and which did not induce development of any visible symptoms of CI, and did not promote AA degradation. One approach to avoid chilling injury under quarantine is to apply postharvest heat treatments, such as temperature conditioning, to induce cold tolerance and to reduce the development of the symptoms (Wang, 1994). At the end of the marketing conditions, Rouge La Toma and Ruby Red grapefruits stored under treatments that included temperature conditioning resulted in lower AA levels than those stored without temperature conditioning (T3 vs. T1, $P<0.001$; T3 vs. T5, $P<0.01$). Tests involving Rouge La Toma cultivars showed the same pattern for the contrasts T4 vs. T2 ($P<0.01$) and for T4 vs. T6 ($P<0.001$). These results agree with the observation that fruits and vegetables show a gradual decrease in AA content as the temperature or time at storage increases (Adisa, 1986). The observed effect of temperature conditioning and/or storage time on AA degradation, could be explained due to direct oxidative destruction of ascorbinase activity, or by indirect degradation through polyphenol oxidase, cytochrome oxidase and peroxidase activity (Lee & Kader, 2000). On the other hand, for Ruby Red grapefruit, temperature conditioning produced higher ($P<0.05$) levels of AA at the end of the marketing period compared to fruits without temperature conditioning (T4 vs. T2). In contrast to Rouge La Toma behavior, Ruby Red cultivars showed no significant differences ($P>0.05$) in AA content between the treatment with temperature conditioning and control treatment (T4 vs. T6), at the end of the marketing conditions. Generally the AA loss extent is lower in more acidic citrus because acidic condition favors AA stability (Nagy, 1980). It is so because citric acid, one of the most important organic acids in citrus, has a complexing action on inorganic metal ions, which in turn can catalyse the degradation of AA in different conditions (Gregory, 1996). Hence, the previous results could be accounted by the significantly higher ($P<0.05$) level of acidity found in Ruby Red grapefruit stored under T4 (1.41 mg citric acid/100 ml of juice) in contrast to Ruby Red grapefruit stored under T2 (1.21 mg citric acid/100 ml of juice). Differences in acid composition can be attributed to physiological factors (Kefford & Chandler, 1970).

AA is very susceptible to chemical and enzymatic oxidation during storage of fruits and vegetables (Lee & Kader, 2000). AA levels showed no significant variations ($P>0.05$) for the period between the end of the transportation and the end of marketing conditions. These results are in accordance with those of Baldwin, Nisperos-Carriedo, Shaw, and Burns (1995) who observed no significant difference in the levels of AA of Valencia oranges during a storage time of 56 days at temperatures of 16°C and 21°C. We would have expected a greater decrease, due mainly to oxidation of AA to dehydroascorbic acid, but AA was probably protected by the ascorbate-sparing effect of the polyphenols that may be attributed to their higher redox potential as compared to AA (Buettner, 1993; Miller & Rice-Evans, 1997). Consequently, the results observed in the present research could be due to temperature conditioning having a more important effect on that fruit stored under treatments that include a longer shipment period.

Table 1
Means and standard deviation of ascorbic acid (mg/100 ml of juice) in Rouge La Toma and Ruby Red grapefruit cultivars in the beginning of the treatment (IT) and the end of marketing conditions (MC)[a]

Treatment	Rouge La Toma		Ruby Red	
	IT	MC	IT	MC
T1	29.28±0.40	31.33±1.32	30.77±0.60	34.02±1.11
T2	29.95±1.40	28.91±0.96	28.90±0.27	25.47±0.75
T3	23.62±1.28	22.17±2.91	29.57±1.70	26.57±2.35
T4	25.69±1.64	22.31±0.90	32.02±2.55	30.57±2.93
T5	32.13±1.70	30.25±1.29	31.22±2.05	32.56±2.15
T6	28.27±0.65	28.26±5.90	28.52±3.95	28.99±2.44

[a] Data are the means of duplicate determinations of three replications of six fruits.

4. Conclusions

Low temperatures, employed for pest disinfestations, did not affect the AA content of Rouge La Toma and

Ruby Red grapefruit cultivars. In addition, all the steps involved in the treatments assayed did not contribute to AA degradation (29 and 41 days). However, AA levels at the end of the marketing conditions showed that Rouge La Toma grapefruit is susceptible to postharvest temperature conditioning for all storage periods of time studied. Meanwhile, Ruby Red only manifested decreased amount of AA due to postharvest temperature conditioning through prolonged periods of time.

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References

Adisa, V. A. (1986). The influence of molds and some storage factors on the ascorbic acid content of orange and pineapple fruits. *Food Chemistry*, *22*, 139–146.

Ames, B. M., Shigena, M. K., & Hagen, T. M. (1993). Oxidants, antioxidants and the degenerative disease of ageing. *Proceedings of the National Academy of Sciences, USA*, *90*, 7915–7922.

AOAC Official Methods of Analysis (AOAC). (1990). In: K. Elrich (Ed.), *Vitamin C (ascorbic acid) in vitamin preparations and juices*. (pp. 1058–1059). Arlington, VA: Association of Official Analytical Chemists, Inc.

Baldwin, E. A., Nisperos-Carriedo, M., Shaw, P. E., & Burns, J. K. (1995). Effect of coatings and prolonged storage conditions on fresh orange flavour volatiles, degrees brix, and vitamin C levels. *Journal of Agricultural and Food Chemistry*, *43*(5), 1321–1331.

Benavente-García, O., Castillo, J., & Del Río, J. A. (1993). Changes in neodiosmin levels during development of *Citrus aurantium* leaves and fruits. Postulation of neodiosmin biosynthetic pathway. *Journal of Agricultural and Food Chemistry*, *41*(11), 1916–1919.

Benavente-García, O., Castillo, J., Marin, F. R., Ortuño, A., & Del Río, J. A. (1997). Use and properties of Citrus flavonoids. *Journal of Agricultural and Food Chemistry*, *45*(12), 4505–4515.

Block, G. (1992). The data support a role for antioxidants in reducing cancer risk. *Nutrition Reviews*, *50*(7), 207–213.

Block, G., Patterson, B., & Subar, A. (1992). Fruits, vegetables, and cancer prevention: A review of the epidemiological evidence. *Nutrition and Cancer*, *18*(1), 1–29.

Buettner, G. R. (1993). The pecking order of free radicals and antioxidants: Lipid peroxidation, α-tocopherol, and ascorbate. *Archives in Biochemistry and Biophysics*, *300*(2), 535–543.

Cao, G., Sofic, E., & Prior, L. R. (1997). Antioxidant and prooxidant behavior of flavonoides: Structure-activity relationships. *Free Radical Biology and Medicine*, *22*(5), 749–760.

Castillo, J., Benavente-García, O., & Del Río, J. A. (1993). Hesperetin7-O-Glucoside and prunin in *Citrus* Species (*C. Aurantium* and *C. Paradisi*). A study of their quantitative distribution in inmature fruits and as immediate precursors of neohesperidin and naringin in *C. aurantium*. *Journal of Agricultural and Food Chemistry*, *41*(11), 1920–1924.

Chalutz, E., Waks, E., & Schiffmann-Nadel, M. (1985). Reducing susceptibility of grapefruit to chilling injury during cold treatment. *HortScience*, *20*(2), 226–228.

Del Río, J. A., Arcas, M. C., Benavente-García, O., Sabater, F., & Ortuño, A. (1998). Changes of polymethoxylated flavones levels during development of *Citrus aurantium* (cv. Sevillano) fruits. *Planta Medica*, *64*(6), 575–576.

Gey, K. F. (1990). The antioxidant hypothesis of cardiovascular disease: Epidemiology and mechanisms. *Biochemical Society Transactions*, *18*, 1041–1045.

Gregory, J. F. (1996). Vitamins. In O. R. Fennema (Ed.), *Food chemistry* (pp. 532–590). New York: Marcel Dekker Inc.

Harris, J. R. (1996). Ascorbic acid: Biochemistry and biomedical cell biology. In J. R. Harris (Ed.), *Subcellular biochemistry* (p. 25). New York: Plenum Press.

Hertog, M. G. L., Feskens, E. J. M., Hollman, P. C. H., Katan, M. B., & Kornhout, D. (1993). Dietary antioxidant flavonoids and risk of coronary heart disease: The Zutphen elderly study. *Lancet*, *342*, 1007–1011.

Kader, A. A. (1988). Influence of preharvest and postharvest environment on nutritional composition of fruits and vegetables. In: B. Quebedeaux, & F. A. Bliss (Eds.), Horticultural and human health: Contributions of fruits and vegetables. *Proceedings of the first International Symposium on Horticulture and Human Health* (pp. 18–32). Englewood Cliffs, NJ: Prentice-Hall.

Kefford, J. F., & Chandler, B. V. (1970). General Composition of citrus fruits. In J. F. Kefford, & B. V. Chandler (Eds.), *The chemical constitution of citrus fruits* (pp. 5–22). Orlando, FA: Academic Press.

Lee, S. K., & Kader, A. A. (2000). Preharvest and postharvet factors influencing vitamin C content of horticultural crops. *Postharvest Biololgy & Technology*, *20*(3), 207–220.

Levine, M., Wang, Y., Padayatti, S. J., & Morrow, J. (2001). A new recommended dietary allowance of vitamin C for healthy young women. *Proceedings of the National Academy of Science USA*, *98*, 9842–9846.

Miller, E. V., & Heilman, A. S. (1952). Ascorbic acid and physiological breakdown in the fruits of the pineaple (*Ananas comosus* L. Merr.). *Science*, *116*, 505–506.

Miller, N. J., & Rice-Evans, C. A. (1997). The relative contributions of ascorbic acid and phenolic antioxidants to the total antioxidant activity of orange and apple fruit juices and blackcurrant drink. *Food Chemistry*, *60*, 331–337.

Nagy, S. (1980). Vitamin C contents of citrus fruit and their products: A review. *Journal of Agricultural and Food Chemistry*, *28*(1), 8–18.

Ortuño, A., Arcas, M. C., Benavente-García, O., & Del Río, J. A. (1999). Evolution of polymethoxylated flavones levels during development of tangelo Nova fruits. *Food Chemistry*, *66*(2), 217–220.

Parviainen, M. T., & Nyyssonen, K. (1992). Ascorbic acid. In: A. P. D. Leenheer, W. E. Lambert, & H. Nelis (Eds.), *Modern Chromatographic Analysis of Vitamins*. New York: Marcel Dekker Inc.

Southon, S. (1998). Increased consumption of fruits and vegetables within the EU: Potential health benefits. In V. Gaukel, & W. E. L. Spiess (Eds.), *European research towards safer and better foods* (pp. 159–168). Karlsruhe: Druckerei Grasser.

Stampfer, M. J., Hennekens, C. H., Mason, J. E., Colditz, G. A., Rosner, B., & Willet, W. C. (1993). Vitamin E consumption and the risk of coronary disease in women. *New England Journal of Medicine*, *328*, 1444–1449.

Wang, C. (1994). Chilling injury of tropical horticultural commodities. *HortScience*, *29*(9), 986–988.

Weber, D. C., & Skillings, J. H. (2000). *A first course in the design of experiments*. Boca Raton, USA: CRC Press.

Wills, R. B. H., Wimalasiri, P., & Greenfield, H. (1984). Dehydroascorbic acid levels in fresh fruit and vegetables in relation to total vitamin C activity. *Journal of Agricultural and Food Chemistry*, *32*(4), 836–838.