The Effect of Modified Atmosphere Packaging and Calcium Chloride Dipping on the Quality and Shelf Life of Kurdistan Strawberries

Mohammad Jouki* and Naimeh Khazaei
Young Researchers Club- Islamic Azad University- Shahr-e-qods branch, Tehran, Iran

Abstract

The present research was conducted to evaluate the effects of MAP and calcium chloride on some quality parameters of strawberry fruits stored at 4°C. Several quality parameters were monitored during the storage period. The samples were analyzed 0, 7, 14, 21 and 28 days during storage. Fruit weight, sugar content, chromatic parameters L*, a*, b*, fruit firmness, total titratable acidity, pH, sensory evaluation are analyzed. The results evidenced that the immersion of fruit in 0.5% calcium chloride solution (CaCl₂) didn’t affect significantly in their physico-chemical characteristics such as: pH, total titratable acidity (ATT). The packaged strawberries retained their weight throughout the experiment as opposed to the samples packaged under air which lost 0.5% of their weight per day because of dehydration. The results indicated that storage in a modified atmosphere (5-10% O₂ and 5-10% CO₂) can be used to maintain the quality of Kurdistan strawberries for a longer time, than if kept in air packaging. Hence any of the packages except packages under air could prove suitable for inhibiting Botrytis growth for 3 week at 4°C. In relation of post-harvest life, the results indicated that the calcium treatment (0.5%) and MAP increased it from 7 (control) to 21 days.

Keywords: Strawberry; Calcium; Modified atmosphere; Quality parameters; Firmness

Introduction

Strawberry is an important small fruit, grown throughout the world. In Iran more than 50,000 tons of strawberries are produced each year. Kurdistan is located in the north west of the country. With more than 40,000 tons production per year it is the largest of the strawberry production areas in Iran [1]. Strawberries have short shelf life due to highly perishability and are susceptible to mechanical injury, physiological disorders, water loss, and decay [2]. The shelf-life of fresh produce is limited to 1–2 days at room temperature [3–6]. The shelf life of fresh strawberry is inversely proportional to respiration rate [7]. Consequently, the most commonly used method for shelf-life extension is low temperature. But storage quality can be further improved by altering the gas atmosphere surrounding the fresh strawberry [8,9]. The respiration rate of fruits and vegetables usually decreases with increasing CO₂ and/or decreasing O₂ concentration [9]. Furthermore, high CO₂ concentration can inhibit the generation of C₂H₄ because it can influence the enzyme’s activity, thus the permeability of cells membrane does not increase quickly. MAP is often used to maintain elevated CO₂ and reduced O₂ concentrations inside consumer-packaged produce containers [10]. Calcium is an essential component for plant cell function, and plant tissue integrity [11–13]. Calcium’s physiological activity as a second messenger in cellular biochemistry and its requirement in cell wall structure make it important to fruit growth and development, as well as general fruit quality [14,15], the rate of fruit senescence [16,17], disease resistance [18–21], and other stresses [22]. While not all impacts of calcium on fruit quality, shelf-life, and fruit rot appear positive [23–25], it is clear that calcium formulation, rate, and timing impact the efficacy of calcium on several parameters [15,18,23]. This is an intermediate report of the impacts of several calcium formulations applied throughout the peach fruit development and growth period. It has been reported that washing some vegetables before packaging could prevent off-odor development caused by enzymatic and microbial activities [26]. Adding CaCl₂ to the irrigation water during cropping can delay the cap opening and deterioration of external appearance [27,28]. Bartley et al. (1991) reported a significantly improved color of mushrooms irrigated with 50 ppm oxine plus 0.075% CaCl₂ prior to harvest and postharvest storage [29]. Morris et al. (1991) immersed strawberry in 0.18% CaCl₂ solution for 5 minutes, there-after storing them in polyethylene bags [30]. The results showed an increase in firmness without any alteration of the color and weight of the fruits. The present study was undertaken to investigate the effect of MAP in combination with CaCl₂ dipping on the physiochemical parameters of strawberries in comparison with the ordinary packaging. In order to accomplish this objective, weight loss, color and sugar contents of pre-dipped strawberries with 0.5% CaCl₂ for 5 min. packed under modified atmospheres of 3% CO₂ : 10% O₂ : 85% N₂ and 10% CO₂ : 5% O₂ : 85% N₂ and stored at 4°C were evaluated.

Materials and Methods

Sample collection and preparation

Strawberries grown in Sanandaj area in Kurdistan, Iran (cultivar Kurdistan) were harvested from strawberry plants in the morning in September 2010. After harvesting, sorting (medium size and ripe strawberries) and cutting their stems, they were transported in air-conditioned vans to the Laboratory of packaging and Post-Harvest Physiology of Fruits at the University of Tehran and divided into two groups: with CaCl₂, and without CaCl₂ dipping. The control was used by the fruits immersed in water for the same duration of time. Then two groups were packaged under ordinary air and MAP packaging
methods, storing at 4°C for further analysis. The analyses were made at 0, 7th, 14th, 21st and 28th days.

**CaCl₂ dipping**

The fruits were disinfected by immersing them in a 2% solution of sodium hypochloride for 1 minute and then after treated by immersing them for 5 minutes in the 0.5% CaCl₂ solution, containing 3 drops per liter of the reflective adhesive (Tween 80). After drying in atmospheric temperature, fruits were randomly separated in groups of six units and conditioned in 20x30 cm plastic trays. The trays were then inserted into the polypropylene bags described above. The bags were either heat-sealed immediately or flushed with a gas mixture prior to sealing.

**Packaging methods**

Polyethylene (PE) packaging rolls were used for preparation of packages of 30 cm x 20 cm. In this study three different gas compositions such as normal atmosphere (normal), MAP1: (CO₂ 10%; O₂ 5%; N₂ 85%) and MAP2: (CO₂ 5%; O₂ 10%; N₂ 85%), were applied with the modified atmosphere packaging machine (200A), combined with a triple gas mixer (B20-010). After the experiment was set up, fruits were stored in a cold room maintained at 4°C, for 28 days. Quality parameters were evaluated after 0, 7th, 14th, 21st and 28th days. All analyses were performed in the laboratory of Tehran University, Department of Food Science.

**Firmness**

Fruit flesh firmness was assessed using a texture analyzer. Speed of 20 mm/s and penetration distance of 6 mm was used to cut the segments at the center, and the firmness was expressed as maximum cutting force (N). The segments similar in thickness were selected for firmness measurement. Six segments from two parallel packages (10 segments/packet) were measured for each treatment on each sampling day [31]. The readings were recorded in N force. The storage duration was determined for each treatment.

**Weight loss**

Weight loss was calculated by the following equation:

\[
\text{Weight loss (g/100 g) = } (W_d - W_f)/W_f \times 100
\]

Where \(W_d\) is first day weight and \(W_f\) is desired day after storage [32].

**pH**

The pH of the strawberry homogenate was analyzed by a pH meter (Metrohm, Herisau, Switzerland) in duplicate measurements on day 0, 7, 14, 21 and 28.

**Acidity**

Each sample (about 25 g from) was blended for 3 min. and filtered by using cheese cloth. The prepared juice of the sample was used for chemical analysis. The acidity was measured by titration with 0.1 N NaOH [33]. Results were expressed as per cent citric acid.

**Sugar contents**

Sugar contents were determined based on the Gravimeter- Fehling method [34].

**Colour**

The homogenate was poured into petri dish and the colour was measured using a colour meter (Minolta Spectramatch, Tokyo, Japan). Triplicate samples were analyzed and three measurements were made on each sample. Analyses were performed day 0, 7, 14, 21 and 28. Three measurements were taken at random locations and the CIELAB L*, a*, b* parameters were recorded. Chroma (C*) and Hue angle values were obtained using the equations [35]:

\[
C* = (a^2 + b^2)^{1/2}
\]

\[
\text{Hue angle} = \tan^{-1} \frac{b^*}{a^*}
\]

**Fungal decay**

The presence of Botrytis cinerea was estimated visually in each individual fruit immediately after opening the packages. Wild strawberry fruits showing surface mycelial development were considered decayed. Results were expressed as% of fruits infected by Botrytis.

**Sensory evaluation**

Samples packaged with different atmospheres were evaluated for overall appearance, firmness, aroma and acidity using a 5-point rating scale with six trained panelists. The attributes and product acceptability were expressed as follows: Visual appearance 5: excellent/fresh; 4: good; 3: acceptable; 2: poor; 1: very poor. Aroma 5: natural; 4: loss of aroma; 3: no aroma; 2: light strange aroma; 1: strong strange aroma. Firmness 5: excellent firmness/juiciness; 4: firm/juicy; 3: acceptable firmness/juiciness; 2: hard; 1: very hard. Acidity 5: very good; 4: good; 3: acceptable; 2: acidic; 1: too much acidity [36].

**Statistical analysis**

Statistical analysis was carried out using the General Linear Models Procedure of SAS [37]. Duncan’s multiple range test was used for multiple comparison and separation of means.

**Results and Discussion**

**Weight loss**

One of the characteristics of strawberry fruits that contribute to their highly perishable character is rapid loss of water [38]. Part of respiration and transpiration of a fresh produce can be expressed by the change of its weight loss [39]. Weight loss was significantly affected by storage time (P<0.01). The amount of weight loss increased during the storage period resulted in increase in weight loss (Figure 1). In this study, significant differences (P <0.05) in weight loss were found for the different packages. After 7 days at 4°C the highest weight losses (2.8%) were obtained for strawberries packed in under air and without CaCl₂ and the lowest values (1%) were presented by the samples packed under MAP and dipped with CaCl₂. As far as CaCl₂ dipping is concerned, had lower weight loss in comparison with without CaCl₂ dipping (Figure 1) which indicated that CaCl₂ dipping was efficient in reducing weight loss. This may be associated to the contribution of calcium to maintain the cellular organization and to regulate enzymatic activities, thereby retarding the moisture loss caused by the senescence [40]. It showed that modified atmosphere could inhibit water transpiration. Therefore, it can extend the shelf-life of strawberry. All these values were in agreement with the permeation values measured for the different samples in independent experiments (Figure 1). At the end of the storage period, control fruits lost 8.50% weight, and packaged fruits under MAP1 and CaCl₂ dipping lost an average of 4.5%. Final water losses were below 6% in samples stored under MAP and dipped with CaCl₂, which is considered the limit for commercial acceptance.
and all samples stored under air showed evidence of dehydration (wrinkling) at the end of the test.

Sugar

The initial sugar concentrations were 10.5% in Kurdistan strawberries. During storage the sugar levels in all the packaged samples dropped slightly. This can be explained by sugars being consumed through respiration. During storage, the sugar concentration tended to increase in normal packaging but this increase was not statistically significant. The minor rise in sugar concentration in the samples under air packaging is probably due to water loss that is the total amount of sugars did not increase but sugars made up a larger percentage of the weight as the strawberries became dehydrated. No differences (P ≥ 0.05) were found between strawberries under MAP1, MAP2 and fruits packed under air during storage time at 4°C.

pH and total titratable acidity

The pH of all the samples was in range 3.55-3.60 at first day of storage time. During the storage period, were observed reduction on fruits’ pH between the first and the fourteenth day, following an increase of the same, but did not suffer a statistically significant variation. Strawberry pH increased after day 14 from 3.60 to 3.68 in samples packed under MAP and was lower in dripped samples with CaCl2 than samples without CaCl2. pH decreased in air packed samples without CaCl2 dripping from 3.6 to 3.52 in the end of storage time. The ATT showed an increase at the beginning of the storage (up to the fourteenth day) and there after a reduction between the fourteenth and twenty-eighth day. The reduction of ATT in strawberries beginning at the 14th day of its storage must have been a result of acid oxidation during the Krebs cycle, once that this constitutes an excellent energy reserve for the fruit. The ATT varied between 0.68 and 1%, showing that it was inferior to 1%, which an average value was observed by Berbari et al. [42]. These results are in agreement with those obtained by Siriphanich [43], who reported that high-CO2 treatments resulted in higher pH values than those of air control strawberries. However, our results regarding to pH and titratable acidity are not in agreement with those obtained by Ozkaya et al. [44] and Almenar et al. [45] who reported the increase in acidity of strawberries during storage and MAP. An explanation of this is that they use other varieties.

Fungal decay

Carbon dioxide can have an inhibiting effect on mould growth and experiments were therefore carried out to establish if the CO2 levels obtained inside the packaging could prevent moulds from growing. No mould growth was detected after 7 days of storage (Figure 2). After 14 day there was no difference between packaging conditions MAP 1 and MAP2. The CaCl2 dripped samples were not attacked by mould during 14 days. The quantity of decayed fruit increases with storage time but can be controlled by the use of an adequate atmosphere. Since the early studies of Brown and Brooks et al. the inhibitory effect of high-CO2 atmospheres on spore germination and mycelium growth of B. cinerea and other fungi has been proved [46,47]. Wells and Uota found that 20% CO2 gave 50% inhibition of B. cinerea mycelium growth and 45% CO2 gave total inhibition at 20°C [48]. In this study the presence of B. cinerea was only observed in the packages under air at the end of storage (85-100%), as seen in figure 2. These results are in agreement with the observations of El-Kazzaz et al. and Sommer et al., who reported that exposure to CO2 levels between 5 and 20%, had some fungicidal effects on strawberry pathogens [49,50]. Hence any of the packages except packages under air could prove suitable for inhibiting Botrytis growth for 3week at 4°C.

Firmness

All the six sample groups were stored at 4°C temperature. All the samples were tested after storage interval of one week. The firmness was decreased after each storage interval. Strawberry firmness decreased by 22% during storage in refrigeration conditions for samples under MAP1+CaCl2 and 77% in samples packed under air without CaCl2, respectively (Figure 3). The strawberry stored in MAP and without CaCl2 dripping had less firmness than those stored in MAP and dripped with CaCl2. The results obtained in this study are in agreement with...
other studies, which have generally reported that fruits stored in MAP are firmer than those stored in air [44,51]. The firmness enhancement could be associated with the different CO₂ concentrations reached inside the strawberry packages. CO₂-induced firmness increases appear to be a common characteristic of strawberry fruits [6,49,52,53]. Gains in firmness were greater (P<0.05) for strawberries packed under MAP owing to the increasing CO₂ concentration in the package headspace. Thus after 7 days at 4°C the firmness of strawberries packed under MA1 and MA2 that were dripped with CaCl₂ increased by 2.55 and 2.52 N cm⁻² respectively, which is in accordance with the results of El-Kazzar et al. for cultivated strawberries [49]. Although it is known that the mechanism responsible for CO₂-induced firming of strawberry fruits depend on cell wall strength, cell-to-cell adhesion, cell packing and the internal pressure or turgor of cells [54], the mechanism responsible for CO₂-induced firming of strawberry tissue is still unknown.

Color

Color of strawberry is one of the most important quality factors of fresh strawberry for consumer preference. The color development rate of strawberry increased with increasing maturation. Color of strawberry was measured by Colorimeter and Color Difference on color coordinates L*, a*, b* values, where L-value is lightness, a-value is redness-greenness, and b-value is blueness-yellowness. L* values decreased in the beginning and became stable at the end of storage. During storage, the L* value tended to decrease in both MAP and normal packaging. However, strawberries from normal atmosphere conditions were significantly darker in color (lower L* value) than fruit storage in MAP. As in the present study, decrease in the L* value of strawberry fruit have previously been reported by others researches [45,51]. The a* value increase significantly during 7 days of storage, which is probably supported by the accumulation of anthocyanin pigments and high degree of red fruit. On the other hand b-values decreased in first two weeks and then became stable. The chroma value describes its brightness while the hue angle represents a coordinate in a standardized colour space. The results are presented in table 1. As expected, Chroma decreased and over the storage time, especially samples under air without CaCl₂ was less bright (lower chroma value). Strawberries became more red (lower hue angle) during the storage period. Sample under air packaging and without CaCl₂ showed the largest difference. Table 1 shows that the color change is less in MAP1 followed by MAP2 and control while the Chroma value was higher in CaCl₂ treated samples. Comparing the samples with CaCl₂ dipping with the strawberries without CaCl₂ dipping showed that this dipping significantly affected their color and resulted in higher L value (brighter strawberries), which is due to the potential of calcium in imparting stability to vacuole membranes [55]. Additionally, obtained results, which demonstrated that MAP was able to retard discoloration and the samples under MAP showed lower decrease in L value.

Sensory quality of bitter orange segments

The sensory analyses were performed to establish any sensorial differences between the different packaging conditions after 7, 14, 21 and 28 days of storage of the strawberries. Four attributes, see table 2, were judged by the assessors. The results of the sensory evaluation are presented in table 2. There was no significant difference in sensory quality of bitter orange segments between normal (air) and MAP (P>0.05) for 7 days. After 14 days there were significant differences in the appearance of strawberries kept in the different packaging conditions. MAP treatment had significant effect on appearance (P<0.001). Strawberries under MAP1 and MAP2 had better appearance and firmness than strawberries packed under air. These observations were well in accordance with the findings from the aroma analyses.

| Treatments | time | L*    | a*    | b*   | Hue   | Chroma |
|------------|------|-------|-------|------|-------|--------|
| MAP 1 + CaCl₂ | Day 0 | 35.89 ± 2.87 | 30.31 ± 3.18 | 22.14 ± 3.45 | 36.16 | 37.53 |
|             | Day 7 | 33.43 ± 3.54 | 30.65 ± 2.57 | 20.65 ± 3.12 | 33.98 | 36.95 |
|             | Day 14| 32.98 ± 4.12 | 30.25 ± 2.76 | 20.24 ± 4.08 | 31.81 | 38.41 |
|             | Day 21| 31.67 ± 3.87 | 30.00 ± 2.44 | 19.26 ± 3.62 | 30.28 | 38.20 |
|             | Day 28| 31.14 ± 3.90 | 32.90 ± 3.20 | 18.66 ± 3.21 | 29.57 | 37.82 |
| MAP 1       | Day 0 | 36.09 ± 2.35 | 30.23 ± 3.16 | 22.80 ± 4.12 | 37.04 | 37.86 |
|             | Day 7 | 32.12 ± 2.90 | 30.95 ± 2.95 | 20.01 ± 4.79 | 32.90 | 36.85 |
|             | Day 14| 31.98 ± 4.12 | 32.54 ± 2.27 | 19.22 ± 3.82 | 30.58 | 37.79 |
|             | Day 21| 30.67 ± 3.87 | 32.41 ± 2.49 | 18.87 ± 3.50 | 30.22 | 37.50 |
|             | Day 28| —      | —      | —    | —    | —     |
| MAP 2 + CaCl₂ | Day 0 | 35.21 ± 2.84 | 30.66 ± 2.57 | 22.24 ± 3.90 | 35.97 | 37.87 |
|             | Day 7 | 33.44 ± 3.03 | 30.55 ± 2.41 | 20.15 ± 3.80 | 33.42 | 36.59 |
|             | Day 14| 32.44 ± 3.03 | 32.41 ± 2.76 | 19.29 ± 3.67 | 30.77 | 37.71 |
|             | Day 21| 30.29 ± 3.55 | 32.06 ± 3.11 | 19.10 ± 3.34 | 30.80 | 37.31 |
|             | Day 28| —      | —      | —    | —    | —     |
| MAP 2       | Day 0 | 36.80 ± 2.66 | 29.54 ± 3.22 | 22.12 ± 3.67 | 36.84 | 36.90 |
|             | Day 7 | 32.20 ± 3.34 | 30.60 ± 2.88 | 20.50 ± 3.80 | 33.83 | 36.83 |
|             | Day 14| 32.87 ± 2.52 | 32.95 ± 2.21 | 19.09 ± 4.21 | 30.10 | 38.08 |
|             | Day 21| —      | —      | —    | —    | —     |
|             | Day 28| —      | —      | —    | —    | —     |
| NAP + CaCl₂ | Day 0 | 35.45 ± 2.44 | 29.73 ± 2.83 | 22.90 ± 4.01 | 37.62 | 37.52 |
|             | Day 7 | 34.45 ± 2.44 | 32.45 ± 2.69 | 20.33 ± 4.35 | 32.08 | 38.29 |
|             | Day 14| 31.45 ± 2.44 | 32.76 ± 2.43 | 19.12 ± 4.05 | 30.28 | 37.93 |
|             | Day 21| —      | —      | —    | —    | —     |
|             | Day 28| —      | —      | —    | —    | —     |
| NAP         | Day 0 | 35.96 ± 3.12 | 30.11 ± 3.00 | 21.50 ± 3.90 | 35.54 | 36.99 |
|             | Day 7 | 33.55 ± 3.61 | 31.16 ± 3.12 | 20.54 ± 4.11 | 32.10 | 36.77 |
|             | Day 14| 29.70 ± 4.23 | 31.51 ± 3.87 | 18.25 ± 3.66 | 30.09 | 36.41 |
|             | Day 21| —      | —      | —    | —    | —     |
|             | Day 28| —      | —      | —    | —    | —     |

MAP = Modified Atmosphere Packaging, NAP = Normal Atmosphere Packaging (packaging under air)

Table 1: Effect of modified atmosphere packaging and CaCl₂ dripping on colour of strawberries stored for 28 days at 4°C.
Mean values followed by the different letter for a given parameter are significantly different (MAP = Modified Atmosphere Packaging, NAP = Normal Atmosphere Packaging (packaging under air).

CaCl\textsubscript{2} had better firmness and appearance. Panelists didn't distinguish strawberries packed under modified atmosphere, samples treated by treatment (0.5%) and MAP increased it from 7 (control) to 21 days. In relation of post-harvest life, the results indicated that the calcium of the sensory attributes and the product acceptability. That's why the below acceptability limit (score 3) at the 28 days of storage for most any difference about acidity. The fruits showed absence of visual any change in their external appearance. Firmness decreased during storage of strawberry samples in MAP and air packed, but intensely fruit stored under air packaging and without CaCl\textsubscript{2} treatment. Firmness reduction was lower in samples that were treated with calcium chloride. It was concluded the 0.5% calcium chloride treatment can extend the storage life of strawberries. The conclusion was drawn by considering the parameters such as firmness, color, weight loss, mould growth and sensory evaluation. The results showed that the above mentioned parameters can be used as indicator for the quality of strawberries. Calcium chloride dripping protected strawberries from spoilage for up to 3 weeks in MAP1 at 4°C. CaCl\textsubscript{2} dripping may offer a new technique for spoilage prevention of horticultural commodities. Its effectiveness, low price, ready availability, and ability to act at low concentrations without obvious off flavors is encouraging; combined with MAP, it could significantly extend the shelf life of fresh produce.

Conclusions

Modified atmosphere packaging and CaCl\textsubscript{2} treatment have not affected acidity and pH of strawberry samples during storage. Fruits color was affected by storage. Strawberries color parameters moved toward a more intense red color (a\textsuperscript{+}) and a less intense yellow color (b\textsuperscript{-}) as not changes during storage; also the L\textsuperscript{+} value decreased in both MAP and air packaging during storage fruit becoming darker in color. Strawberries dripped with CaCl\textsubscript{2} showed that this dipping significantly affected their color and resulted in higher L\textsuperscript{+} value (brighter strawberries). Strawberries kept in modified atmosphere maintained their weight and appearance better than those that packaged under air. The strawberry fruits treated with 0.5% calcium by immersion increased their post-harvest life from 7 to 21 days, without any attack of fungus or any change in their external appearance. Firmness decreased during storage of strawberry samples in MAP and air packed, but intensely

![Table 2: Effect of modified atmosphere packaging and CaCl\textsubscript{2} dripping on the sensory attributes of strawberries stored at 4°C.](image)

Although strawberries packaged under active MAP1 were found acceptable for 21 days in terms of sensory quality. The scores for strawberries packed under air were and were not dripped with CaCl\textsubscript{2} were below acceptability limit (score 3) at the 28 days of storage for most of the sensory attributes and the product acceptability. That's why the viability of strawberries packaged under air was limited to 12 days. In relation of post-harvest life, the results indicated that the calcium treatment (0.5%) and MAP increased it from 7 (control) to 21 days.

In strawberries packed under modified atmosphere, samples treated by CaCl\textsubscript{2} had better firmness and appearance. Panelists didn't distinguish any difference about acidity. The fruits showed absence of visual infections or any change in their external appearance. Probably the calcium was incorporated into the cell wall of fruits conferring high resistance of infection [56,57].

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