QUALITY OF STRAWBERRIES AFTER STORAGE IN CONTROLLED ATMOSPHERES AT ABOVE OPTIMUM STORAGE TEMPERATURES

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Abstract. 'Chandler' strawberries (Fragaria x ananassa Duch.) were stored in 5% O2 + 15% CO2 or 10% O2 + 20% CO2 at 4 or 10°C to study the effects of controlled atmospheres (CA) at temperatures above the optimum for strawberries. Physical and chemical evaluations were made after 1 week plus 1 day at 20°C. Berries stored in CA lost less weight, were firmer, lighter in color (higher L* value), and purer red (higher a* and chroma values) than those stored in air, especially at 4°C. However, the only difference in these physical characteristics between the two CA treatments was higher chroma for the berries in 5% O2 + 15% CO2. The CA berries also had higher soluble solids, titratable acidity and ascorbic acid than the air-stored fruit, especially at 4°C. However, the reduced respiration rates have also been observed when strawberries were stored under CA (Woodward and Topping, 1972; Li and Kader, 1989). An O2 level of 0.5% was more effective than 1 or 2% O2, and concentrations of CO2 in the range of 15 to 20% were more effective than 10% CO2 in decreasing the rate of respiration during storage of 'Selva' strawberries at 2°C (Li and Kader, 1989). However combinations of reduced O2 plus elevated CO2 were no more effective than reduced O2 alone. Reduction in respiration rate can help minimize compositional changes during storage, which could better maintain the taste and nutritional value of the fruit.

The main benefit from CA for strawberries is control of decay (Kader, 1990), primarily gray mold rot caused by Botrytis cinerea Pers., which is the most serious postharvest disease of strawberry fruit (Maas, 1984). Decay control in CA is due to the elevated CO2 levels used (≥10%; Couey and Wells, 1970) since O2 levels (0.5% or less at 3°C) found to be necessary to decrease decay caused by B. cinerea caused objectionable off-flavors to develop in the fruit (Couey et al., 1966). However, Sommer et al. (1973) concluded that high CO2 atmospheres are effective only at temperatures above 5°C. They found that suppression of decay was modest or undetectable at lower temperatures because little fungal growth occurred regardless of the atmosphere.

While most of the studies of the effects of CA on strawberry quality attributes other than decay have been conducted at temperatures of 0 to 2°C, there have been a few studies that relate to the potential effects of CA at higher temperatures likely to be encountered in normal commercial handling. Ke et al. (1993), in testing CA for efficacy in insect control, reported that 'Selva' strawberries held in 50% CO2 or 0.25% O2 for 8 days at 5°C had less desirable flavor when compared to those stored in 20% CO2. They also reported that fruits in 20% CO2 maintained better visual quality while tasting as good as those stored in air. Poor flavor was related to the accumulation of anaerobic volatiles. Although fruits stored in 20% CO2 at 5°C had good appearance, a slight increase in anaerobic volatiles was observed (Ke et al., 1993). Browne et al. (1984) also reported that 'Cambridge Favourite' strawberries stored in CA with 20% CO2 at 2°C or higher developed off-flavors. Woodward and Topping (1972), however, reported that the higher the temperature, the longer strawberries could be stored in 20% CO2 without showing damage. The tolerance of strawberry fruit to low O2 concentrations is also temperature dependent. Strawberries seem to be most tolerant to low O2 levels at 0°C, perhaps due to reduced O2 consumption (Ke and Kader, 1989).

Concentration ranges of 5 to 10% O2 and 15 to 20% CO2 have been recommended as optimal for CA storage of straw-
berry at near the recommended storage temperature of 0C (Kader, 1980; Kader, 1992). However, strawberries may be handled in CA at significantly higher temperatures than recommended, and O₂ and CO₂ levels that are beneficial at near 0C may be detrimental to fruit quality at higher temperatures. Therefore, we decided to evaluate the effects of O₂ and CO₂ concentrations within the reported optimum range on the physical and chemical quality characteristics of 'Chandler' strawberries stored at 4 or 10C. Although these temperatures are above the optimum of 0C, they are likely to be encountered in normal commercial operations.

**Material and Methods**

**Plant material.** 'Chandler' strawberries were obtained from the Vairão Agricultural Experiment Station, located in the north of Portugal, near Vila do Conde. The strawberries were grown in double rows on raised beds covered with black plastic mulch. A total of four harvests/experiments were conducted during the 1994 summer season from June to July.

**Treatment and storage conditions.** Fruit were removed from the field with minimal delay after harvest and transported to the laboratory in Porto within 1 hour. Thirty berries per treatment were selected at each harvest for uniformity of color development (between three-quarter and full red) and freedom from defects. The fruit were weighed and placed in cold rooms at 4 or 10C and 90 to 95% relative humidity (RH) for 1 hour in order for them to reach the desired temperature before further treatment.

In the first experiment, the strawberries were stored in air or 5% O₂ + 15% CO₂. In the second experiment, the CA was 10% O₂ + 20% CO₂. For both experiments, the storage temperatures were 4 and 10C, and the RH in the rooms was maintained at 90 to 95%. Each experiment was repeated once with fruit from subsequent harvests. Air-treated samples were held in uncovered jars at the ambient RH of the rooms. The CA mixtures were obtained by mixing nitrogen, air and CO₂ from pressurized cylinders and the gas mixtures were distributed uniformly into three replicate jars per treatment, each jar containing 10 fruit. The gas mixtures were humidified prior to entering the containers by bubbling through a container with water, which maintained the RH at about 95%. The gas composition was analyzed daily by sampling from the inlet port of the containers. The O₂ and CO₂ concentrations were determined using a Shimadzu Gas Chromatograph Chromatopac C-R6A (Shimadzu Europa GmbH, Germany) equipped with a TCD detector and 3 m x 0.32 cm column packed with Carbosieve SII, 80/100 mesh (Supelco). The flow rate of the carrier gas (He) was 30 ml min⁻¹. The injection and detector temperatures were set at 120 and 210C, respectively. The temperature of the column oven was programmed for 40C for 6 min and subsequently for 15C min⁻¹ to 170C and hold for 5 min.

After one week storage, the strawberries from the air and CA treatments were transferred to the laboratory at room temperature (20 ± 2C) and held for 1 day in uncovered jars to simulate a retail display period. All measurements of physical and chemical quality attributes were conducted after the total storage period of 7 days at 4 or 10C plus 1 day at 20C.

**Weight loss.** Weight loss was calculated from the weight of the 30 individual berries per treatment measured before and after storage. Concentrations of chemical constituents were expressed in terms of both fresh and dry weight in order to show the actual concentrations of the chemical constituents in the stored strawberries as well as any differences between treatments that were obscured by differences in water content. The dry weight was determined by drying a weighed aliquot of homogenized fruit tissue representing each of the three, 10-berry replicates per treatment at 70C for six days and reweighing.

**Color assessment.** Surface color of each fruit was measured after storage with a hand-held tristimulus reflectance colorimeter (Minolta CR-300, Minolta Corp., Ramsey, New Jersey, USA). Color was recorded using the CIE-L*a*b* uniform color space, where L* indicates lightness, a* indicates chromaticity on a green (-) to red (+) axis, and b* chromaticity on a blue (-) to yellow (+) axis. Numerical values of a* and b* were converted into hue angle (H° = tan⁻¹ b*/a*) and chroma [Chroma = (a*² + b*²)⁻¹/²]. The L* value is a useful indicator of darkening during storage, either from oxidative browning reactions or increasing pigment concentrations. The a* value is a measure of redness and is highly correlated with anthocyanin concentration in strawberries. The H° is an angle in a color wheel of 360°, with 0, 90, 180 and 270° representing the hues red - purple, yellow, bluish - green and blue, respectively, while chroma is the intensity or purity of the hue. Together, L*, H° and chroma give an accurate description of the surface color of a sample.

**Firmness measurements.** Firmness was measured by compression (3 mm deformation) at the equatorial part of the strawberry fruit with an Instron Universal Testing Instrument (Model 4501, Instron Corp., Canton, Ohio, USA). A 100 Newton (N) load cell was used for the firmness determination of fruits. Crosshead speed was 100 mm min⁻¹. A 12 mm diameter convex tip probe was used. This test measured strawberry firmness based on the resistance of the fruit flesh to deformation by the probe. Results were expressed in N (Kader, 1982).

**Soluble solids.** Three replicate samples of 10 berries per treatment were homogenized in a laboratory blender at high speed for 2 min. The homogenates were centrifuged at 800 x g for 30 min, filtered through cheesecloth, and the soluble solids content (SSC) of the resulting clear juice samples was determined at 20C with a hand held Atago refractometer model ATCl. Soluble solids content was expressed in terms of fresh and dry weight.

**Titratable acidity and pH.** The pH of the juice was determined using a Crison MicroPH 2002 pH meter (Crison Instruments, S.A., Barcelona, Spain) using a xerolyte electrode Ingold, which had been previously standardized to pH 4 and pH 7. Aliquots (6.00 g) of juice were diluted with 100 ml distilled water. The titratable acidity was determined by titration with 0.1 N NaOH to an end point of pH 8.1. The results were calculated as percent citric acid [(ml 0.1 N NaOH x 0.064 x 6.00 g (juice) x 100)], and expressed in terms of fresh and dry weight.

**Ascorbic acid.** A 5-g subsample of homogenized fruit tissue from each of the three, 10-berry samples per treatment was combined with 100 ml of a mixture of 6% metaphosphoric acid in 2 N acetic acid for total ascorbic acid analysis. The fruit-acid mixtures were centrifuged for 20 min at 5000 x g. The analysis was performed by the dinitrophenylhydrazine method of Terada et al. (1978). The concentration of the total ascorbic acid was calculated per 100 g of fresh and dry weight of tissue using a standard curve for absorbance measured at 540 nm.

**Statistical analysis.** The experiment was set up as an incomplete block design with each of the two CA treatments com-

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pared to air storage in two of the four harvests. Overall treatment means were compared by the Least Significant Difference (LSD) test at \( P = 0.05 \), and Analysis of Variance (ANOVA) was used to determine the effects of harvest date, storage temperature and atmosphere. The Statistical Analysis System computer package (SAS Institute, Inc., 1982) was used for analysis of the data.

**Results and Discussion**

_Harvest effects._ There was significant variability due to the harvest date in every attribute of the strawberries that was measured (Tables 1 and 2). The strawberries tended to lose more weight in storage and to be softer after the first harvest (Table 1). The color of the strawberries changed slightly during the course of the season, from a bright, pure red to a darker, more reddish-blue hue (Table 1). The pH of the strawberries increased over the first three harvests then decreased at the last harvest, but the TA (DW basis - see below for discussion) decreased and levelled off after the first harvest based on DW measurements, while ascorbic acid levels generally increased. Since we did not evaluate the strawberries at the time of harvest, it is not possible to determine if the differences between the harvests were due to differences in the initial condition of the fruit or to changes in their behavior during storage.

_Weight loss._ Overall, weight loss was greater in strawberries stored in air than CA storage for all the harvests. Although there were no significant differences in weight loss between air storage at 4 and 10C, strawberries stored in CA at 10C lost more weight than those stored in CA at 4C (Table 1). The greater weight loss observed during air storage in this study could have been because the jars containing the fruit stored in air were not covered, despite the room RH levels being similar to those in the CA containers. Controlled atmospheres do not directly contribute to water loss of fruit during storage, but the need for a closed container in order to maintain the gas composition might have resulted in reduced air movement and higher RH surrounding the CA fruits, and consequently reduced water loss compared to air storage (Kader, 1986). However, some other researchers have reported greater weight loss in CA. For example, Roelofs and Waart (1993) reported greater weight loss of red currants stored in CA compared to air storage at 1C. Greater weight loss during CA storage might, in some cases, be caused by the dry conditions of the pressurized gases used to create the CA.

_Firmness._ The strawberries stored in CA at 4 or 10C were consistently firmer than those stored in air (Table 1). However, CA storage did not seem to delay softening as effectively at the higher temperature since the strawberries stored in CA at 4C were firmer than those at 10C (Table 1). The results obtained in this study are in agreement with other studies, which have generally reported that berries stored in CA are firmer than those stored in air (Harris and Harvey, 1973; Li and Kader, 1989; Ke and Kader, 1989; Ke et al., 1991; Smith and Skog, 1992; Smith, 1992; Picón et al., 1993; Larsen and Watkins, 1995a; Larsen and Watkins, 1995b). It has also been reported

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<sup>a</sup>Mean separation within columns by LSD, \( P = 0.05 \), \( n = 30 \).

<sup>b</sup>Main effects and interactions not significant (ns) or significant (*) at \( P = 0.05 \) by ANOVA (F test).

that berries maintained their firmness for about 12 hours after transfer from CA to air (Li and Kader, 1989; Larsen and Watkins, 1995b). Some of these authors have even reported that strawberry firmness is higher after CA storage when compared to initial samples (Smith and Skog, 1992; Smith, 1992; Picón et al., 1993). However, Smith and Skog (1992) reported that cultivars react differently to high CO2 storage, and found that 'Chandler' berries (as used in our study) stored in 15% CO2 at 0°C for 42 hr were not significantly firmer than the initial samples.

The relatively high storage temperatures used in this study might have contributed to a decrease in firmness that was not avoided by the increase in CO2. Smith (1992) found that the increase in firmness with increasing CO2 levels that he observed in 'Redcoat' strawberries was higher at 0°C than at 21°C. While Smith (1992) and others who have reported that strawberry firmness increases during storage in elevated CO2 atmospheres measured the biophysial point of the fruit, we have found that biophysial point measurements can lead to erroneous results (Nunes et al., 1995). When firmness of strawberries was measured as the biophysial point, our results suggested that the berries that lost more water were firmer than those with lower water loss. However, these results appeared to be due to toughening of the epidermis as a consequence of water loss rather than retention of flesh firmness. The force required for 3 mm deformation seemed to be more accurate in measuring the true firmness of the strawberries (Nunes et al., 1995). Since water loss was less in CA than air storage in the present study, the higher firmness values we measured in the CA fruit are more likely to be a real effect of the atmosphere treatments.

**Color.** Strawberries stored in CA generally had better color appearance than those stored in air, especially at 4°C. Strawberries stored in 5% O2 + 15% CO2 at 4°C were lighter (higher L* value), more red (higher a* value) and had a more intense color (higher chroma) than either those fruit stored in air at 4°C or in the same atmosphere at 10°C (Table 1). Although no significant differences were noticed in a* and chroma between strawberries from the first harvest stored in 5% O2 + 15% CO2 or air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1). However, fruits stored in 10% O2 + 20% CO2 at 4°C had higher L*, a* and chroma values than at 10°C. The higher b* values of strawberries stored in 5% O2 + 15% CO2 and air at 10°C, those values were higher for strawberries from the third harvest stored in 5% O2 + 15% CO2 (Table 1). Overall, strawberries from the second and fourth harvests stored in 10% O2 + 20% CO2 showed little or no consistent differences in color compared to air treatments except for higher L* and a* values in the 10% O2 + 20% CO2 treatment at 4°C (Table 1).
age at 10C. Chroma was also higher in the strawberries stored at 4C. This could be due either to greater inhibition of ripening at 4C or to more discoloration of the berries during CA storage at the higher temperature.

Ke et al. (1991) reported that storage for 10 days in air + 20% CO2 at 0 or 5C did not significantly affect the color (a-value) of 'Selva' and 'Pajaro' strawberries. However, higher CO2 levels resulted in reduced redness of fruits. Color changes during storage for 10 days at 5C in strawberries harvested full red were not significant when the O2 levels were reduced to 0.25% (Ke and Kader, 1989; Ke et al., 1991). Li and Kader (1989) reported that exposure of 'Selva' strawberries to 0.5% O2 + 20% CO2 for 4 days at 2C retarded reddening of the fruit flesh, but had no significant effect on the skin compared to the air treatments.

**Chemical characteristics.** Overall, strawberries stored in CA had higher pH when compared to those stored in air at either 4 or 10C (Table 2). Ke et al. (1991) and Ke and Kader (1989) reported that low O2 treatments at 0 or 5C did not significantly affect the pH of 'Selva' and 'Pajaro' strawberries, but that high CO2 treatments resulted in higher pH values than those in air. However, Li and Kader (1989) found no significant differences in the pH of 'Selva' strawberries exposed to 0.5% O2, air + 20% CO2 or 0.5% O2 + 20% CO2 at 2C.

The concentrating effect of water loss during storage tended to obscure the changes in SSC in CA, TA and ascorbic acid content when expressed on a fresh weight basis (Table 2). Expressing the SSC, TA and ascorbic acid content on a dry weight basis more clearly showed the actual changes in those constituents. Although the data were expressed in terms of both fresh and dry weight, the following discussion refers only to dry weight data. No significant differences in TA were found for the second harvest between CA and air treatments at 4C, and CA fruit had lower TA than the air control at 10C (Table 2). However, TA of strawberries from the first and third harvests stored in 5% O2 + 15% CO2 at either 4 or 10C were generally higher than the air control, and strawberries from the fourth harvest stored in 10% O2 + 20% CO2 at 4 or 10C also had higher TA than those stored in air (Table 2). When the two CA treatments were compared, 5% O2 + 15% CO2 was more effective than 10% O2 + 20% CO2 in retarding the loss of acidity in strawberries.

Weichman (1986) indicated that higher concentrations of acids are maintained in lower levels of O2 and acid losses are also reduced at low CO2 levels (below 3%), whereas high CO2 concentrations can enhance acid losses. Organic acids are reported to decrease during ripening of fruits (Weichman, 1986), probably due to use as a substrate for respiration. Thus, it appears that CA is generally more effective than air storage in retarding the ripening-associated loss of organic acids. In other studies with strawberries, however, no significant differences in TA have been found between CA and air storage (Ke and Kader, 1989; Li and Kader, 1989; Ke et al., 1991). This may be due to differences in water loss between air and CA storage as discussed above. The 5% O2 + 15% CO2 atmosphere retarded acid losses better than 10% O2 + 20% CO2, probably due to the effect of low O2. Talasila et al. (1992) have shown that strawberry respiration is reduced to a much greater extent by low O2 than by high CO2 levels.

The SSC of the strawberries was consistently higher in CA than in air storage, and fruit from the first and third harvests stored in 5% O2 + 15% CO2 appeared to have higher SSC than those from the second and fourth harvests that were stored in 10% O2 + 20% CO2 (Table 2). However, Ke et al. (1991) reported no changes in SSC of 'Selva' strawberries stored at 0 or 5C in low O2 and high CO2 atmospheres compared to air storage, and El-Kazzaz et al. (1983) also reported no changes in SSC of 'Aiko' strawberries stored in CA at 4C. Since there were also no significant temperature or atmosphere effects in our study when SSC was expressed on a fresh weight basis, while those same factors were significant for SSC expressed on a dry weight basis, it seems likely that differences in water loss between the treatments are responsible for the discrepancy in results.

Several studies have indicated that pH, TA and SSC do not change during low O2 and high CO2 storage of strawberries (El-Kazzaz et al., 1983; Li and Kader, 1989; Ke and Kader, 1989; Brecht et al., 1992). However, Piccin et al. (1993) noticed decreases in these chemical components during low O2 and high CO2 storage of 'Chandler' and 'Douglas' strawberries, and acid content was higher in apples stored in CA compared to low temperature storage alone (Drake, 1993). Results in the present study showed decreases in both TA and SSC in fruits stored in air compared to CA in most cases (Table 2). This observation may be explained by higher respiration rates in air compared to CA with consequently greater depletion of substrate during storage in air.

Li and Kader (1989) and Ke and Kader (1989) reported that CA storage at 2C had no effect on ascorbic acid content of 'Selva' strawberries. However, in this study ascorbic acid was higher in strawberries stored in CA than in air, especially at 4C (Table 2). No significant differences were found in ascorbic acid levels of fruits stored in air or CA at 10C for the first, second and fourth harvests (Table 2). There was also no apparent difference between the effectiveness of 5% O2 + 15% CO2 and 10% O2 + 20% CO2 at 4C in terms of maintaining ascorbic acid levels. Therefore, while CA did seem to retard ascorbic acid degradation during storage, at least at an intermediate temperature of 4C, it is not clear whether the effect was primarily due to the reduced O2 levels or elevated CO2 levels. It could be suggested that the effect of temperature overcame the effect of CA in inhibiting the ascorbic acid degradation at 10C. However, Barth et al. (1993) reported better retention of ascorbic acid in broccoli stored in elevated CO2 (20%) at 10C compared to broccoli stored in air. Several authors have also suggested that the lower the O2 content of the storage atmosphere, the smaller the losses of ascorbic acid, due to inhibition of enzymatic breakdown of ascorbic acid (Weichman, 1986; Kader, 1986; Weichman, 1987; Zagory and Kader, 1989). However, elevated CO2 can accelerate ascorbic acid degradation, and this effect was reported to be temperature, CO2 level and storage time dependent (Zagory and Kader, 1989). So, the ratio of CO2 to O2 in the atmosphere is also important in retarding ascorbic acid losses during storage (Klein, 1987).

**Conclusions**

Controlled atmosphere storage can play an important role in preserving the appearance as well as the nutritional value of strawberries by delaying ripening or senescence of the fruits. Controlled atmosphere storage was more effective than air storage in retaining the physical and chemical quality attributes of strawberries, even at higher than optimum storage temperatures. The benefits of CA storage were greater at 4C than 10C, and an atmosphere of 5% O2 + 15% CO2 main-
tained higher levels of TA, SSC and ascorbic acid than 10% O2 + 20% CO2. These results suggest that O2 and CO2 levels may be adjusted to maximize their beneficial effects on individual quality parameters of strawberries depending on the anticipated temperature during postharvest handling.

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**Literature Cited**


