Postharvest Heat Treatment on Spanish Strawberry (*Fragaria* × *ananassa* Cv. Tudla)

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Spanish strawberries (*Fragaria* × *ananassa* cv. Tudla) after harvesting were not treated or subjected to heat treatment by submersion in water at different temperatures (25, 35, 45, and 55 °C) for 15 min. Afterward, the fruits were stored at 1 °C for 2 days. Subsequently, their ripening parameters of quality were monitored during a shelf life of 3 days at 18 °C. Fruits heated at 45 °C produced the lowest values for postharvest losses, weight loss, and titratable acidity, the highest values of fruit firmness and soluble solids content, and the best values for sensorial appearance. However, these fruits lost most rapidly the initial value of calyx color and calyx and fruit skin brightness. Heat treatment at 45 °C should be especially useful for strawberries with a foreseeable high incidence of decay during their shelf life.

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

INTRODUCTION

Strawberries are a main export product of Spain, mainly due to their being the earliest to arrive on the European market. For this reason, improving the quality of the fruit during its shelf life is of more interest to Spanish producers than lengthening its storage life. Studies of postharvest heat treatment were observed to delay the decay of different fruits while maintaining their quality (Ben-Yehosua et al., 1987; Teitel et al., 1989; Paull, 1990; Lurie and Klein, 1992). Moreover, heat treatment causes increases in soluble solids content and decreases in the titratable acidity of the fruits (Klein and Lurie, 1991), two interesting effects which improve the sensorial quality of strawberries, especially if extended storage is not required. Couey and Follstad (1966), using moist air at 44 °C, controlled effectively postharvest decay of five California strawberry cultivars (Fresno, Solana, Lassen, Shasta, and Z5A). Hot water dips avoid more effectively water losses of the produce than any dry treatment, even when a moist atmosphere is employed. Additionally, submersion in water allows a more efficient and homogeneous heating of the fruits. Decay of different fruits, such as mangos (Spalding and Reader, 1986), melons (Teitel et al., 1989), or papayas (Paull and Chen, 1990), has been controlled successfully using hot water dips. In this paper, water dips of different temperatures were assayed to improve the marketable quality of the most cultured Spanish strawberry (cv. Tudla) during its transport and shelf life.

EXPERIMENTAL PROCEDURES

The fruits (*Fragaria* × *ananassa* cv. Tudla) were harvested early in the morning 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 five batches of 20 kg each; the fruits of four of them were submerged for 15 min at 25, 35, 45, and 55 °C, respectively, in thermostatically controlled water baths. Afterward, the fruits were dried, using a dry air stream, and placed in a room at 1 °C for 2 days, simulating their transport to the northern European market. The fifth group, that exempt from heat treatment, was directly placed at 1 °C, this being used as the control group. Subsequently, all of the fruits were placed at 18 °C during a shelf life period of 3 days. Sampling was conducted before heat treatment, after refrigeration, and every day during shelf life. The experiment was performed in triplicate.

The incidence of postharvest losses (fruits with visible mycelial growth and/or damaged surfaces) was monitored in samples of 100 fruits randomly selected from each treatment.

Fruit appearance was separately evaluated by three trained testers on samples of 50 fruits from each treatment according to a subjective scale, on which 1 was the best possible score and 5 the worst. Five of these fruits were tasted to examine the possible occurrence of off-flavor.

Another 50 fruits were chosen for measuring the fruit firmness using 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).

The juices extracted from these fruits were employed to determine soluble solids content, using an Atago DBX-55 refractometer (Atago Co. Ltd., Tokyo, Japan), and titratable acidity with a Crison automatic titrator (Crison Instrumente A. G., Baar, Switzerland), which measures the volume of 0.1 N NaOH required by 10 mL of juice to attain pH 8.0.

Weight changes of the strawberries were measured on four samples of 25 fruits for each treatment throughout the experimental period.

The same fruits were used to study the changes in calyx and skin color, employing the $L^*a^*b^*$ color spacing system using a Minolta CR200 chromameter (Minolta Camera Co., Osaka, Japan). For these purposes in each fruit a determination was done on a leaf of the calyx and on the equatorial zone of the fruit, respectively.

Analysis of variance was carried out on all data. A 5% level of least significant difference (lsd) was employed to establish differences between the means obtained for the treatments.

RESULTS AND DISCUSSION

Heating at 45 °C caused a clear delay in the onset of decay (Figure 1). Fruit treated at this temperature did not show appreciable incidence during the first 2 days of shelf life, while the control group showed at the same stage >75% of rotted fruits. The two groups treated at 25 and 35 °C displayed intermediate levels of decay. Heating at 55 °C seriously damaged the fruits, resulting in their being unmarketable after treatment. These fruits showed an unnatural skin color and a considerable loss of firmness. For this reason they were discarded and were not subjected to any subsequent analysis.

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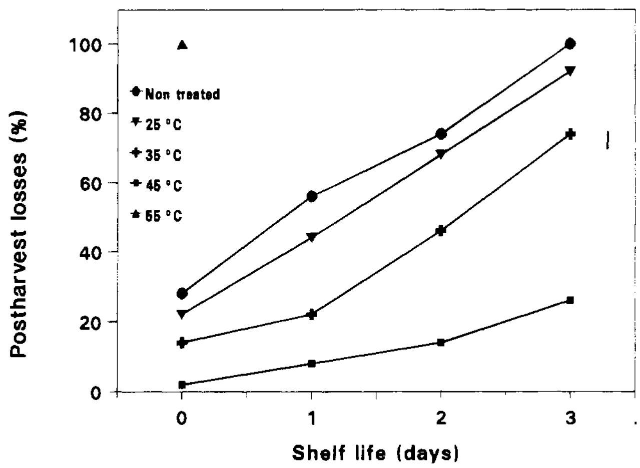

Figure 1. Changes in postharvest losses during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Initial value at harvest = 0%. Vertical bar represents least significant difference at $P \le 0.05$.

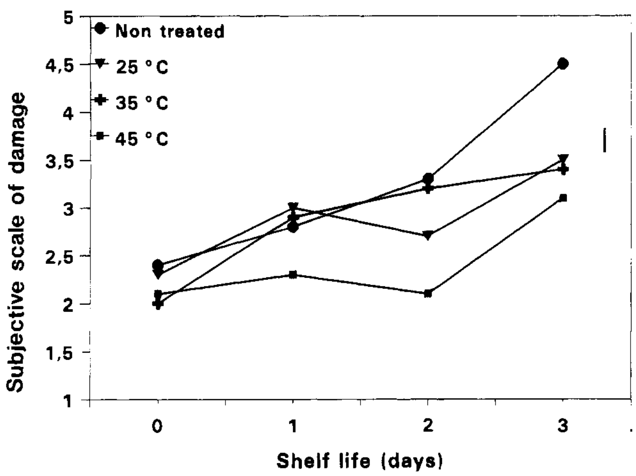

Figure 2. Changes in subjective valuation of the general appearance during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Initial value at harvest = 2.0. Vertical bar represents least significant difference at $P \le 0.05$.

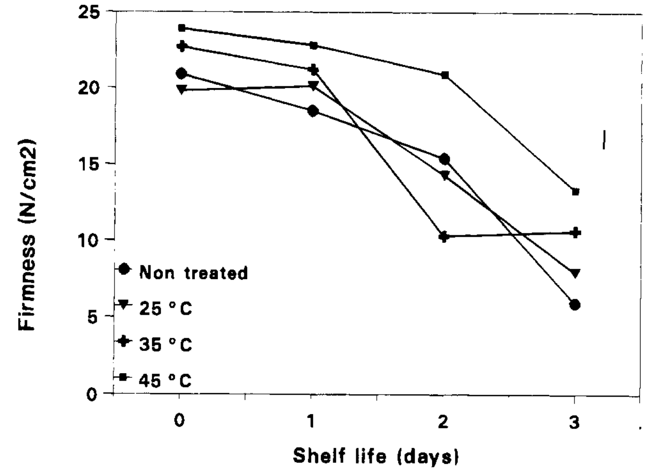

Figure 3. Changes in firmness during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Initial value at harvest = 23.0 N/cm^2. Vertical bar represents least significant difference at $P \le 0.05$.

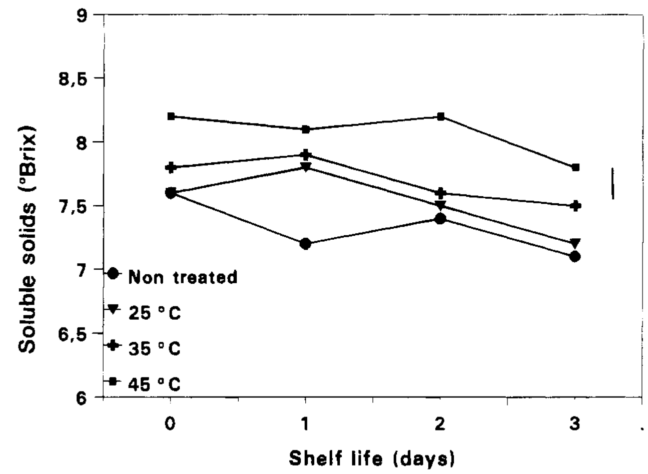

Figure 4. Changes in juice soluble solids content during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Initial value at harvest = 7.9 °Brix. Vertical bar represents least significant difference at $P \le 0.05$.

The appearance of the strawberries heated at 45 °C was judged to be statistically ($P \le 0.05$) better than that of the other fruits during the entire period of shelf life (Figure 2). No clear differences were found between those of the other treatment groups. Only the non-treated fruits had a significantly ($P \le 0.05$) less acceptable appearance at the end of the experiment. No off-flavor was detected in any of the assayed treatments.

Fruits heated at 45 °C maintained significantly ($P \le 0.05$) higher values of firmness than did the strawberries from the other treatments during the entire shelf life (Figure 3). Only after 3 days of shelf life did these fruits show an appreciably lower value of firmness than at harvesting (23 N/cm^2). Heat treatment caused a retention of the initial value, as was previously reported by Tsuji et al. (1984) in plums, by Biggs et al. (1988) in tomatoes, or by Klein et al. (1990) in apples.

The juice obtained from fruits heated to 45 °C showed a significantly ($P \le 0.05$) higher content of soluble solids than did that from nontreated strawberries or those treated at a lower temperature, during practically the entire shelf life period (Figure 4). The increase in sweetness is another important factor to be considered for evaluating strawberry quality. Heat treatment can improve the soluble solids content of this fruit and, in consequence, its possible acceptance by the consumer. A possible explanation for the decreases in the soluble solids content of the juices obtained from the fruits treated at lower temperatures could be that in strawberries the heat treatment would affect the metabolism of the mono- and disaccharides in the same way as in other fruits, such as tomatoes and apples. Once removed from high temperature to 20 °C, respiration measured as CO_2 production falls almost immediately to 80% that of controls for the duration of shelf life (Klein and Lurie, 1991).

In the same way as was observed in other commodities (Klein and Lurie, 1991), heat-treated strawberries were markedly lower in titratable acidity than were the nontreated ones (Figure 5). However, no clear differences were observed among the fruits heated to the different temperatures, with the exception of the fruits from the 25 °C treatment, which showed values similar to those of the nontreated ones until the second day of shelf life. Probably the main effect was due to the water dip, because the values of titratable acidity are not ordered according to the temperature employed. The initial significant ($P \le 0.05$) decrease observed in the

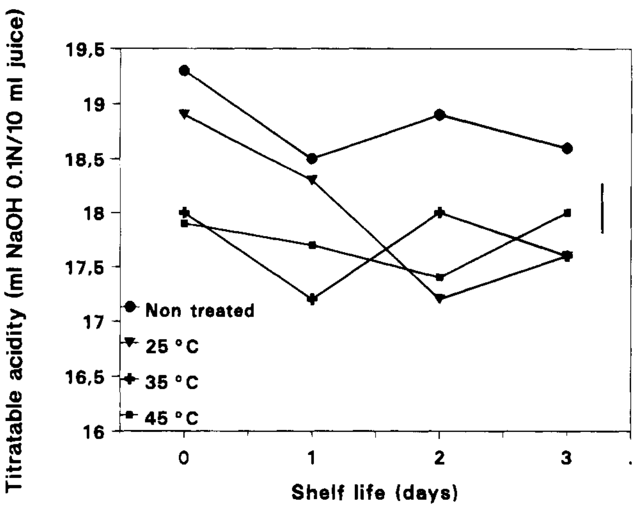

Figure 5. Changes in juice titratable acidity during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Initial value at harvest = 18.4 mL of 0.1 N NaOH. Vertical bar represents least significant difference at $P \leq 0.05$.

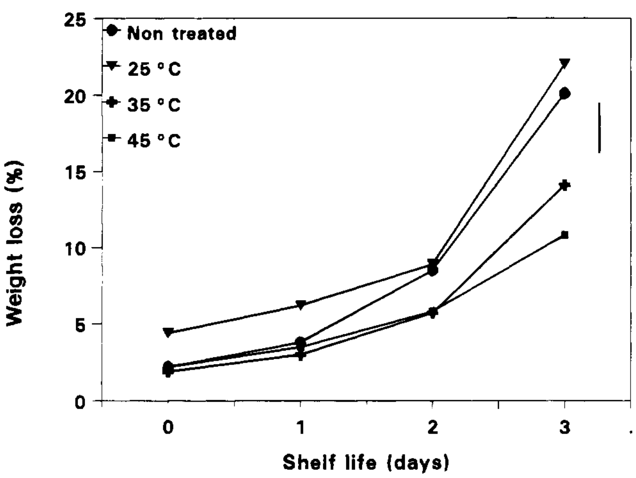

Figure 6. Changes in weight loss (percent) during shelf life of strawberries previously heated in water for 15 min at different temperatures and stored for 2 days at 1 °C. Vertical bar represents least significant difference at $P \leq 0.05$.

juice obtained from fruits treated at 35 or 45 °C may be due to the increase in the activity of different enzymes involved in the metabolism of the organic acids, as established by Lurie and Klein (1990) in heated apples.

Weight loss of fruits increased during the shelf life study for all heat treatments (Figure 6). Nevertheless, the fruits heated at 35 and 45 °C showed a better retention of weight than did those from the other treatments, these differences being statistically significant ($P \leq 0.05$) from 2 days of shelf life. This fact was due to the higher incidence of rotted fruits found among nontreated fruits and those heated at 25 °C. Heat treatment did not increase the permeability to water of the fruit cells in strawberry.

Maintenance of harvest values of calyx color can be considered to assess the marketability of strawberries subjected to different postharvest treatments. Nontreated strawberries sustained better brightness and green color, measured with *L* and *a* values, respectively, than did the treated fruits, especially those heated at 45 °C, which displayed lower values during the entire shelf life (Table 1). In spite of this action the strawberries treated at 45 °C maintained the best sensorial appearance, as was concluded earlier. On the other

Table 1. Changes in Parameters of the Calyx Color during Shelf Life of Strawberries Previously Heated in Water for 15 min at Different Temperatures and Stored for 2 Days at 1 °C

parameter	shelf life (days)	heat treatment[a]			
		nontreated	25 °C	35 °C	45 °C
L	at harvest	37.8 aBC	37.8 aB	37.8 aAB	37.8 aA
L	0	41.6 aA	39.2 bA	37.5 cB	37.8 cA
L	1	38.5 aB	35.9 bC	38.5 aA	35.9 bB
L	2	37.2 aC	33.3 cD	36.7 aC	34.7 bC
L	3	34.4 aD	33.0 bD	32.4 bD	32.2 bD
a	at harvest	−6.2 aA	−6.2 aA	−6.2 aA	−6.2 aA
a	0	−5.9 aA	−4.4 bB	−5.8 aA	−3.4 cB
a	1	−4.5 aB	−2.1 bC	−3.0 aB	−1.6 bC
a	2	−3.8 aC	1.1 dD	−2.0 bC	−0.3 cD
a	3	2.4 aD	3.8 bE	2.6 aD	1.8 aE
b	at harvest	25.7 aA	25.7 aA	25.7 aA	25.7 aA
b	0	23.8 aA	23.3 aB	23.4 aB	23.4 aB
b	1	20.7 abC	19.3 cC	21.2 aC	20.4 bC
b	2	19.4 bD	16.8 cD	20.6 aD	19.2 bD
b	3	16.9 bE	15.5 cE	17.1 bE	18.0 aE

[a] Each value is the mean of 25 replications. In each parameter, values of the same row followed by the same small letter and values of the same column followed by the same capital letter are not statistically different ($P \leq 0.05$) according to the multiple range test of Duncan.

Table 2. Changes in Parameters of the Fruit Skin Color during Shelf Life of Strawberries Previously Heated in Water for 15 min at Different Temperatures and Stored for 2 Days at 1 °C

parameter	shelf life (days)	heat treatment			
		nontreated	25 °C	35 °C	45 °C
L	at harvest	46.5 aA	46.5 aA	46.5 aA	46.5 aA
L	0	44.0 aB	40.9 cB	41.8 bB	37.8 dB
L	1	42.6 aC	40.4 bB	40.6 bC	38.7 cB
L	2	38.0 aD	33.8 cD	37.6 aD	36.4 bC
L	3	37.0 aD	36.6 aC	36.6 aD	34.5 bD
a	at harvest	30.0 aA	30.0 aA	30.0 aA	30.0 aA
a	0	29.2 cA	30.6 bA	30.2 bA	31.8 aA
a	1	30.0 aA	30.2 aA	28.4 bB	29.4 aB
a	2	28.5 abB	28.1 bB	28.5 abB	29.3 aB
a	3	30.0 bA	30.0 bA	30.0 bA	31.2 aA
b	at harvest	23.1 aA	23.1 aA	23.1 aA	23.1 aA
b	0	22.1 aA	19.9 aB	21.0 aB	19.5 aB
b	1	20.7 aC	18.7 bC	19.2 bC	19.1 bB
b	2	19.1 aD	16.1 cD	18.7 aC	17.0 bC
b	3	16.5 abE	15.5 abD	17.1 aD	16.0 bD

[a] Each value is the mean of 25 replications. In each parameter, values of the same row followed by the same small letter and values of the same column followed by the same capital letter are not statistically different ($P \leq 0.05$) according to the multiple range test of Duncan.

hand, no clear differences were observed between the treatments with regard to the yellow component of the calyx color, measured with the *b* value. In general, all of the color parameters of the calyx decreased during shelf life, coinciding with the progressive deterioration of this perishable produce.

The skin color is an important factor in strawberry marketability, because, normally, it is the consumers' only consideration when purchasing this commodity, especially if the fruits are covered with a plastic film. Nontreated fruits also most effectively maintained the brightness of skin (Table 2). No clear differences were observed among the treatments upon the red color (*a* value). However, the strawberries heated at 45 °C showed the highest values.

Heat treatment by dips in water at 45 °C should be especially useful for strawberries with a foreseeable high incidence of decay during their shelf life, for example, those fruits harvested immediately after rain or during the latest period of harvesting.

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