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Effects of Continuous Application of CO_2 on Fruit Quality Attributes and Shelf Life during Cold Storage in Cherry Tomato

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Abstract

'Unicon' cherry tomato (*Solanum lycopersicum*) is one of the most highly perishable horticultural crops due to its high water content and respiration rate. This study was carried out to assess the effect of continuous application of CO_2 (control [air], 3%, and 5%) on the quality and shelf life of cherry tomato fruits stored at 10°C and 85 ± 5% relative humidity (RH) at two maturity stages (pink and red). Continuous application of CO_2 did not affect the soluble solids content (SSC) or titratable acidity (TA) of the fruit at either maturity stage during storage. However, there was a significant difference among treatments in terms of flesh firmness, cell wall thickness, pectin content, vitamin C content, skin color, lycopene content, weight loss, ethylene production rate, respiration rate, and acetaldehyde and ethanol production. Fruits treated with 5% CO_2 maintained their high quality with regards to vitamin C, skin color (*a**), lycopene content, weight loss, physiological parameters (ethylene production rate, respiration rate, and volatile compounds), flesh firmness, cell wall thickness, and pectin content at both maturity stages compared with 3% CO_2 treatment and the control. Continuous application of CO_2 (5%) reduced the ethylene production rate and the production of volatile compounds during storage. Therefore, cherry tomato 'Unicon' fruit can be stored for two weeks without losing fruit quality at both maturity stages under continuous application of 5% CO_2 as a postharvest treatment.

Additional key words: cell wall thickness, maturity stage, perishable, postharvest, volatile compounds

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Introduction

Tomatoes are consumed broadly throughout the world, and their consumption has recently been shown to have health benefits due to their high phytonutrient contents (Levy and Sharoni, 2004; Hsu et al., 2008). Postharvest recommendations indicate that tomatoes, including cherry tomatoes, should be stored at 10°C or higher to avoid chilling injury (Jimenez and Cantwell, 1996 and Roberts et al., 2002) and that even 10°C may be harmful to tomato flavor (Maul et al., 2000). One of the most characteristic phytonutrients in tomato is lycopene, a carotenoid with a high capacity for reducing the risk of chronic diseases that represents ~80% of the total carotenoid contents in tomato fruit (Rao et al., 1998). Lycopene accounts for

the reddening of tomatoes due to the differentiation of chloroplasts into chromoplasts (Egea et al., 2011). Hence, this carotenoid is fundamental for the nutritional quality and commercial value of this fruit (Dumas et al., 2003).

The storability of apples can be increased by treating fruits with high concentrations of CO_2 for a short period of time. Burg and Burg (1967 and 1969) found that CO_2 functions as a competitive inhibitor of ethylene action. Beyer (1979) reported that such an action is related to ethylene metabolism; CO_2 can affect this metabolism by inhibiting ethylene oxidation. The activity of CO_2 in delaying the aging rate is associated with reduced respiratory movement and a hindrance of the succinic oxidase complex, particularly succinic dehydrogenase (Ranson et al., 1960 and Shipway and Bramlage, 1973). In addition to its respiration - blocking activity, CO_2 at high levels diminishes ethylene evolution in fruits, such as apple, pears, and tomato (Bramlage, et al., 1977; Buescher, 1979; Looney, 1975; Marcellin and Chaves, 1983 and Wang and Mellenthin, 1975). According to Farber (1991), the optimum conditions for modified atmosphere packaging (MAP) storage of fruits and vegetables are 3 - 8% CO_2 and 2 - 5% O_2.

Due to the low storability of cherry tomato fruit, many studies have focused on designing various practical approaches for extending the storage period, including controlled atmosphere (CA) storage. Short - term exposure of tomato fruit to 80% CO_2 stimulates the ethylene biosynthetic pathway due to the inhibition of the ripening process (Hirofumi et al., 1998). Treatment with 60% CO_2 for 24 hr reduced ethylene production in tomato fruit, but it sharply increased immediately after the CO_2 treatment. Surface blemishes, increased softening, and uneven ripening were also observed in fruits after removal from elevated CO_2 levels (Kubo et al., 1990 and Morris, 1977). However, no studies have investigated the effects of continuous application of CO_2 at low temperature on fruit quality attributes and shelf life in cherry tomato. Maintaining fruit quality and adding commercial value will benefit both producers and consumers. Tomato fruit is perishable, chilling sensitive, and easily affected by numerous fungal diseases (Hoeberichts et al., 2002). In addition, tomato fruit has a short shelf life due to its high water content, and its climacteric nature leads to ethylene production and a high respiration rate after harvest. Therefore, in the current study, we examined the effects of continuous application of CO_2 on fruit quality attributes and shelf life in cherry tomato.

Materials and Methods

Plant Material and Treatments

Cherry tomato (*Solanum lycopersicum*) 'Unicon' fruits were harvested at the pink and red maturity stages from a commercial farm in Kangwon Province, Republic of Korea on October 15, 2015. The fruits were immediately transported to the Postharvest Quality Management Laboratory, Department of Horticulture, Kangwon National University in an air-ventilated automobile within 30 min of harvest. Upon arrival, defect-free fruits of uniform color were sorted, washed with cold water, and air-dried for 6 hrs. The sorted fruit were carefully transferred to 0.75 L plastic containers (16 fruits per container) for CO_2 treatment. The treatments were conducted using a continuous application of CO_2 (control [untreated, air], 3%, and 5%) with two maturity stages of fruit (pink and red) in a completely randomized design (CRD). CO_2 was taken from a gas cylinder using a syringe and immediately injected into the container, and the required percentage of CO_2 was confirmed using a handheld PBI Dansensor gas analyzer (CheckMate 9900, Ringsted, Denmark). The treated fruits were stored at 10℃ and 85 ± 5% RH. Evaluations were made on cherry tomato fruit stored in an evaluation room, and data were collected from each treatment at 2-day intervals.

Weight Loss, Flesh Firmness, Surface Color, Titratable Acidity, Soluble Solids Content, Ethylene Production Rate, and Respiration Rate

Weight loss was determined by measuring the fresh weight of fruit and comparing the value to the initial fresh weight. Fresh weight was measured every two days for 15 d, and weight loss was calculated by subtracting fresh weights from the initial weight of the fruit. Flesh firmness was measured using a Rheo meter (model compact-100II, Meschede, Germany) with a maximum force of 10 kg and a 3 mm diameter round stainless steel probe with a flat tip. Surface color (*a** value) was measured on fruits marked along their equator regions, with three readings taken using a Chroma meter (model CR- 400, Minolta Co., Tokyo, Japan). Cherry tomato juice was analyzed for soluble solids content (SSC) using a refractometer (Model-Atago Inc., Tokyo, Japan); the results were expressed in °Brix. Titratable acidity (TA) was analyzed using a DL 22 Food and Beverage Analyzer (Mettler Toledo Ltd., Zurich, Switzerland). Diluted juice (1 mL of juice: 19 mL of water) was titrated with 0.1 N sodium hydroxide and the results were expressed as mg·100 g^{-1} of citric acid. The ethylene production rate was measured using a GC-2010 Shimadzu (Shimadzu Corporation, Tokyo, Japan) fitted with a BP 20 wax column (30 m × 0.25 mm × 0.25 μm) and a flame ionization detector (FID). The detector and injector were operated at 127°C and the oven was set at 50°C. The carrier gas (N) flow rate was 0.67 mL· s^{-1} (Park et al., 2000). The respiration rate was measured with a PBI Dan - sensor (CheckMate 9900, Ringsted, Denmark).

Vitamin C and Lycopene Content, Ethanol and Acetaldehyde Production

Vitamin C was analyzed using high performance liquid chromatography (HPLC) (model: Waters Associates, Milford, MA, USA) through a 717 plus auto sampler using a ZORBAX Eclipse XDB-C_{18} analytical column (4.6 cm × 250 mm × 5 μm, Agilent Co., Torrance, USA), a Waters 600 controller pump, and a Waters 486 tunable absorbance detector at 265 nm. The mobile phase was 1: 9 and 100% MeOH: 0.1 M KH_2PO_4, and the flow rate was 1.0 mL· min^{-1} (Li and Chen, 2001). Frozen fruit tissue (1 g) was mixed with 10 mL of 5% metaphosphoric acid and homogenized using a T25 Ultra-Turrax (IKA Korea. Ltd., Seoul, Republic of Korea) until combined. The mixture was centrifuged at 20,000 rpm for 10 minutes at 4°C and filtered through a 0.45 μm filter membrane. The sample (1 mL) was analyzed by HPLC with three replicates (Kim et al., 2011). The lycopene content of the fruit was analyzed as described, with slight modifications (Fish et al., 2002). Frozen fruit was ground with a mortar and pestle, and 1 g ground sample was homogenized with 1 mL distilled water using a T25 Ultra - Turrax stainless steel blender (IKA Korea. Ltd., Seoul, Republic of Korea). Tubes containing homogenized samples were covered with aluminum foil and placed on ice and combined with 20 mL of hexane - ethanol - acetone (2 : 1 : 1), followed by gentle shaking. The samples were centrifuged at 15,000 rpm for 20 min, followed by the addition of 3 mL distilled water per vial. The samples were agitated for 2 min, incubated at ambient temperature for a few min, and read using a spectrophotometer (Thermo Fisher Scientific, Madison, WI, USA) at 503 nm. Hexane was used as a blank. Ethanol and acetaldehyde were measured using the same procedure used to measure the ethylene production rate.

Cell wall Thickness and Water-soluble Pectin

Cell wall thickness was measured under a scanning electron microscope (SEM, Supra 55VP, Carl Zeiss, Germany) as described by Islam et al. (2016). Water soluble pectin was analyzed based on the protocol of Blumenkrantz and Asoe - Hansen (1973).

Statistical Analysis

Significance tests were conducted by analysis of variance (ANOVA) using SAS Version 9 software (SAS Institute, Cary, NC, USA) and Excel 2010 (Microsoft Co., WA, USA). Mean comparisons were made using least significance difference (LSD) at 5% probability.

Result and Discussion

Weight loss leads to quantitative crop losses, as well as a reduction in quality due to shriveling and wilting, softening of tissue, and a loss of crispness (Kader, 1986). We detected a significant ($p < 0.05$) difference in cherry tomato fruit quality among treatments at both maturity stages (Fig. 1A and B). The highest weight loss was found in the control, followed by 3% CO_2 treatment, while the least weight loss was observed in fruits after 5 days of 5% CO_2 treatment at the pink maturity stage. However, there was no difference between 3% CO_2 and 5% CO_2 treatments until day 13, after which weight loss increased significantly in fruits treated with 3% CO_2. The control fruits at both maturity stages showed more weight loss than the treated fruits due to higher respiration rates and ethylene production (Fig. 3C and D, 4A and B), which in turn resulted in water loss or shrinkage of the fruit surface. These results indicate that the continuous application of 5% CO_2 reduces weight loss in tomato fruit due to reduced ethylene production and respiration during cold storage.

There was significant difference ($p<0.05$) in flesh firmness among treatments at both maturity stages (Fig. 1C and D). Fruits treated with 5% CO_2 were much firmer than those treated with 3% CO_2 and the control at both maturity stages during the entire storage period (Fig. 1C and D). At the red maturity stage, untreated fruit were the softest, followed by fruits under 3% CO_2 treatment and those under 5% CO_2 treatment. At the pink maturity stage, however, there was no significant difference between fruits treated with 3% CO_2 and untreated fruits throughout the storage period. At both maturity stages, fruits treated with 5% CO_2 maintained firmness throughout the storage period. Similarly, Porritt and Meheriuk (1977) reported that treatment with 20 -30% CO_2 at 0°C for two weeks reduced the softening of 'Newton' apple fruit without inducing CO_2 injury. In the current study, 5% CO_2 -treated fruits were firmer than those treated with 3% CO_2 and the control. At the pink maturity stage, flesh firmness was reduced from 9.80 N to 5.48 N and 7.85 N in control and 5% CO_2-treated fruits, respectively. The higher the level of CO_2 treatment, the firmer the flesh and the higher the cell wall thickness. Treatment with 10 to 20% CO_2 for 10 - 14 days reduced the degradation of flesh firmness in 'Golden Delicious' apple fruit (Lau et al., 1977). As the storage period increases, the thickness of the fruit cell wall decreases, along with cell wall breakage (Kashmire and Kader, 1978).

Continuous application of CO_2 treatment significantly ($p<0.05$) affected the surface color change of tomato fruit during cold storage (Fig. 2A and B). Fruit color peaked earlier in untreated fruits than in treated fruits. After 11 days, the color values of control fruits and fruits treated with 3% CO_2 were significantly lower than those of 5% CO_2-treated fruits. Continuous CO_2 application delayed the color change at the pink maturity stage. This result is supported by the finding of Sozzi et al. (1999) that red color developed slowly in tomato fruit at the breaker stage as a result of CO_2 treatment. Aharoni et al. (1989) and Mitcham (1997) also reported that high CO_2 concentrations significantly reduced chlorophyll degradation in green vegetables compared with the untreated control. Similarly, the fruits maintained their red color at the end of storage. Color development in cherry tomatoes at the pink stage began on day 3 and 5 under 3% and 5% CO_2 treatment, respectively. By contrast, color development in untreated fruit began on day 5 and reached its peak on day 7. However, under 3% CO_2 treatment, color development began

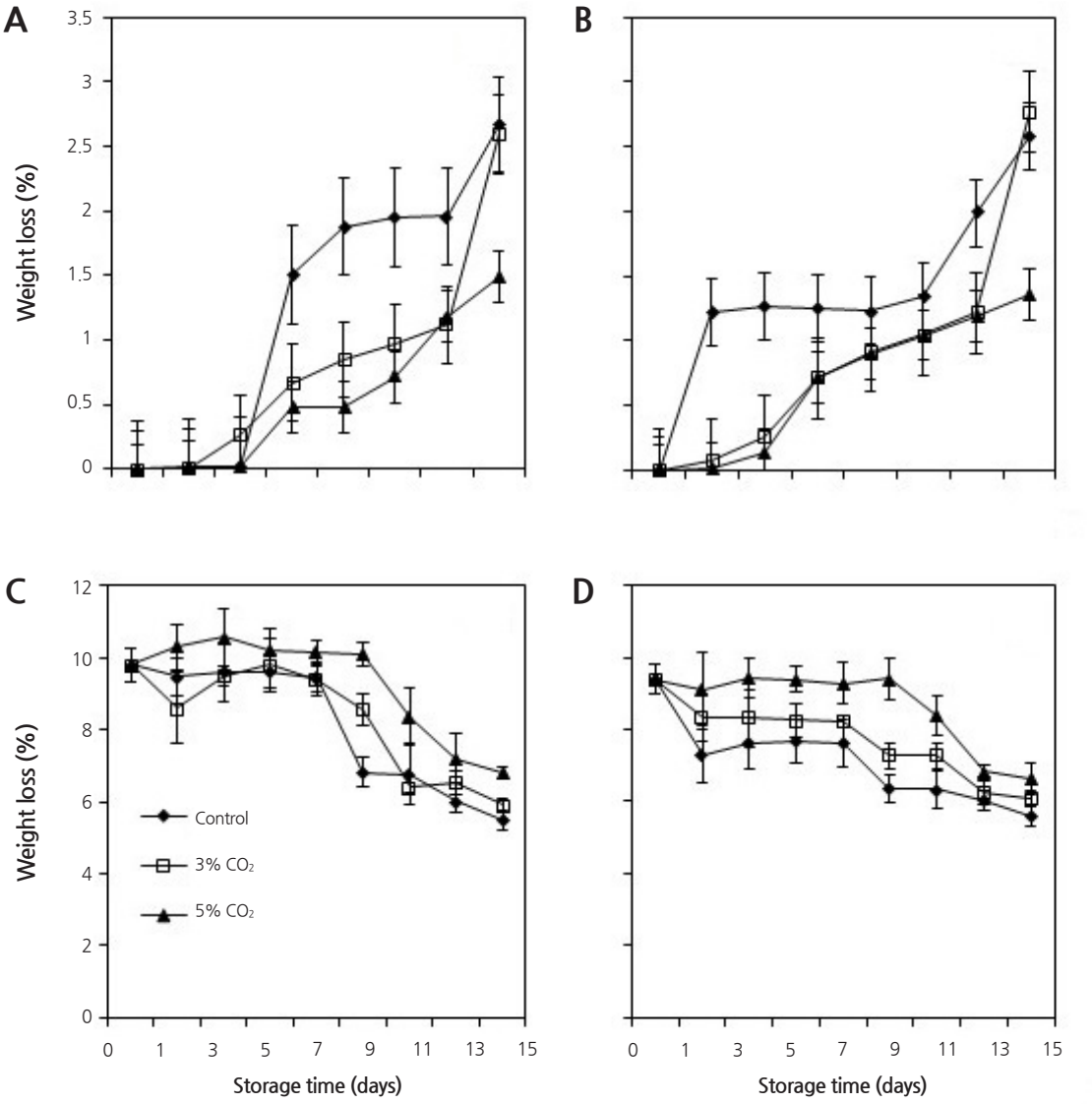

Fig. 1. Effect of continuous application of CO_2 on weight loss and flesh firmness in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A and C=pink and B and D=red maturity stages. Vertical bars represent mean +/- SE (n=5) when larger than the symbols.

earlier than in untreated fruit and increased slowly until it reached a climacteric peak on day 11. Similarly, at the red maturity stage, fruit under 5% CO_2 treatment maintained better color than fruit under control and 3% CO_2 treatment throughout the storage period (Fig. 2B).

There was no significant difference ($p < 0.05$) in titratable acidity among treatments at both maturity stages, although the acidity values of the fruits decreased with increasing storage (Fig. 2C and D). Riquelme et al. (1994) reported that storing strawberries under low O_2 and high CO_2 concentrations did not affect titratable acidity. Similarly, Biale (1960) reported that treatment with 60% CO_2 had no effect on titratable acidity in 'Valencia' orange fruit, whereas storage under high CO_2 levels increased the organic acid contents in lemon. At the pink maturity stage, we detected a decrease in acidity levels from day 3 to day 7 in the control group, which subsequently became similar to those of the other treatments. There was reduction in acidity

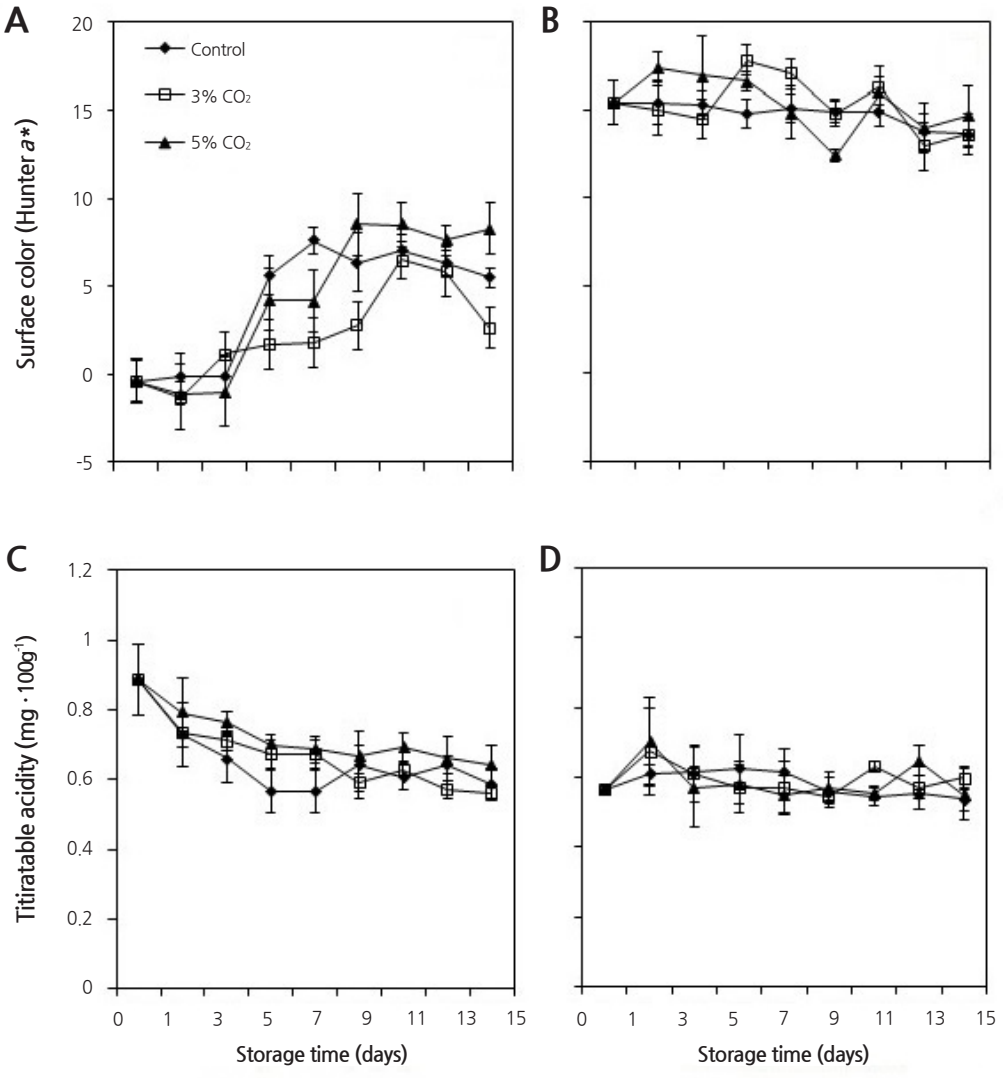

Fig. 2. Effect of continuous application of CO_2 on surface color ($a*$ value) and titratable acidity in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A and C=pink and B and D=red maturity stages. Vertical bars represent mean +/- SE (n = 9 for surface color and n = 5 for titratable acidity) when larger than the symbols.

level from 0.89 mg·100 g^{-1} to 0.59 mg·100 g^{-1} in untreated fruit, from 0.89 mg·100 g^{-1} to 0.57 mg·100 g^{-1} in fruits treated with 3% CO_2, and from 0.89 mg·100 g^{-1} to 0.65 mg·100 g^{-1} in fruits treated with 5% CO_2. This result is in agreement with the findings of Couvey and Olsen (1977).

No significant difference ($p < 0.05$) was observed between treatments with regard to soluble solids content (SSC) at both maturity stages (Fig. 3A and B). Ryall and Pentez (1982) reported that SSC was not affected by CO_2 level or long-term application of CO_2. However, SSC levels showed a decreasing trend on the last day at both maturity stages, which might be associated with utilization of SSC during respiration.

Analysis of variance of the effects of continuous application of CO_2 on ethylene production revealed a significant difference ($p<0.05$) among treatments at both maturity stages (Fig. 3C and D). The ethylene production rate was lower in fruits treated with 5% CO_2 from the beginning of the experiment, followed by 3% CO_2 treatment, compared to untreated fruits at both maturity

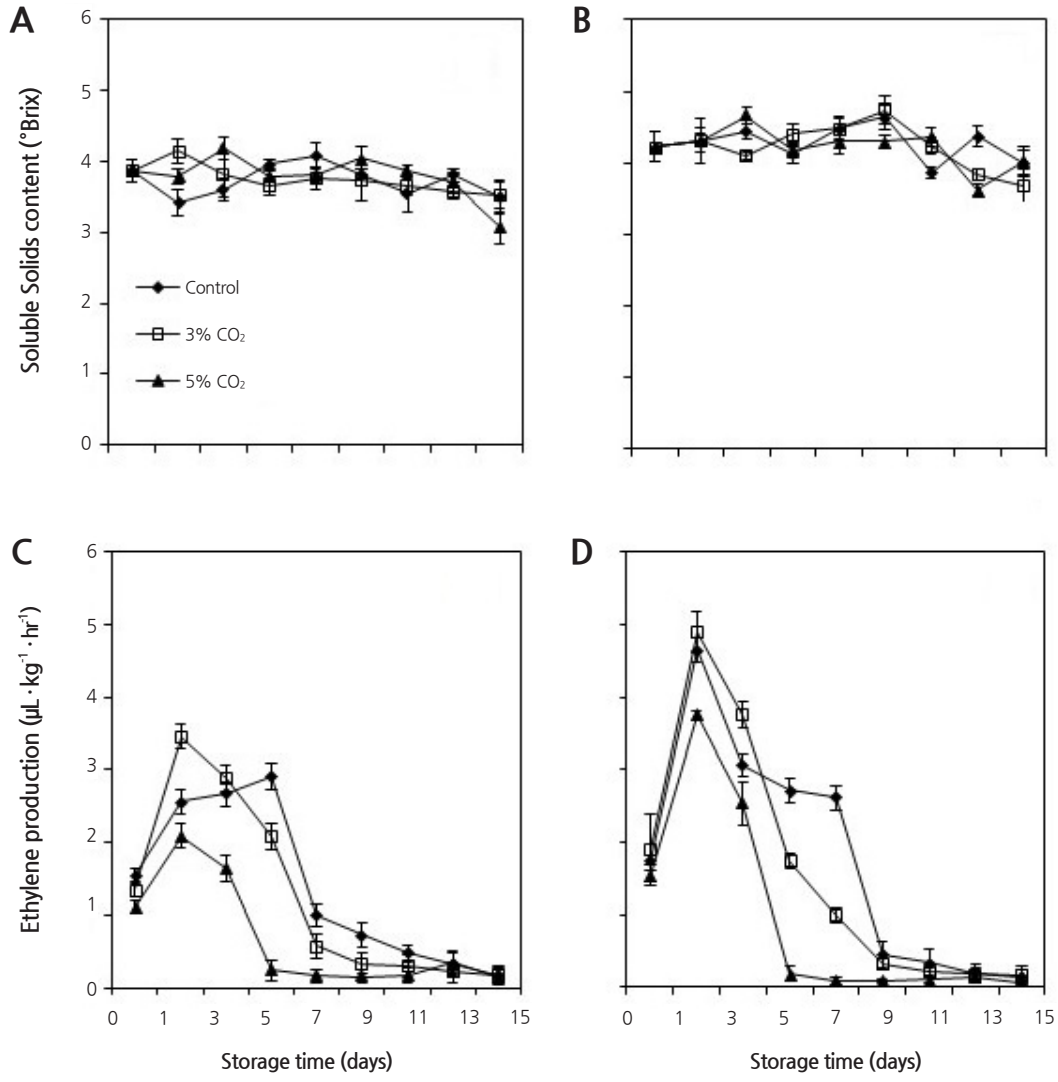

Fig. 3. Effect of continuous application of CO_2 on soluble solids content (SSC) and ethylene production rate in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A and C=pink and B and D=red maturity stages. Vertical bars represent mean +/- SE (*n*=5 for SSC and *n*=3 for ethylene production rate) when larger than the symbols.

stages. These observations are similar to those of Burg and Burg (1967), who detected inhibited ethylene production under CO_2 treatment due to its competitive action, which in turn helps regulate ethylene biosynthesis during storage. Even though all treated fruits at both maturity stages exhibited peak ethylene production on the same day, 5% CO_2-treated fruits produced the lowest ethylene levels, which declined drastically. Indeed, a reduced O_2 uptake rate during high CO_2 treatment, accompanied by inhibited ethylene production, was found to extend the shelf life of tomato fruit (Kubo et al., 1985). At the pink maturity stage, both control and 3% CO_2-treated fruit had a high ethylene production rate until day 5, followed by a slight decrease. A similar trend was observed at the red maturity stage as well. The respiration rate was lower under 5% CO_2 treatment compared with 3% CO_2 and the control throughout the entire storage period, regardless of fruit maturity (Fig. 4A and B). The respiration rate reached its peak on day 1 in all treatments. Even though the respiration rate decreased after day 1 under all treatments, the rate of reduction was higher under control and 3% CO_2 treatments than under 5% CO_2 treatment throughout the experimental period.

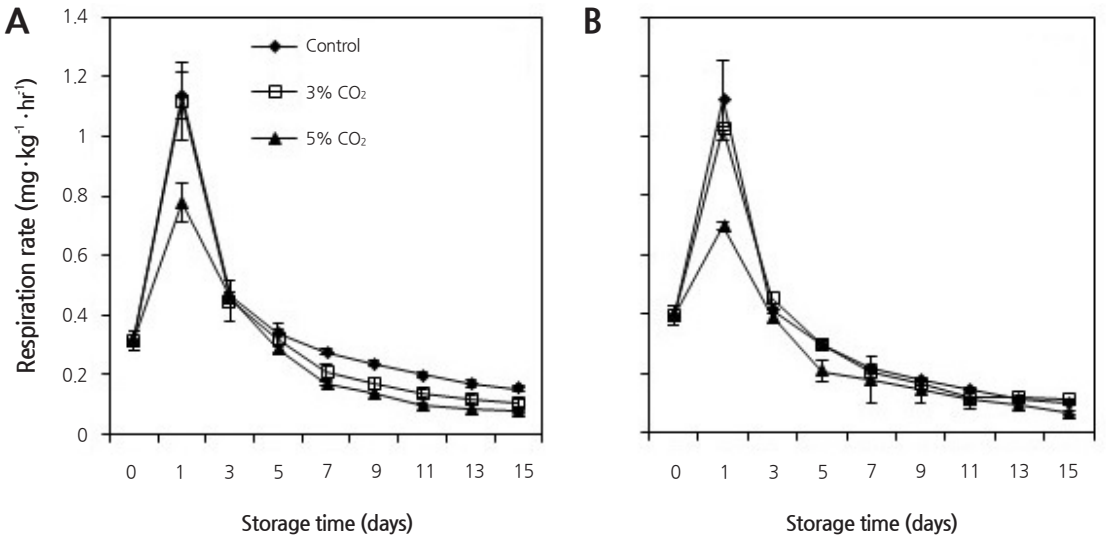

Fig. 4. Effect of continuous application of CO_2 on respiration rate in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A=pink and B=red maturity stages. Vertical bars represent mean +/- SE (n=3) when larger than the symbols.

This result is in agreement with the findings of Kader (1986), who detected reduced respiration rates due to elevated CO_2 concentrations, which is responsible for changes in the activities of various enzymes that hasten fruit ripening and senescence.

There was a significant difference ($p<0.05$) in vitamin C content among treatments at both maturity stages (Fig. 5A and B). Continuous application of 5% CO_2 delayed the decrease in vitamin C content for 7 days at the pink maturity stage. The vitamin C contents of fruits under 3% CO_2 and control treatment were higher than those of 5% CO_2-treated fruits on day 1 at the pink maturity stage. Subsequently, vitamin C levels decreased in both 3% CO_2-treated and control fruits at the end of storage at both maturity stages. This result indicates that as fruit ripening advances, organic acid contents decline. Similarly, Islam et al. (1996) detected increased ascorbic acid contents in tomato fruit with increasing maturity, with high concentrations of vitamin C found at the pink maturity stage, followed by a slight decrease when the fruits reached the red maturity stage. As shown in Fig. 5B, vitamin C contents were maintained under 5% CO_2 treatment compared with the control and 3% CO_2 treatment throughout the storage period. At the end of storage, the highest vitamin C content (31.78 mg·100 g^{-1} and 30.06 mg·100 g^{-1} at both maturity stages, respectively) was found in fruit treated with 5% CO_2. At both maturity stages, vitamin C levels remained stable in fruit treated with 5% CO_2 compared to 3% CO_2 and the control throughout the storage period. These results indicate that the rate of vitamin C loss was lower in the 5% CO_2-treated group than in the 3% CO_2-treated and control groups at both maturity stages throughout the entire storage period (Fig. 5A and B). Vitamin C is generally considered to be a good indicator of nutritional quality during the processing and storage of fruits; if vitamin C levels are well maintained, the other fruit quality parameters are also well maintained (Uddin et al., 2002).

There was significant difference ($p<0.05$) in lycopene biosynthesis and/or content among treatments at both maturity stages (Fig. 5C and D). At the pink maturity stage, the lycopene contents at harvest were similar for all treatments but increased over time until reaching a peak on day 7 (24.96 mg·kg^{-1}) and day 11 (23.68 mg·kg^{-1}) after control and 3% CO_2 treatment, respectively. Similarly, in 5% CO_2-treated fruit at the pink maturity stage, lycopene contents increased from 6.65 mg·kg^{-1} on day 1 to 20.65 mg·kg^{-1} on day 15 (Fig. 5C). At the red maturity stage, no significant change in lycopene content was observed under any

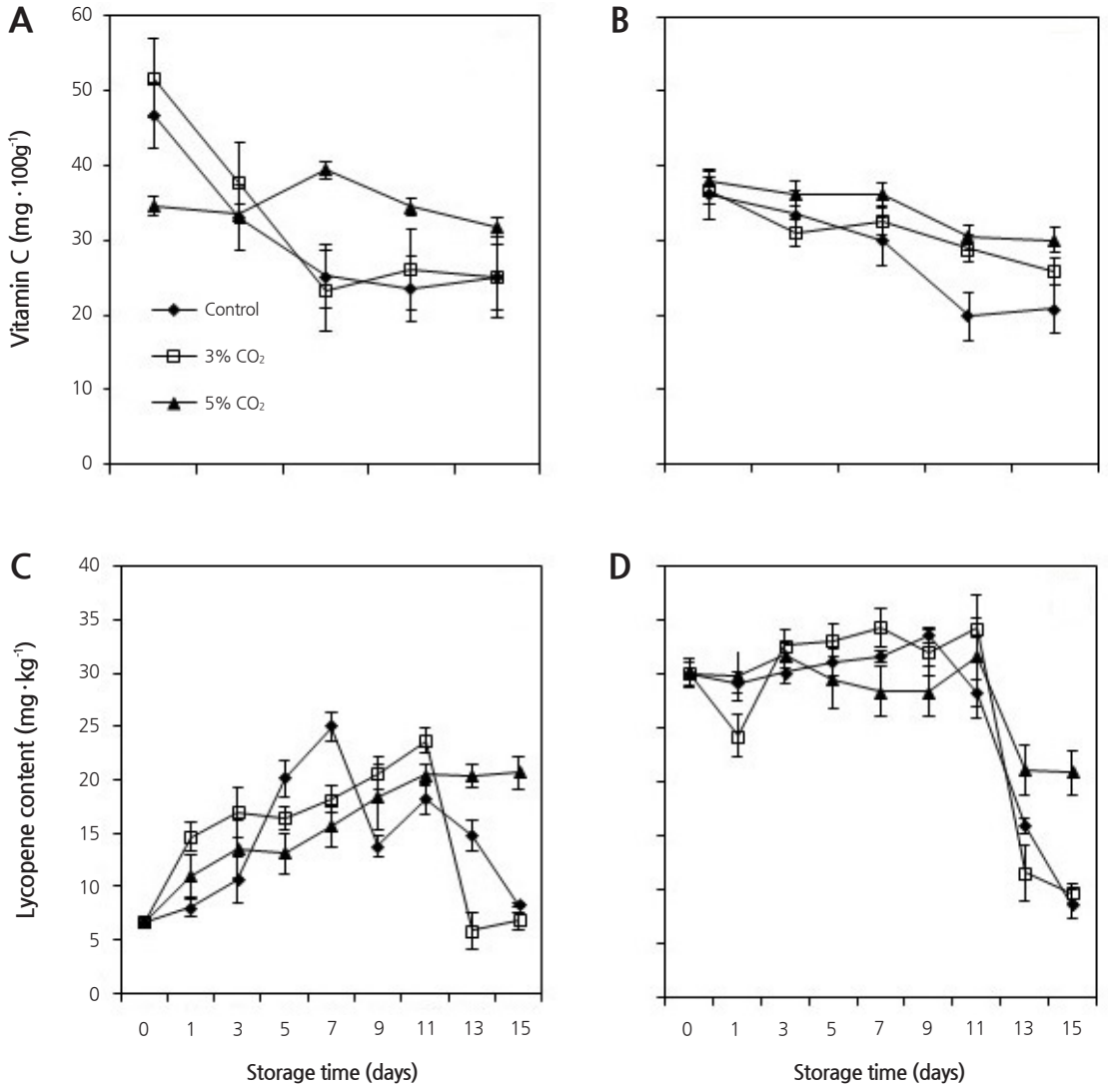

Fig. 5. Effect of continuous application of CO_2 on vitamin C and lycopene contents in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A=pink and B=red maturity stages. Vertical bars represent mean +/- SE (n=3) when larger than the symbols.

treatment until day 11 of storage. The lycopene content strongly decreased from 28.31 mg·kg^{-1} on day 11 to 8.65 mg·kg^{-1} on day 15 and from 28.31 mg·kg^{-1} on day 11 to 9.72 mg·kg^{-1} on day 15 in control and 3% CO_2-treated fruit, respectively, whereas the lycopene content under 5% CO_2 treatment decreased only slightly during this period, from 30.11 mg· kg^{-1} on day 11 to 20.88 mg·kg^{-1} on day 15. Untreated fruit showed an immediate decline at both pink and red stages. Therefore, treatment with high levels of CO_2 (5%) delayed the formation of lycopene and/or maintained the lycopene content at the end of the storage period. Similarly, Sozzi et al. (1999) reported a delay in total carotenoid and lycopene biosynthesis under elevated CO_2 levels.

Volatile compounds, such as acetaldehyde and ethanol, were affected by the continuous application of CO_2 at both maturity stages. We detected very low levels of ethanol formation in cherry tomato fruit during cold storage under all treatments regardless of fruit maturity (Fig. 6A and B). After day 9, ethanol levels in fruits in the control group were lower than those of fruits treated with 3% and 5% CO_2 at the pink maturity stage. Acetaldehyde formation was affected by the continuous application

of CO_2 (Fig. 6C and D). The rate of acetaldehyde formation was low until day 1 for all treatments at both maturity stages, after which the levels of this compound in the control and 3% CO_2 treatment groups increased up to day 5 and then decreased slowly at the pink maturity stage. By contrast, at the red maturity stage, acetaldehyde levels in control and 3% CO_2-treated fruits decreased after day 3. Irrespective of fruit maturity, acetaldehyde formation decreased after a few days under all treatments. These results indicate that fruit ripening leads to the increased production of volatiles, such as ethanol and acetaldehyde, in fruits stored for long periods of time without anti-aging postharvest treatment. Indeed, Janes and Frenkel (1978) and Nanos et al. (1992) found that fruits such as pear and strawberry produce ethanol and acetaldehyde when they are allowed to ripen.

There was significant difference ($p<0.05$) in cell wall thickness among treatments at both maturity stages (Fig. 9A, B, C, D, E, and F). Cell wall thickness decreased with increasing storage at both maturity stages, except for fruits treated with CO_2. At both maturity stages, we detected rapid degradation of cell wall thickness (outer, middle, and inner) in the control, followed by 3% CO_2 treatment, throughout the storage period. Fruits treated with 5% CO_2 appeared more compact than the other fruits at both maturity stages (Fig. 7 and 8). These results are in agreement with the finding that 5% CO_2 treatment affects the activities of enzymes, such as polygalacturonase (PG) and pectin methyl esterase (PME), which are responsible for fruit softening during storage (Goulao and Oliveira, 2008).

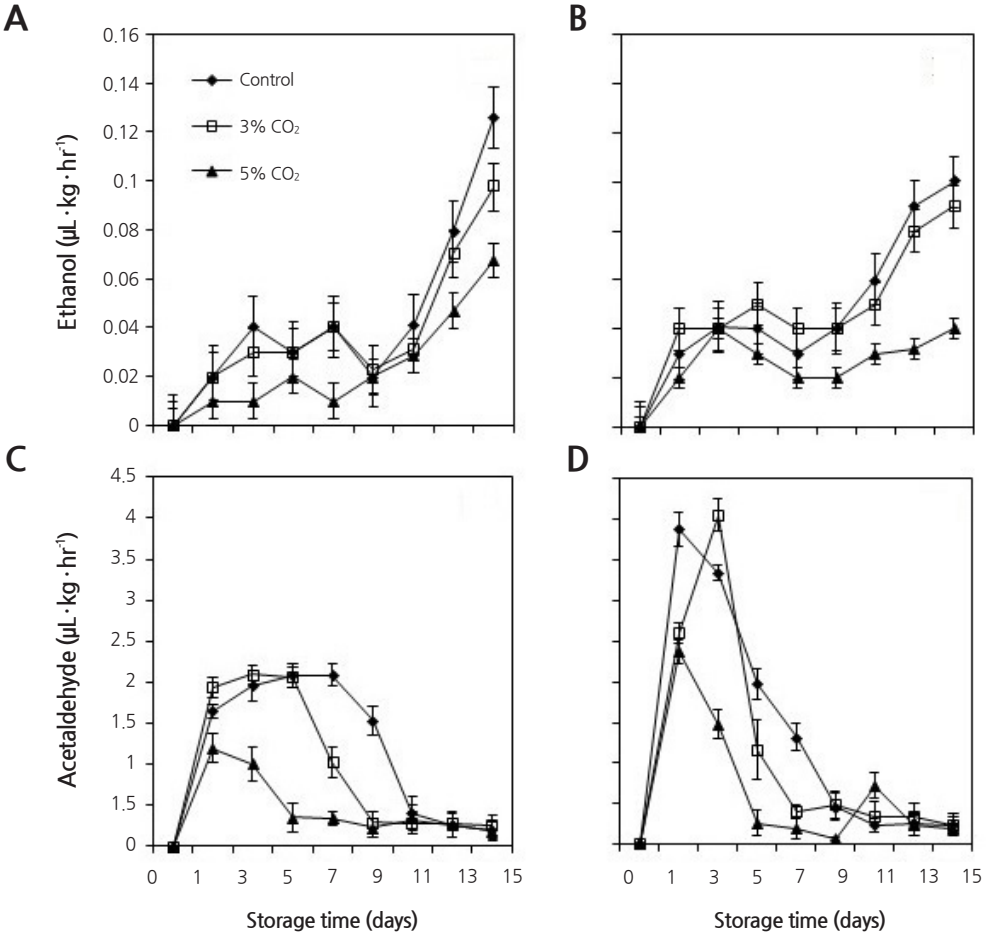

Fig. 6. Effect of continuous application of CO_2 on ethanol and acetaldehyde production in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A and C=pink and B and D=red maturity stages. Vertical bars represent mean +/- SE (n=3) when larger than the symbols.

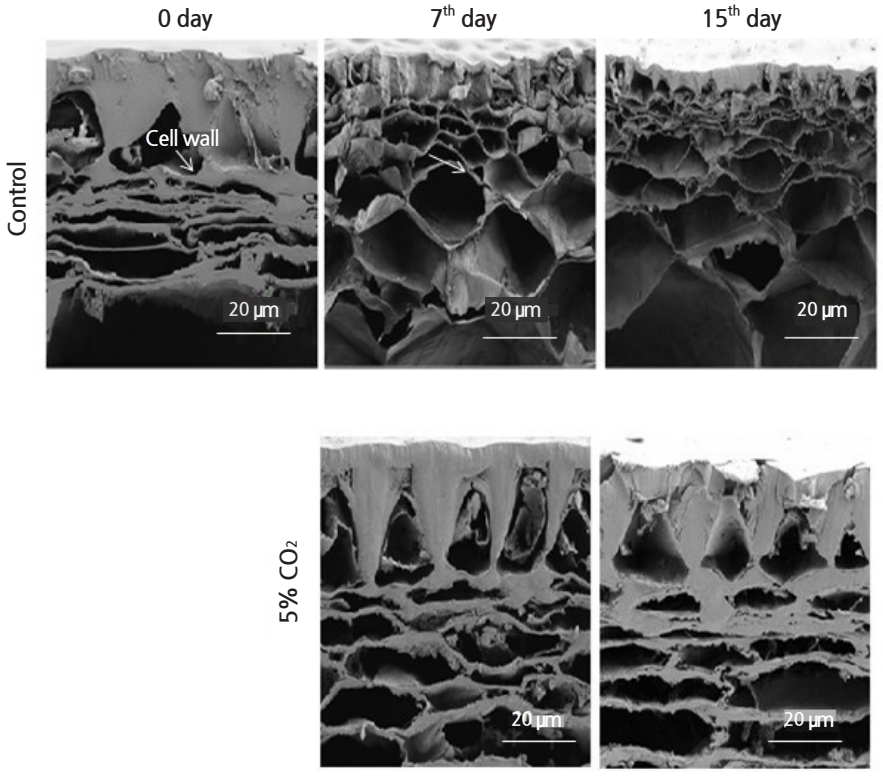

Fig. 7. Effect of continuous application of CO_2 on cell wall thickness in 'Unicon' cherry tomato fruit at the pink maturity stage.

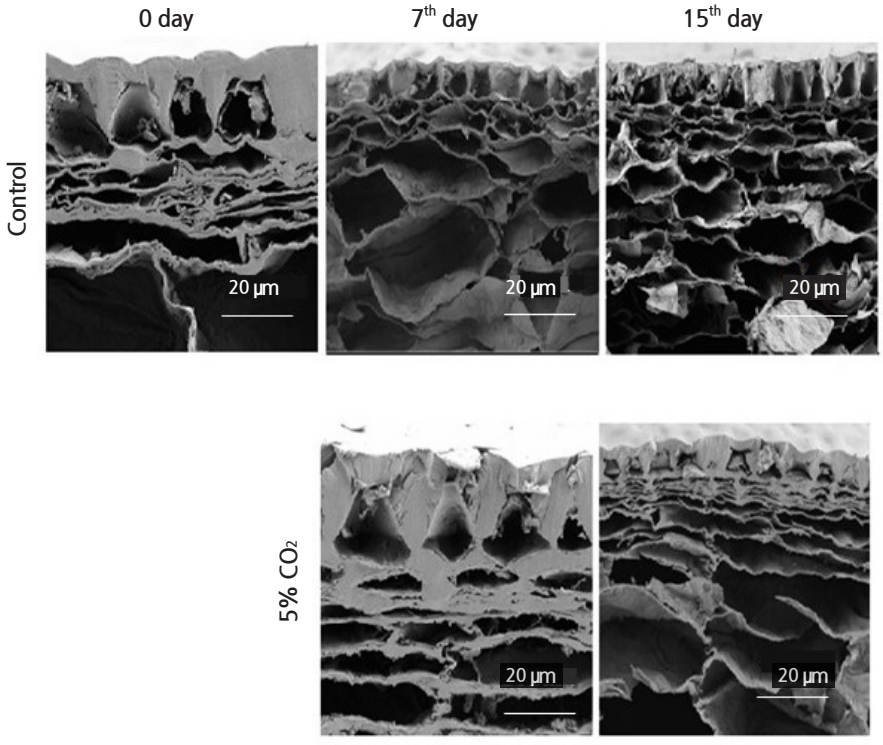

Fig. 8. Effect of continuous application of CO_2 on cell wall thickness in 'Unicon' cherry tomato fruit at the red maturity stage.

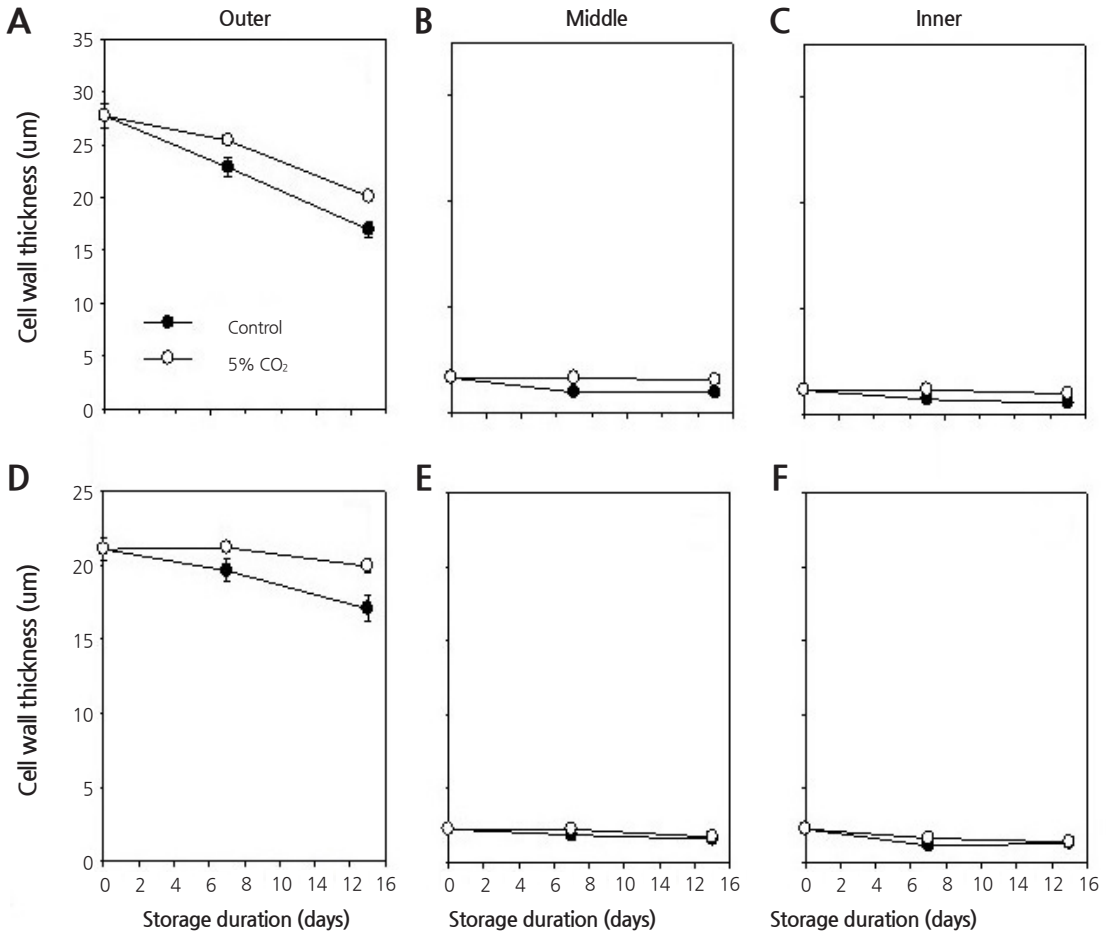

Fig. 9. Effect of continuous application of CO_2 on cell wall thickness in the outer (A, D), middle (B, E), and inner (C, F) cortex in 'Unicon' cherry tomato fruit at the pink (A, B, C) and red (D, E, F) maturity stages stored at 10°C for up to 15 days. Vertical bars represent mean +/- SE (n=3) when larger than the symbols.

The continuous application of CO_2 significantly ($p < 0.05$) affected water-soluble pectin contents at both maturity stages (Fig. 10A and B). Water-soluble pectin levels increased more rapidly in control fruit than in CO_2-treated fruit at both maturity stages. At the pink maturity stage, water-soluble pectin levels increased from 40 mg·kg^{-1} to 70 mg·kg^{-1} and from 40 mg·kg^{-1} to 60 mg·kg^{-1} in control and 3% CO_2-treated fruits, respectively. However, 5% CO_2 treatment reduced the rate of solubilization of pectin at both maturity stages compared with the control and 3% CO_2 treatments. Treating fruits with high CO_2 levels delayed the onset of the climacteric rise and prolonged tomato fruit ripening, resulting in delayed fruit softening. This result is in agreement with the finding of Wills et al. (1981) that elevated CO_2 levels reduce the breakdown of pectic substances responsible for maintaining a firm texture in fruit for a long period of time.

Based on the overall results, we concluded that 'Unicon' cherry tomato fruit can be stored for 15 days at 10°C under continuous application of 5% CO_2, compared to 3% CO_2 and control fruits. To obtain the best surface color quality, along with an acceptable texture and other tomato quality parameters, we recommend the continuous application of 5% CO_2 as a postharvest treatment during storage..

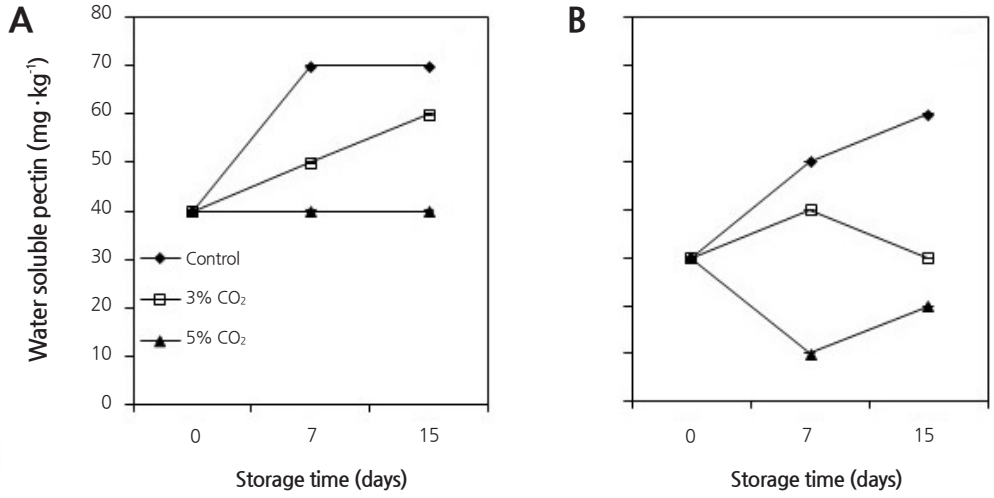

Fig. 10. Effect of continuous application of CO_2 on water soluble pectin in 'Unicon' cherry tomato fruit at two maturity stages stored at 10°C for up to 15 days. A=pink and B=red maturity stages. Vertical bars represent mean +/- SE (n=3) when larger than the symbols.

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