ARTICLES

Effects of Postharvest Dips in Calcium Chloride on Strawberry

José M. García,* Salvador Herrera, and Ana Morilla

Departamento de Fisiología y Tecnología de Productos Vegetales, Instituto de la Grasa, CSIC, Apartado 1078, 41080 Sevilla, Spain

Spanish strawberries (*Fragaria* × *Ananassa* cv. Tudla) with foreseeable high decay were, after harvesting, either left untreated, dipped in water, or dipped in different calcium chloride ($CaCl_2$) solutions at 25 or 45 °C. Subsequently, the fruits were stored at 1°C for 1 day. Their ripening quality parameters were then monitored during a shelf life of 3 days at 18 °C. Dipping the fruits in 1% $CaCl_2$ solution was the most effective treatment for increasing the calcium content of the fruits, for controlling their postharvest decay, and for maintaining their firmness and soluble solids content. The treatments did not affect the sensorial quality of fruits.

Keywords: *Fragaria* × *ananassa; ripening; decay; quality*

INTRODUCTION

Pre- and postharvest calcium applications have been used to delay senescence, to reduce postharvest decay, and to control the development of many physiological disorders in fruits and vegetables (Poovaiah, 1986; Conway et al., 1994). In apples, vacuum infiltration of calcium chloride ($CaCl_2$) has been used commercially to enhance the storage potential (Rajapakse et al.; 1992). However, it is difficult to infiltrate enough calcium into fruit to eliminate decay without damaging the fruit (Conway and Sams, 1987). Lurie and Klein (1992), using $CaCl_2$ in postharvest dips combined with heat treatment, obtained better fruit quality than with either treatment separately. In berries, foliar applications of $CaCl_2$ have been reported to delay ripening and mold development in strawberries (Chéour et al., 1990; Chéour et al., 1991) and raspberries (Montealegre and Valdés, 1993). Postharvest dips in concentrated solutions of $CaCl_2$ have been used to improve firmness in blueberries (Hanson et al., 1993). Calcium must be applied directly to the fruit surface to be effective, as little or no subsequent translocation of calcium from the leaves to the fruit occurs (Chamel, 1989). For this reason, vacuum infiltrations are normally the most effective treatment. However, the sensitive texture of the berries prevents its use. Dips in solutions of $CaCl_2$ should be a nondamaging treatment for this kind of fruit and could result in more efficient calcium translocation to the fruit tissues than foliar applications. Moreover, postharvest dips could be easily combined with heat treatment. Heat allows demethylation of pectin by pectin methylesterase (PME), to form anionic COO^- groups with which calcium ion (Ca^{2+}) can form salt-bridge cross-links. This may make the cell wall less accessible to the enzymes that cause softening. Therefore, the combination of both treatments may control ripening, softening, and decay at the same time (Sams et al., 1993).

Couey and Follstad (1966) effectively controlled the fruit decay of strawberries caused by *Botrytis cinerea* and *Rhizopus stolonifer*, without damaging fruit quality, by heating with moist air at 44 °C. Recently, strawberry decay has been controlled with postharvest dips in hot water at 45 °C. Moreover, the treated fruits showed the lowest values for weight loss and titratable acidity and the highest values of fruit firmness and soluble solids content (García et al., 1995b).

The antisenescent effects of heat treatment and calcium applications could be additive in strawberries, as has been reported in apples (Lurie and Klein, 1992). In this paper, the effects of dipping the most widely cultivated Spanish strawberry (cv. Tudla) in $CaCl_2$ solutions at different temperatures on their quality are described.

EXPERIMENTAL PROCEDURES

The fruits (*Fragaria* × *ananassa* cv. Tudla) were harvested early in the morning following a rainy day, when the foreseeable postharvest decay is the highest, and transported to the laboratory where undamaged fruits at the same ripening stage (80% of the skin with red color) were selected and randomly distributed among seven treatments groups of 20 kg each. The fruits of one of these treatment groups were submerged for 15 min at 25 °C in water (control at 25 °C); the fruits of three other groups were submerged in 1, 2, and 4% $CaCl_2$ solutions, respectively; and the fruits of another two treatments were submerged for 15 min at 45 °C in water (control at 45 °C) or in 1% $CaCl_2$ solution (all of the treatments were done in thermostatically controlled water baths). Afterward, the fruits were dried with a dry air stream and placed in a room at 1 °C for 1 day. The seventh group was placed directly in the room at 1 °C without any other postharvest treatment (dry control group). Subsequently, all of the fruits were placed at 18 °C for a shelf-life period of 3 days. Sampling was conducted at harvest, after refrigeration, and every day during storage. The experiment was performed twice in the same season.

The incidence of postharvest losses (fruits with visible mycelial growth and/or with damaged surfaces) was monitored in four samples of 50 fruits that were randomly selected from each treatment group. Fruit appearance was separately evaluated by 10 trained testers on samples of 50 fruits from each treatment group according to a subjective scale (1 was the best possible score and 5 the worst). Five of these fruits from each group were tasted to test for the possible occurrence of off-flavor. Another 50 fruits were chosen for measuring the fruit firmness with a Zwick 3300 densimeter (Zwick Gmbh & Co., Ulm, Germany) with a 5-mm disk (force required to depress the disk 2.4 mm into the fruit).

0021-8561/96/1444-0030$12.00/0

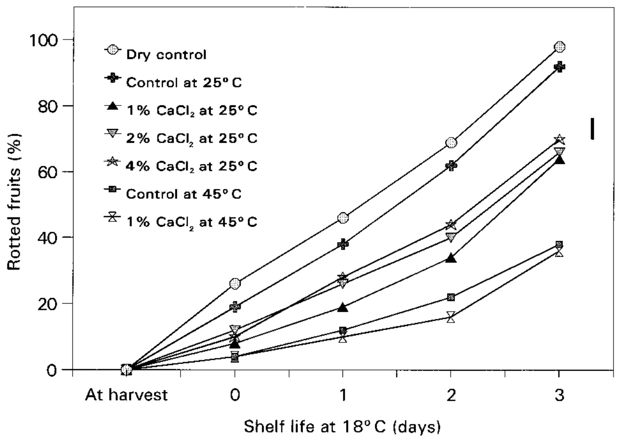

Figure 1. Changes in postharvest losses of strawberries during shelf life. Fruits had previously been submerged in different $CaCl_2$ solutions for 15 min at different temperatures and stored for 1 day at 1 °C. Vertical bar represents least significant difference at $p \leq 0.05$.

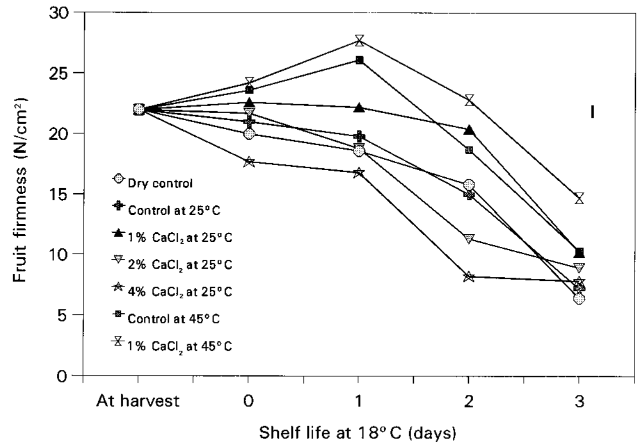

Figure 2. Changes in firmness of strawberries during shelf life. Fruits had previously been submerged in different $CaCl_2$ solutions for 15 min at different temperatures and stored for 1 day at 1 °C. Vertical bar represents least significant difference at $p \leq 0.05$.

The juices extracted from these fruits, in five groups of 10 fruits for each treatment, were employed to determine the content of soluble solids, with an Atago DBX-55 refractometer (Atago Company Ltd., Tokyo, Japan), and titratable acidity, with a Crison automatic titrator (Crison Instrumente A. G., Baar, Switzerland) that measures the volume of 0.1 N NaOH required by 10 mL of juice to reach pH 8.0. Results are expressed as percent citric acid in the juice.

Weight changes of the strawberries were measured on four samples of 25 fruits for each treatment group throughout the experimental period. Calcium content was measured on four replicates of 50 g (5 g from each of 10 fruits) for each treatment assayed (dry control and dips in water or 1% $CaCl_2$ solutions at 25 or 45 °C). After 1 day of storage, the tissues were dried at 110 °C and ground. From each sample, 1 g of dried material was ashed, dissolved in 5 mL of 2 N HCl, and filtered. The samples were analyzed by atomic absorption spectrophotometry with a Perkin-Elmer 3030 spectrophotometer (Perkin-Elmer Hispania S. A., Barcelona, Spain). Calcium concentration is reported as percent of dry weight.

Analysis of variance was carried out on all the data. A 5% level of least significant difference (lsd), calculated by Duncan's multiple range test, was employed to establish differences between the means obtained for the treatments.

RESULTS AND DISCUSSION

Postharvest dips in $CaCl_2$ solutions significantly reduced strawberry decay during shelf life (Figure 1), the treatment with 1% $CaCl_2$ being the most effective of the treatments at 25 °C. However, the temperature of the treatment was the main factor that controlled decay. The fruits treated at 45 °C showed significantly less decay than the other fruits. At this temperature, the treatment with 1% $CaCl_2$ gave better results throughout the shelf-life period than the treatment with water at the same temperature, but the differences between these treatments were never significant. These results confirm the results obtained in the same laboratory with heat treatment of strawberries at 45 °C (García et al., 1995b) and those obtained on postharvest decay of apples with heat treatment and/or dips in $CaCl_2$ solutions (Klein and Lurie, 1994).

No significant differences were found in the appearance of the fruits among treatment groups (data not shown). Moreover, the tasters did not find off-flavor in the fruits. Therefore, treatments used did not affect the sensorial quality of the fruits.

After the first day of shelf life, the fruit treated with 1% $CaCl_2$ solution at 45 °C showed significantly higher values of fruit firmness than the other fruits during the rest of the storage (Figure 2). Before this time, the differences between the fruits dipped in 1% $CaCl_2$ and those that were submerged in water at the same temperature (45 °C) were not significant. Later, however, the fruits heated in water lost their firmness more markedly. The fruits treated with $CaCl_2$ at 25 °C showed significantly higher values for firmness than the fruits of the dry control and the rest of the treatments at 25 °C throughout the shelf life, but they also had significantly less firmness than the fruits of the treatments at 45 °C after refrigeration at 1 °C and the first day of shelf life at 18 °C. Nevertheless, from the second day onwards no statistically significant differences were apparent between the firmness values of these fruits and the ones heated at 45 °C in water. The fruits treated with 4% $CaCl_2$, on the other hand, showed significantly lower firmness values than the other fruits until the third day of shelf life. In strawberries, both postharvest treatments, temperature, and calcium applied by dips may act synergistically to maintain or even enhance the initial firmness values of the fruits during shelf life. Similar effects have been found in apples by different authors (Sams et al., 1993; Klein and Lurie, 1994). Chéour et al. (1991) found a decrease in strawberry softening after foliar application of $CaCl_2$, and García et al. (1995b) found the same effect in strawberries with dips at 45 °C. The combination of both treatments probably allows the formation of salt bridge crosslinks with the pectin molecules of the cell wall after their heat-induced demethylation.

Heat treatment at 45 °C delayed any decrease in the soluble solids content during the shelf life of the strawberries (Figure 3). The heated fruits showed higher values than the fruits treated at 25 °C or the untreated ones. The differences between the soluble solids content of the juice obtained from the heated fruit and the values for the juices extracted from the fruits dipped in water at 25 °C or from the untreated ones increased with the time of shelf life, and the difference became statistically significant from the second day of this period. It was also possible to see a slight, but clear, effect of the $CaCl_2$ treatments in delaying the decrease in soluble solids, especially if the treatment was carried out in combination with heating at 45 °C. This effect increased with the time of shelf life, and, on the third day, the differences between the soluble solids content

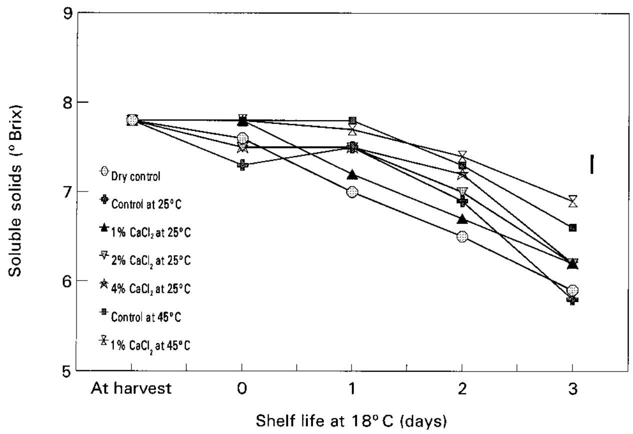

Figure 3. Changes in soluble solids content of the juice obtained from strawberries during shelf life. Fruits had previously been submerged in different $CaCl_2$ solutions for 15 min at different temperatures and stored for 1 day at 1 °C. Vertical bar represents least significant difference at $p \leq 0.05$.

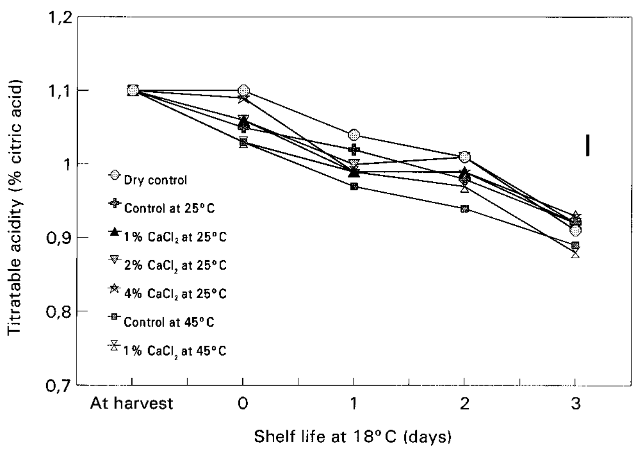

Figure 4. Changes in titratable acidity of the juice obtained from strawberries during shelf life. Fruits had previously been submerged in different $CaCl_2$ solutions for 15 min at different temperatures and stored for 1 day at 1 °C. Vertical bar represents least significant difference at $p \leq 0.05$.

of the $CaCl_2$-treated fruits and the values of their respective controls at 25 or 45 °C became significant. These results agree with those found in tomatoes by García et al. (1995a), who used preharvest foliar applications of $CaCl_2$ and postharvest heating in a room at 37 °C for 3 days, and also with those obtained in strawberries by García et al. (1995b), who used postharvest dips at 45 °C. The delay in the decrease in soluble solids observed may be explained by the effect of the heating and $CaCl_2$ on sugar metabolism, as has been found in tomatoes and apples (Klein and Lurie, 1991).

No clear effects of $CaCl_2$ dips were seen on the titratable acidity of the juices obtained from the fruits (Figure 4). No statistically significant differences were found between the values obtained from the $CaCl_2$-treated fruits and those from the different control fruits. However, the fruits heated at 45 °C showed the lowest values of acidity, especially the ones dipped in water. Treatment with $CaCl_2$ seems to reduce the effect of heat by increasing the activity of enzymes involved in the metabolism of the organic acids (Lurie and Klein, 1990).

The differences in fresh weight losses among the fruits of the different treatments assayed were increased during shelf life (Figure 5), becoming significant at the end of this period. The fruits dipped in 2 and 4% $CaCl_2$ at 25 °C showed the lowest losses until the third day of storage. At this time, the losses of fresh weight of these

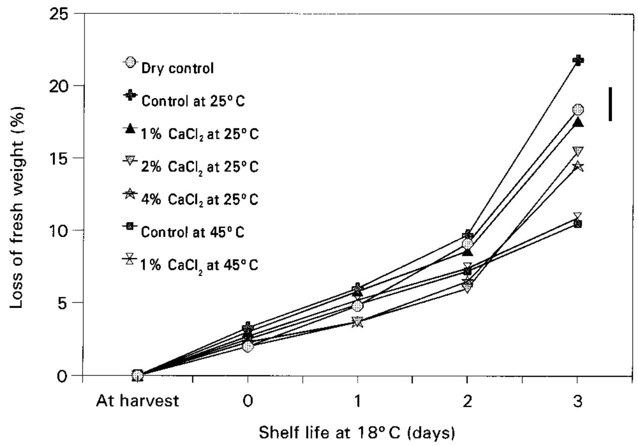

Figure 5. Changes in weight loss (%) of strawberries during shelf life. Fruits had previously been submerged in different $CaCl_2$ solutions for 15 min at different temperatures and stored for 1 day at 1 °C. Vertical bar represents least significant difference at $p \leq 0.05$.

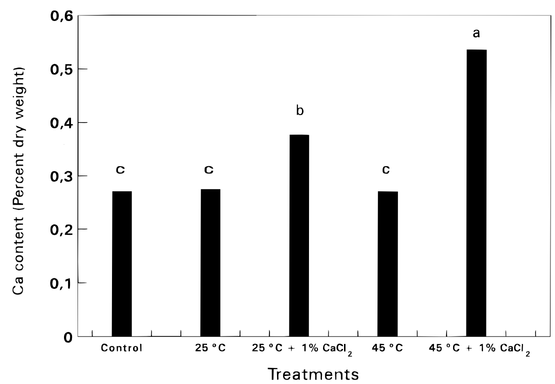

Figure 6. Calcium content (percent dry weight) of strawberries previously submerged in water or 1% $CaCl_2$ solution for 15 min at different temperatures and stored for 1 day at 1 °C. Mean separation by Duncan's multiple range test ($p \leq 0.05$).

fruits significantly surpassed the losses of the fruit dipped at 45 °C. No additional effect was seen with 1% $CaCl_2$ instead of water in the dips at 45 °C. The fruits treated with 1% $CaCl_2$ at 25 °C, the fruits of the dry control, and the fruits dipped in water at 25 °C showed, without appreciable differences among them, the highest values of fresh weight losses. Dips in 2 or 4% $CaCl_2$ concentrations at 25 °C and dips in water at 45 °C seemed to reduce water permeability of the fruits slightly.

The fruits dipped in 1% $CaCl_2$ solution at 25 °C had a significantly higher calcium content than the fruits of the different controls after 1 day of storage at 1 °C and 1 day of storage at 18 °C (Figure 6). However, the calcium content of these fruits was significantly lower than that of fruits dipped in 1% $CaCl_2$ at 45 °C. Heating at 45 °C, therefore, enhanced the penetration of the calcium from 1% $CaCl_2$ dips into the fruits.

ACKNOWLEDGMENT

We thank Mrs. M. C. Martínez-Peláez for excellent technical assistance.

LITERATURE CITED

Chamel, A. R. Permeability characteristics of isolated Golden Delicious apple fruit cuticles with regard to calcium. *J. Am. Soc. Hortic. Sci.* **1989**, *114*, 804−809.

Chéour, F.; Willemot, C.; Arul, J.; Desjardins, Y., Makhlouf, J.; Charest, P. M.; Gosselin, A. Foliar application of calcium chloride delays postharvest ripening of strawberry. *J. Am. Soc. Hortic. Sci.* **1990**, *115*, 789−792.

Chéour, F.; Willemot, C.; Arul, J.; Makhlouf, J.; Desjardins, Y. Postharvest response of two strawberry cultivars to foliar application of $CaCl_2$. *HortScience* **1991**, *26*, 1186−1188.

Conway, W. S.; Sams, C. E. The effects of postharvest infiltration of calcium, magnesium, or strontium on decay, firmness, respiration, and ethylene production in apples. *J. Am. Soc. Hortic. Sci.* **1987**, *112*, 300−303.

Conway, W. S.; Sams, C. E.; Kelman, A. Enhancing the natural resistance of plant tissues to postharvest diseases through calcium applications. *HortScience* **1994**, *29*, 751−754.

Couey, H. M.; Follstad, M. N. Heat pasteurization for control of postharvest decay in fresh strawberries. *Phytopathology* **1966**, *56*, 1345−1347.

García, J. M.; Ballesteros, J. M.; Albi, M. A. Effect of foliar applications of $CaCl_2$ on tomatoes stored at different temperatures. *J. Agric. Food Chem.* **1995a**, *43*, 9−12.

García, J. M.; Aguilera, C.; Albi, M. A. Postharvest heat treatment on a Spanish strawberry (*Fragaria* × *ananassa* cv. Tudla). *J. Agric. Food Chem.* **1995b**, *43*, 1489−1492.

Hanson, E. J.; Beggs, J. L.; Beaudry, R. M. Applying calcium chloride postharvest to improve highbush blueberry firmness. *HortScience* **1993**, *28*, 1033−1034.

Klein, J. D.; Lurie, S. Postharvest heat treatment and fruit quality. *Postharvest News Information* **1991**, *2*, 15−19.

Klein, J. D.; Lurie, S. Time, temperature and calcium interact in scald reduction and firmness retention in heated apples. *HortScience* **1994**, *29*, 194−195.

Lurie, S.; Klein, J. D. Calcium and heat-treatments to improve storability of Anna apples. *HortScience* **1992**, *27*, 36−39.

Montealegre, J. R.; Valdés, J. M. Efecto de aplicaciones de calcio en precosecha sobre la susceptibilidad de frutos de frambuesa a *Botrytis cinerea*. *Fitopatologia* **1993**, *2*, 93−98.

Poovaiah, B. W. Role of calcium in prolonging storage life of fruits and vegetables. *Food Technol.* **1986**, *40*, 86−89.

Rajapakse, N. C.; Hewett, E. W.; Banks, N. H.; Cleland, D. J. Vacuum infiltration with calcium chloride influences oxygen distribution in apple fruit flesh. *Postharvest Biol. Technol.* **1992**, *1*, 221−229.

Sams, C. E.; Conway, W. S.; Abbot, J. A.; Lewis, R. J.; Ben-Shalom, N. Firmness and decay of apples following postharvest pressure infiltration of calcium and heat treatment. *J. Am. Soc. Hortic. Sci.* **1993**, *118*, 623−627.

Received for review June 2, 1995. Revised manuscript received September 18, 1995. Accepted October 5, 1995.[⊗] This research was supported by Proyecto de Investigación ALI92-0393 from the Plan Nacional de Ciencia y Tecnologia de Alimentos and by the Asociación Onubense de Productores y Exportadores de Fresa (FRESHUELVA).

JF950334L

[⊗] Abstract published in *Advance ACS Abstracts,* December 1, 1995.