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EFFECT OF THREE CALCIUM APPLICATIONS IN PRE-HARVEST ON THE BEHAVIOR OF FUERTE AVOCADO (*Persea americana* Mill.) UNDER REFRIGERATED STORAGE

P. Undurraga[1], J. A. Olaeta[1]and J. Ramirez[1]
[1] Facultad de Agronomía. Pontificia Universidad Católica de Valparaíso. San Francisco s/n La Palma Quillota. Chile. Correo electrónico: pundurra@ucv.cl

In order to increase the shelf life of Fuerte avocados, calcium chloride applications to the trees with 72% of Ca were carried out in three stages of fruit growth, corresponding to 7, 9 and 11% of oil, in doses of: 0 (control), 0.23 and 0.33%, (commercial product), plus surfactant (120 cc of LI-700 ® / 100 L of water). When the fruit reached 13% of oil, fruits of similar size (200 to 250 g) were harvested and refrigerated at 7 ± 1 ºC with 90-95% of Relative Humidity, for 12, 24 and 36 days. In each storage period, the following were evaluated: weight loss, pulp resistance to pressure, calcium content in pulp and browning of epidermis and pulp. Then, the fruit was left to soften at room temperature up to 0.92 kg of pressure, and softening time was evaluated, whereas sensory evaluation was made on taste, skin and pulp color, texture and fibrousness. Fruit with calcium chloride applications, in doses of 0.23 and 0.33%, from 24 days of refrigerated storage onwards, show a greater pulp resistance to pressure and less browning of pulp in comparison with the control. In all storage periods, calcium chloride dose of 0.33% results in increased chroma and calcium content in pulp of fruits.

Key words: browning, keeping quality, oil percentage, pulp firmness, fibrousness

EFECTO DE TRES APLICACIONES DE CALCIO EN PRECOSECHA SOBRE EL COMPORTAMIENTO EN ALMACENAMIENTO REFRIGERADO DE PALTA (*Persea americana* Mill.) CV. FUERTE

P. Undurraga[1], J. A. Olaeta[1] y J. Ramirez[1]
[1] Facultad de Agronomía. Pontificia Universidad Católica de Valparaíso. San Francisco s/n La Palma Quillota. Chile. Correo electrónico: pundurra@ucv.cl

Con el fin de aumentar la vida útil de poscosecha de paltas cv. Fuerte, se realizaron en 3 estadios de desarrollo de la fruta, correspondientes a 7, 9 y 11% de aceite, aplicaciones al árbol de Cloruro de Calcio con 72% de Ca, en dosis de: 0 (testigo), 0,23 y 0,33% (producto comercial), más surfactante (120 cc de LI-700 ® / 100 L de agua). Cuando la fruta alcanzó un 13% de aceite, se cosecharon frutos de tamaño homogéneo (200 a 250 g) y se refrigeraron a 7 ± 1 ºC con 90-95% de Humedad Relativa, por 12, 24 y 36 días. En cada período de almacenamiento se evaluó: pérdida de peso, resistencia de la pulpa a la presión, contenido de calcio en la pulpa y pardeamiento de la epidermis y pulpa. Luego, la fruta se dejó ablandar a temperatura ambiente hasta 0,92 Kg de presión y se evaluó, tiempo de ablandamiento y con evaluación sensorial: sabor, color de piel y pulpa, textura y fibrosidad. Frutos con aplicaciones de Cloruro de Calcio, en

dosis de 0,23 y 0,33%, desde los 24 días de almacenamiento refrigerado, presentan una mayor resistencia de la pulpa a la presión y un menor pardeamiento de la pulpa respecto del testigo. Dosis de Cloruro de Calcio al 0.33%, en todos los períodos de almacenamiento, produce un aumento del croma y del contenido de calcio en la pulpa de los frutos.

Palabras clave: pardeamiento, conservación, porcentaje de aceite, firmeza de pulpa, fibrosidad.

1. Introduction

The increase of Chilean avocado production over the last years has positioned Chile among the main exporting countries worldwide (ODEPA, 2007). However, because of the effect of the duration of avocado storage, Hass cultivar has become the only variety with great demand for these purposes; whereas Fuerte cultivar, with important cultivations in our country, would be possibly exported to Europe if its duration in refrigerated storage increased. This would allow expanding the export season for Chilean avocado.

Ca has effects on texture and resistance to diseases affecting this fruit. In addition, it delays ripening and senescence, affecting the fruits in 3 ways: keeping the cell wall structure, the function of the cell membrane and regulating the cell processes by its action in signal transmission (Watkins, 1995). Because of all this, the scientific world has great interest in Ca (Yuri, 1995).

Furthermore, some of the changes avocados suffer during ripening, and which may be delayed by Ca, are the following: softening, alteration in pigment, changes in fruit aroma and taste, changes in permeability of cell membranes and changes in the respiratory activity (Guadarrama, 2001).

It has been determined that avocados having high calcium content delay up to 50% ripening and softening, with decrease of respiration rates and ethylene-production rates (Gil, 2004). In addition, the appearance of physiological disorders and rots is avoided through calcium applications before storage (Bramlage, 1995). Moreover, calcium applications in Fuerte avocados during pre-harvest increase fruit firmness and reduce the percentage of physiological weight losses and injuries caused by cold, in both skin and flesh (López and Cajuste, 1995).

Foliar applications of calcium imply the absorption by the fruit; however, since the effectiveness of contact with the fruit is low (1-2%), calcium must be applied several times (Yuri *et al.,* 1998). Therefore, it is estimated that reiterative foliar applications of calcium on Fuerte avocado within the season would help to improve the keeping quality of the fruit in refrigerated storage.

Since Chile is far from markets of interest, which means a longer time of transport (e.g. 35 days to Europe for Fuerte avocado), it is necessary to search for new

techniques to extend the post-harvest life of avocados.

In the present trial, the effect of foliar applications of Ca during post-harvest in Fuerte avocado was evaluated in the last phase of fruit growth, in order to delay maturity and senescence and extend its post-harvest shelf life.

2. Materials and methods

Foliar applications of calcium chloride (72% Ca) were made on 20-year-old Fuerte avocado trees, grafted on Mexícola, established in San Isidro Quillota (Latitude 32° 49' S, Longitude 71° 16'W). A total of 18 trees were divided into 3 groups (6 trees) and received the following applications in 3 growth stages: 7% (06/14/2006), 9% (07/19/2006) and 11% (07/28/2006) of oil, doses of 0; 0.23% and 0.33% (commercial product) plus surfactant (120 cc LI-700®) / 100 l water every time, with a total 0 in the season; 0.7 and 1% calcium chloride. A sprayer with rod and 1-mm nozzle with 25 l/tree application was used. The oil % was determined through dry weight.

When the fruit reached 13% oil (08/02/2006), 588 total fruits having homogenous size were harvested and taken to the Post-Harvest Laboratory of Faculty of Agricultural Science of Pontificia Universidad Católica de Valparaiso, Chile. Then, the fruits were placed in plastic boxes of one row each, divided in groups according to each application to the tree, and refrigerated at 7 ± 1ºC with 90-95% relative humidity for 0, 12, 24 and 36 days. Totally, 12 treatments were conducted with 4 replications, in general, of 12 fruits each.

In each storage period, the following was evaluated: weight loss percentage (weight difference), pulp resistance to pressure (8 mm in diameter cone penetrometer Effegi), skin browning (colour determined by colorimeter Minolta CR-200, values expressed in CIE Lab and modified by Mc Guire, 1992), and pulp by visual evaluation. Then, the fruit was left to soften at ambient temperature until the first fruit reached 1.84 kg firmness, registering the softening time for each date and evaluating with a sensory panel: taste, skin and flesh colour, texture and fibrousness. The calcium content in flesh (based on dry weight percentage) was measured only on days 0 and 36 of refrigerated storage. Only one fruit per replication was used for this last evaluation.

The variables flesh resistance to pressure, flesh browning and calcium content in pulp were analyzed by a completely randomized bifactorial design (4 times of storage and 3 doses of calcium). For the first two variables, their analyses were conducted through the Kruskal-Wallis method since they did not show a normal distribution (Conover, 1999), using for mean separation the separation test for Kruskal-Wallis ($p \leq 0.05$).

A completely randomized monofactorial design, dose of calcium as factor, was used for the variables of skin browning and weight loss, by monitoring the same fruits. The experimental unit in this case was 4 fruits by replication. Regarding variables of taste, skin and flesh colour, texture and fibrousness, a completely

randomized bifactorial (4x3) design was also used with 8 replications, which corresponded to the number of non-trained judges who evaluated the samples. In this case, the experimental unit was one fruit. The responses were classified as 1: Very umpleasant to 10: Very pleasant. For the separation of means, Duncan's multiple range test was used ($p \leq 0.05$).

3. Results and discussion

For the pulp resistance to pressure, an interaction was detected between the factors of calcium chloride and refrigerated storage period, with the pulp resistance to pressure decreasing as the storage time passes, but with a calcium effect that delayed firmness loss (Table 1). This coincided with Yuri *et al.* (1998), who indicate calcium has effects on the delay of fruit ripening and senescence.

In the same cultivar, López and Cajuste (1995) determined that 10 mg/L dose of calcium nitrate delays the firmness loss of fruits up to 30 days, at 5 ± 1ºC. In this context, Yuri *et al.* (1998), working on apples, also mention that foliar applications of calcium delay fruit softening.

Table1: Interaction effect between calcium chloride in pre-harvest and refrigerated storage period on pulp resistance to pressure (kg) and pulp browning (%) in Fuerte avocado

Treatment in Fuerte fruits	Pulp resistance to pressure (kg)	Pulp browning (% injuries)
0 sda - 0 % Ca	12.42 d	0.00 a
0 sda - 0.7 % Ca	12.42 d	0.00 a
0 sda - 1 % Ca	12.42 d	0.00 a
12 sda - 0 % Ca	10.67 cd	0.00 a
12 sda - 0.7 % Ca	11.88 d	0.00 a
12 sda - 1 % Ca	12.42 d	0.00 a
24 sda - 0 % Ca	4.85 b	8.05 b
24 sda - 0.7 % Ca	9.78 c	2.30 a
24 sda - 1 % Ca	10.59 cd	4.60 ab
36 sda - 0 % Ca	2.32 a	29.90 e
36 sda - 0.7 % Ca	5.19 b	23.00 d
36 sda - 1 % Ca	5.05 b	12.65 c

Values with the same letter do not differ among themselves [mean separation test for Kruskall – Wallis (P≤0.05)].
sda = days of storage at 7ºC.

According to Farre *et al.* (1992), the above-mentioned could occur because calcium is positively related to greater resistance of cell membranes to degradation, delaying biochemical processes caused by semipermeability loss.

The same interaction occurred in pulp browning, observing that although browning appears with time, greater dose of calcium tends to reduce its effect. This coincides with the results achieved by López and Cajuste (1995) who by

treating Fuerte fruits with 30 mg/L dose of calcium nitrate, obtained lower level of pulp browning.
This may be attributed to a better conservation of the integrity of cell walls and membranes, caused by a higher calcium application, which impedes the loss of their selectivity, delaying the union of enzymes with the substrate to provoke the effect (Bangerth, 1979).

Regarding the variable of skin browning, effect of dose of calcium chloride was only observed. In the treatments applied, greater chroma, or lower opacity, was obtained in all the evaluated dates with dose of 1% calcium chloride (Table 2). This coincides with López and Cajuste (1995), who achieved a lower browning of skin in Fuerte avocados by applying calcium nitrate with a dose of 30 mg/L. All this must be caused by the effect delaying maturity produced by higher dose of calcium in avocado, for keeping better the integrity of cell membranes and wall (Cline and Hanson, 1992).

Table 2: Effect of doses of calcium chloride applied in pre-harvest on browning of skin (%) in Fuerte fruits, refrigerated at 7±1ºC

Treatment	0 sda	12 sda	24 sda	36 sda
0% Ca	23.40 a	22.56 a	25.07 a	23.14 a
0.7% Ca	24.42 a	23.96 a	24.48 a	22.83 a
1% Ca	26.91 b	26.44 b	27.74 b	26.16 b

Values with the same letter in each column do not differ among themselves (Duncan P≤0.05).
sda = days of storage at 7ºC.

Regarding the weight loss in Fuerte avocados, no effect of dose of calcium was observed in each of the periods of refrigerated storage (Table 3). This does not coincide with the results of López and Cajuste (1995), who achieved lower weight losses through foliar applications of calcium in Fuerte avocados in pre-harvest.

This difference in result may be caused by the different doses applied and because the present trial was conducted with higher content of dry matter in the fruit and, thus, lower content of free water.

Table 3: Effect of doses of calcium chloride on the weight loss (g) in Fuerte avocados

Difference of weight loss (g) in Fuerte avocados			
	12 sda	**24 sda**	**36 sda**
0 % Ca	6.5 a	1.2 a	1.4 a
0.7 % Ca	6.0 a	0.9 a	1.1 a
1 % Ca	5.1 a	1.5 a	0.9 a

Values with the same letter in each column do not differ among themselves (Duncan P≤0.05).
sda = days of storage at 7ºC.

Regarding the calcium content in the fruit, an effect of the period of refrigerated storage was observed as well as of separated doses of calcium (Table 4). With a longer period of refrigerated storage, the calcium content increased, which could be caused by the loss of turgor affecting the fruit as it ripens, making the nutrient more concentrated. In addition, by increasing the doses of calcium, applied during pre-harvest, the calcium content in the fruit was higher, which would suggest that the product was incorporated to the fruit in pre-harvest applications.

Table 4: Effect of period of refrigerated storage and dose of calcium chloride applied in pre-harvest on the calcium content in pulp (% dry weight) in Fuerte avocados

Factor	Level	Ca in pulp
Time	0 sda	0.035 a
	36 sda	0.074 b
Dose	0 % Ca	0.036 a
	0.7 % Ca	0.053 b
	1 % Ca	0.067 c

Values with the same letter in each variable do not differ among themselves (Duncan P≤0.05).
sda = days of storage at 7°C.

With regard to the increase, the result coincides with that obtained by Yuri *et al.* (1995), who determined, in apples, that applications of Ca increase the element in the fruit and reduces the incidence of physiological disorders. Flores (2004) and Basiouny (1994) also achieved the increase of the calcium content in Berkeley and Tifblue blueberries with foliar applications in pre-harvest. Likewise, Solís *et al.* (1998) treating Hass avocados, indicate that the applications of calcium nitrate increased the levels of K, Ca, Mg, Fe, Zn and Mn in leaves, with a tendency to also increase in the fruit.

Regarding sensory analysis, effect of the time of refrigerated storage was only observed (Table 5).

Table 5: Effect of time of refrigerated storage on browning of skin and pulp, taste, texture and fibrousness in Fuerte fruits stored until 36 days in refrigeration

Storage time	Browning of skin	Browning of pulp	Taste	Texture	Fibrousness
12 sda	4.65 b	4.80 b	3.44 a	3.32 a	3.13 a
24 sda	3.52 a	3.95 a	3.42 a	4.10 ab	4.57 b
36 sda	4.13 ab	4.80 b	4.32 a	4.57 b	4.21 b

Values with the same letter in each column do not differ among themselves (Duncan P≤0.05).
sda = days of storage at 7°C.

Clear increases of fibrousness as well as losses of texture were obtained, whereas variations in browning, following a similar pattern, showed lower browning, in both pulp and skin, in avocados stored for 24 days at 7 ± 1ºC with 90-95 % relative humidity. Nevertheless, it is worth mentioning that, although in

medium levels of acceptance, taste did not show any significant changes in time of storage.

4. Conclusions

Applications in doses of 0.7% and 1% calcium chloride in pre-harvest on Fuerte avocado trees with maturity levels of 7, 9 and 11% oil, and subsequently harvested with 13% oil, increase the calcium content in the fruit; they also delay softening and reduce browning of pulp, but do not have effect on the weight loss or the organoleptic quality of the fruit for until 36 days of storage at 7 ± 1º C, and 90-95% relative humidity, plus 4 days of commercialization period.

Applications in doses of 1% chloride in pre-harvest on Fuerte avocados with maturity levels of 7, 9 and 11% oil, and subsequently harvested with 13% oil, delay the browning of skin, measured by chroma, for until 36 days of refrigerated storage at 7 ± 1º C, and 90-95% relative humidity.

Applications in doses of 0.7% and 1% calcium chloride in pre-harvest on Fuerte avocados with maturity levels of 7, 9 and 11% oil, and subsequently harvested with 13% oil, reach 36 days of refrigerated storage at 7 ± 1º C, and 90-95% relative humidity, with 4 days of commercialization period at ambient temperature, with good organoleptic quality at consumption maturity

5. Bibliography

Bangerth, F. 1979. Calcium-related physiological disorders of plants. Annual Review of Phytopathology. 17:97-122.

Basiouny, F. 1994. Shelf life and quality of Rabbiteye Blueberry fruit in response to preharvest application of CaEDTA, Nutrical and Paclobutrazol. Acta Horticulturae 368: (893-900).

Bramlage, W. 1995. Calcio y desórdenes fisiológicos. Pp. 73-81. In Universidad de Talca, Escuela de Agronomía. Calcio en fruticultura Symposium Internacional. Talca, 7-18 de Octubre 1995. Talca, Chile.

Cline, A. and A. Hanson.1992. Relative Humidity around apple fruit influences its acumulation of calcium. J. Amer. Soc. HortScience. 117:542-546.

Conover, W. 1999. Practical non parametric statistic. 584 p. 3ª Edición. Edición Editorial John Wiley, New York, USA.

Farre, M., G. Hermoso, y S. Jaime, 1992. La nutrición del aguacate en la Costa del Sol. Pp. 29-52. In Junta de Andalucía eds. Riego y nutrición del aguacate en el litoral andaluz. Sevilla. Consejería de Agricultura y Pesca. Sevilla, España.

Flores, A. 2004. Efecto de aspersiones de tres productos a base de calcio en precosecha sobre la calidad poscosecha de frutos de arándano (*Caccinium corynbosum L.*) variedad Berkely. 23 p. Tesis Ing. Agr. Universidad de Chile. Facultad de Ciencias Agronómica. Santiago, Chile.

Gil, G. 2004. Madurez de la fruta y manejo poscosecha. 431 p. Ediciones Universidad Católica de Chile. Santiago, Chile.

Guadarrama, A. 2001. Fisiología poscosecha de frutos. 139 p. Universidad Central de Venezuela. Facultad de Agronomía. Maracay, Venezuela.

López, L., y J. Cajuste. 1995. Efecto de las aplicaciones de diferentes fuentes de calcio en precosecha sobre la calidad de fruto de aguacate 'Fuerte'. Disponible en *http://www.avocadosource.com/journals/cictamex/cictamex_1995/agroind_1_95.pdf*. Leído el 13 de febrero de 2007.

Mc Guire, R. 1992. Reporting of Objetive Color Measurements. HortScience, 27(12): 1254-1255.

Oficina De Estudios De Políticas Agrarias (ODEPA), 2007. Frutales: Producción estimada de huertos industriales. Disponible en. http://www.odepa.gob.cl/

Solís, J., A. Barrientos, C. Pérez, M. Arriagada, M. Martínez, y J. Reyes. 1998. Aplicaciones foliares de nitrato de calcio, su efecto en el contenido nutrimental de hoja y mesocarpio en aguacate (Persea americana Mill.) cv. Hass. Disponible en *http://www.avocadosource.com/journals/chapingo/1998_iv_2(113)_foliar_calciumnitrate.pdf*. Leído el 13 de febrero de 2007.

Watkins, C. 1995. Calcio: rol en la maduración y senescencia de fruta. Pp. 65-72. Universidad de Talca, Escuela de Agronomía. Calcio en fruticultura Symposium Internacional. Talca, 17-18 de octubre 1995. Talca, Chile.

Yuri, J. 1995. Aspectos fundamentales de la bioquímica y fisiología del calcio. Pp. 25-36. Universidad de Talca, Escuela de Agronomía. Calcio en Fruticultura Symposio Internacional. Talca, 17-18 de octubre 1995. Talca, Chile.

-------- C. Moggia, J. Retamales. 1995. Calcio en Pomáceas: La Experiencia Chilena. Pp. 105-127. Universidad de Talca, Escuela de Agronomía. Calcio en fruticultura. Symposium Internacional. Talca, 17-18 de octubre 1995. Talca, Chile.

-------- J. Retamales, C. Moggia, J. Vasquez, y A. Neira. 1998. Calcio y Bitter Pit. Pp. 60-74. Centro de Pomáceas Universidad de Talca. Memoria 1993-1997. Talca, Chile.