THE EFFECT OF ETHYLENE IN MAINTAINING QUALITY OF TOMATO SLICES

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Diterima 29 Juni 2008 / Disetujui 14 Juni 2009

ABSTRACT

Processes such as slicing tomato fruits disrupt the plant tissue so the products become more perishable compared with the intact fruit. Ethylene production is stimulated during the slicing of fresh cut tomato slices. Experiments were conducted to investigate if ethylene absorbent and exogenous ethylene influences the quality of tomato slices cv. 'Revolution' during storage at 5°C. In the experiment of ethylene absorbent, experiment was laid out in a completely randomised design. The treatments were plus 10 g and minus ethylene absorbent ($KMnO_4$; Purafil®; 5°C for 12 d). In the experiment of ethylene concentrations, experiment was laid out in a completely randomised design. The treatments were exogenous ethylene concentrations of 0 (control), 0.1, 1 or 10 $\mu L\ L^{-1}$ respectively (5°C for 6 h). In both experiments, the treatments were replicated 5 fold. Results showed that ethylene absorbent resulted in reduced ethylene accumulation, and CO_2 accumulation in enclosed containers, and firmer slices. Ethylene applied 2 days after slicing stimulated the rate of ethylene production, CO_2 production, and produced softer slices during storage. Changes in soluble solids concentration and titratable acidity development were independent of ethylene effects. These experiments showed that ethylene produced by slicing or introduced exogenously had an undesirable effect of accelerating softening of tomato slices.

***Key words**: sliced tomato, ethylene.*

INTRODUCTION

Ethylene is produced in large quantities at the time of ripening in tomato and it is used commercially to ensure uniformity of ripening of intact tomatoes (Louis Russo *et al.,* 1975). Ethylene production is stimulated by various types of mechanical stress, including bruising and cutting (Yang and Hoffman, 1984).

The endogenous plant hormone ethylene stimulates the rate of ripening processes such as colour development and softening (Abeles *et al*., 1992), and is involved in deteriorative changes such as loss of firmness in a number of fruits and vegetables (Saltveit, 1999). This unwanted softening can be induced by ethylene even when produce are stored at low storage temperatures (Watada, 1986). For example, kiwi fruit stored at 0°C softened when a very low level of ethylene (0.03 $\mu L\ L^{-1}$) was present (Arpaia *et al*., 1985). 'McIntosh' apples (Liu, 1977) and 'Cox's Orange Pippin' apples (Knee, 1976) stored at 3.3°C, softened when ethylene was present at the low level of 1 $\mu L\ L^{-1}$.

If fresh-cut fruits is placed in packages, ethylene levels could accumulate and result in undesirable changes in the quality of the slices. One way to overcome this inherent problem might be to introduce an ethylene absorbent within the package. Abe and Watada (1991) showed that ethylene absorbents (such as $KMnO_4$ or the commercial product Purafil®) placed inside packages or impregnated into package films, were effective in reducing the rate of softening in kiwi fruit slices and banana sections. Moreover, exposure to ethylene could also alter the physiological changes of the tissue. Exposure of 'mature green' whole tomato to ethylene has been reported by Mencarelli and Saltveit (1988) to cause ripening but did not significantly increase the rate of ripening (indicated subjectively by ripeness score) of 'mature green' slices stored at 20°C. Recently, Hong and Gross (2000) studied the involvement of ethylene in chilling injury development (indicated by water-soaked areas) of sliced tomatoes at the 'red-ripe' stages of maturity. They found that sliced tomatoes in packages stored at 5°C with high ethylene levels had fewer water-soaked areas than sliced stored in packages with low ethylene levels. However, the work of Mencarelli and Saltveit (1988) and Hong and Gross (2000) did not determine the role of ethylene in quality changes such as softening in sliced tomatoes. Therefore, this study was undertaken to examine the effect of ethylene removal and the effect of ethylene exposure after slicing on quality changes in sliced tomatoes.

METHODOLOGY

Plant materials

The experiments were carried out in the Horticultural Postharvest Laboratory, 'School of Agronomy and Horticultural', The University of Queensland, Australia from January-February 2005. Tomato cv. 'Revolution' was harvested from a Gatton experimental field. Medium sized fruit were chosen with a mean fruit mass of 150 ± 14.62 g, and equatorial and longitudinal dimensions of 68.73 ± 1.56 mm and 65.37 ± 2.36 mm, respectively. 'Turning' maturity fruits with hue value, h° 70 - 90, and firmness 20 ± 0.8 N were selected. A total of 5 slices (each 7 mm-thick) were obtained from each fruit using the commercial slicer (Fasline®, model 919/927, Carol Stream Illionis).

Ethylene treatments and assessments

To determine the effects of ethylene removal on slice quality, porous plastic mesh sachets containing an ethylene absorbent ($KMnO_4$; 10 g Purafil®, Purafil Inc., Doraville, GA, USA) were placed inside the lids of the glass containers prior to sealing. The control jars contained no ethylene absorbent. Five slices from the equatorial regions of a single tomatoes were vertically stacked in sealed 2.2 L glass containers and stored at 5°C for up to 12 days (Abe and Watada, 1991). Measurements made were conducted on cumulative ethylene production and respiration rate (Abe and Watada, 1991; Hong and Gross, 2000), by sealing the lid during the storage time. Additional replicates were prepared for firmness assessments.

To assess the influence of ethylene exposure after slicing, sliced tomatoes were stored in ventilated 2.2 L glass jars at 5°C and then 2 days later, jars with sliced tomatoes were injected with 0.1, 1 or 10 $\mu L\ L^{-1}$ ethylene and held sealed at 5°C for 6 hours. Sliced tomatoes were kept in fresh air before ethylene exposure. After 6 hours of ethylene treatment, the lids were removed and sliced tomatoes were placed vertically stacked in ventilated 1-litre plastic containers (Wu and Abbott, 2002) and stored at 5°C for the remaining storage time up to 12 days.

Assessments and experimental design

Sliced tomatoes were taken from storage and analyzed for ethylene production, respiration rate, soluble solids, titratable acidity and firmness. Head space in jars was sampled and analysed for ethylene by a gas chromatography (Shimadzu model GC-8A fitted with a flame ionisation detector), and for CO_2 concentrations using a Shimadzu model GC-8A gas chromatography fitted with a thermal conductivity detector. Pericarp firmness was determined at a speed 1 mm/sec by measuring the force required for a 4 mm diameter cylindrical probe to penetrate the cut surface 3 mm (Wu and Abbott, 2002). Juice was extracted using a food blender and used for determining soluble solids content by using a digital refractometer Atago Digital Refractometer PR-101 (Fuji, Japan) and titratable acidity by titrating 10 g of juice to pH 8.1 with 0.1 N NaOH.

The ethylene absorbent experiment was laid out in a completely randomised design. The treatments were plus and minus ethylene absorbent ($KMnO_4$; 5°C for 12 d). The ethylene concentrations in experiment was laid out in a completely randomised design. The treatments were exogenous ethylene concentrations of 0 (control), 0.1, 1 or 10 $\mu L\ L^{-1}$ respectively (5°C for 6 h). In both experiments, the treatments were replicated 5 fold. The experiments were repeated twice, and similar results were obtained. Data collected were analysed with analyses of variance and treatments different with least significant different ($LSD_{0.05}$).

RESULTS AND DISCUSSION

Results

Effect of ethylene absorbent

Ethylene absorbent was effective in absorbing most of the endogenously produced ethylene during storage for 12 days at 5°C in sealed containers (Fig. 1A). Without ethylene absorbent, levels of ethylene accumulation in the glass containers gradually increased. Similarly, CO_2 accumulated faster in glass containers without the absorbent than in those with the ethylene absorbent (Fig. 1B). Sliced tomatoes stored in jars with ethylene absorbent were significantly firmer ($p<0.05$) than those in jars without absorbent (Fig. 2). By the end of storage, absorbent-treated sliced tomatoes had lost 12 % of their initial firmness whereas control sliced tomatoes had lost 25 % of their initial firmness.

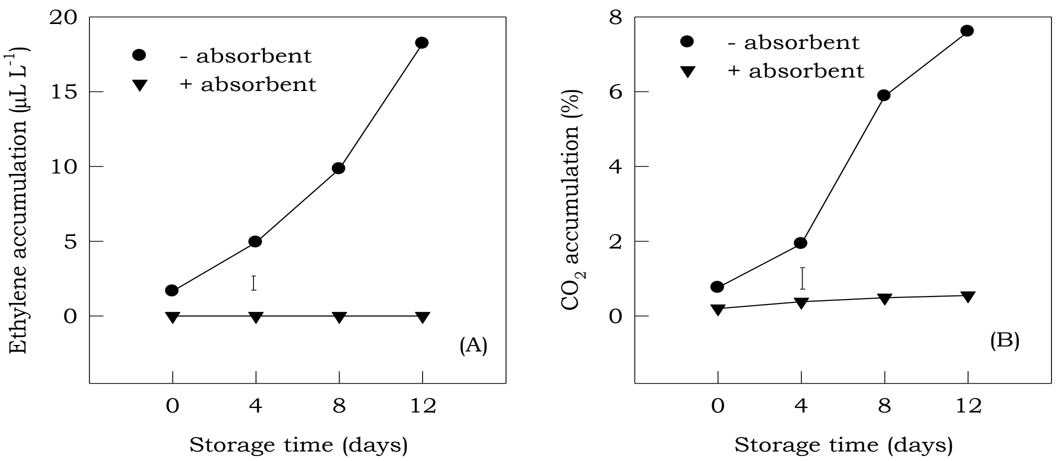

Figure 1 Changes in ethylene accumulation (A) and CO_2 accumulation (B) during storage of sliced tomato treated with or without ethylene absorbent at 5°C. Vertical bars indicate $LSD_{0.05}$.

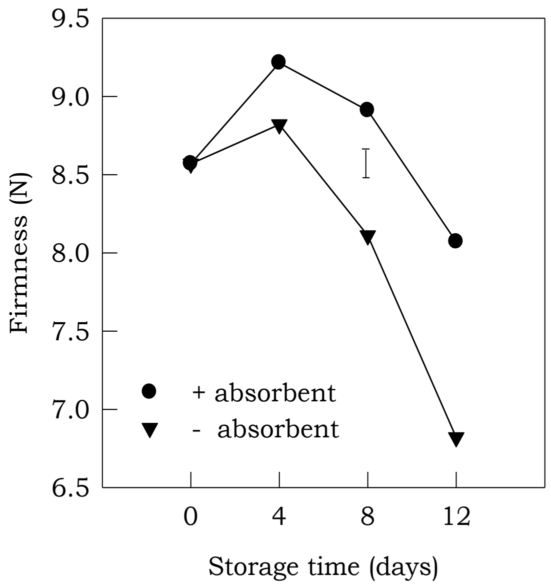

Figure 2 Changes in pericarp firmness during storage of sliced tomatoes treated with or without ethylene absorbent at 5°C. Vertical bars indicate LSD $_{0.05}$.

The ethylene absorbent did not significantly affect (p>0.05) the soluble solids content (Fig. 3A) and titratable acidity (Fig. 3B). Soluble solids content increased until 8 days of storage but titratable acidity steadily decreased over 12 days of storage

Effect of exogenous ethylene

Ethylene treatment after 2 days in storage resulted in an initial increase in the rates of ethylene production (Fig. 4A) and respiration (Fig. 4B) in a concentration-dependent manner. Subsequently, ethylene production decreased until day 9 (Fig. 4A), whereas respiration rate gradually decreased until the end of storage (Fig. 4B). Ethylene production by control slices (in the absence of exogenous ethylene treatment) was not significantly different (p>0.05) from than in slices treated with 0.1 $\mu L\ L^{-1}$, after day 6 (Fig. 4A). With respiration rate, these treatment differences disappeared after day 9 (Fig. 4B). The slices treated with 10 $\mu L\ L^{-1}$ ethylene had the highest rate of ethylene production, although the rate was not significantly different from slices treated with 1.0 and 0.1 $\mu L\ L^{-1}$ ethylene throughout storage (Fig. 4A). Similarly, the slices treated with 10 $\mu L\ L^{-1}$ ethylene had the highest respiration rate, although this was not significantly different from slices treated with 1.0 $\mu L\ L^{-1}$ ethylene until day 6, and with 1.0 and 0.1 $\mu L\ L^{-1}$ ethylene from day 9, of storage (Fig. 4B).

Exposure of sliced tomatoes to ethylene caused a significant loss (p<0.05) of firmness (Fig. 5). When slices were treated with various concentrations of ethylene after 2 days in storage, by day 6 treated slices had lost 20 - 30% of their initial firmness, whereas control slices showed no significant loss. Generally, slices treated with10 $\mu L\ L^{-1}$ ethylene were the softest. Even by day 12, slices not treated with ethylene were still significantly firmer (p<0.05) than those treated with 10 $\mu L\ L^{-1}$ ethylene (Fig. 5).

Ethylene treatment did not significantly affect (p>0.05) the soluble solids contents (Fig. 6A) and titratable acidity (Fig. 6B). Soluble solids were generally constant from day 3 up to day 12 of storage, but titratable acidity gradually declined after day 9.

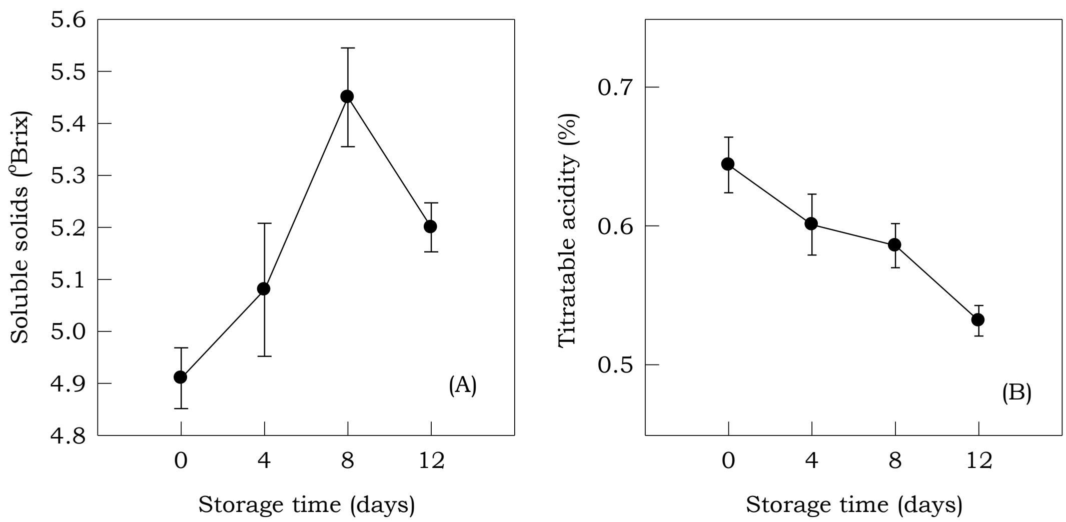

Figure 3 Changes in soluble solids (A) and titratable acidity as % citric acid (B) during storage of sliced tomatoes at 5°C. Vertical bars indicate SEM's, and as there were no differences between treatments, all data are combined.

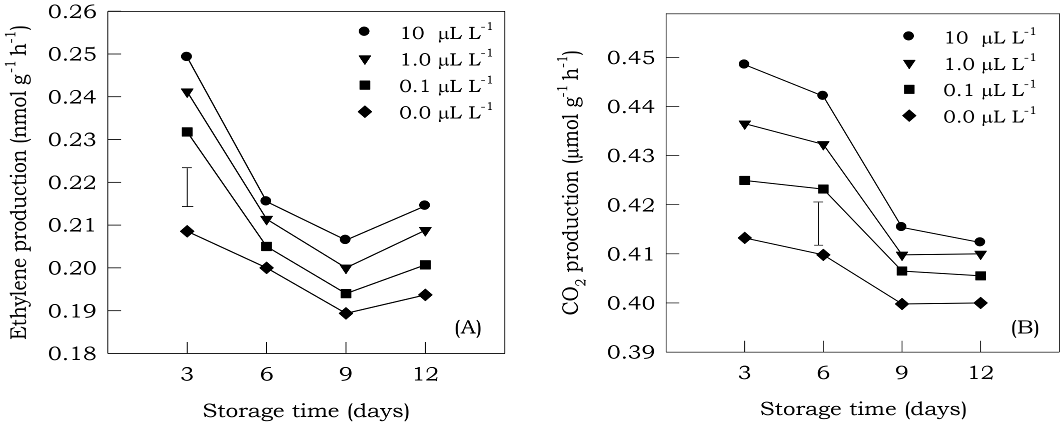

Figure 4 Changes in ethylene production (A) and respiration rate (B) during storage of sliced tomatoes at 5°C following treatment with ethylene (5 °C, 6 h, applied 2 days after slicing). Vertical bars indicate LSD $_{0.05}$.

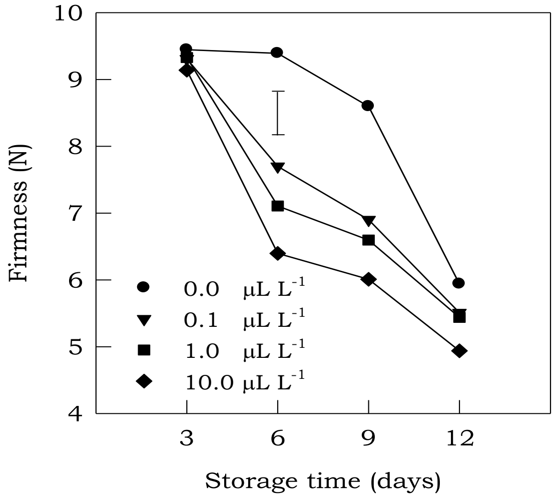

Figure 5 Changes in firmness during storage of sliced tomatoes at 5°C following treatment with ethylene (5°C, 6 h, applied 2 days after slicing). Vertical bar indicates LSD $_{0.05}$.

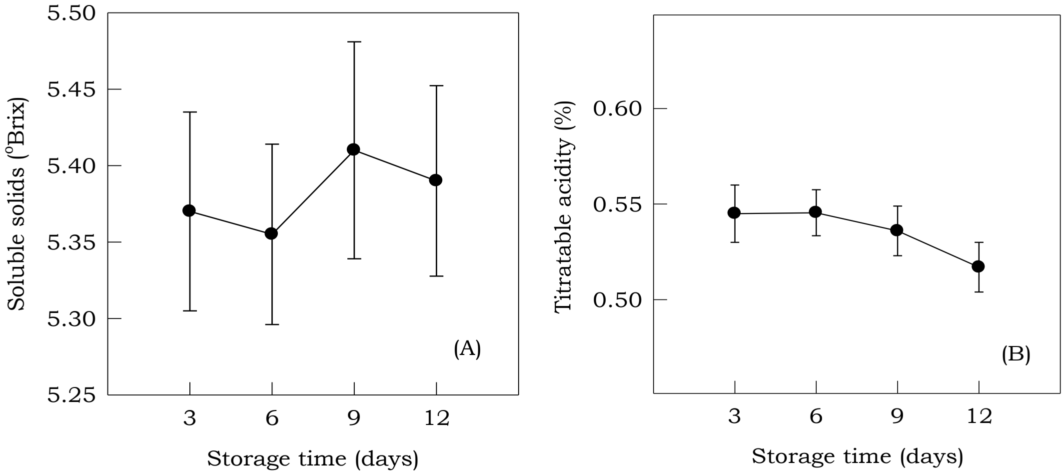

Figure 6 Changes in soluble solids (A) and titratable acidity (as % citric acid, B) following treatment with ethylene (5°C, 6 h, applied 2 days after slicing) during storage of sliced tomatoes at 5°C. Vertical bars indicate SEM's, and as there were no differences between treatments, all data are combined.

Discussion

One strategy to prevent fresh-cut produce from ethylene is by removing ethylene gas from the environment. In this experiment, exposure of sliced tomatoes to ethylene during storage accelerated ripening as indicated by a rapid decline in firmness (Fig. 2). Application of ethylene absorbent could remove this slicing-induced ethylene and therefore assisting in reducing the rate of quality loss.

The ethylene absorbent was effective in absorbing most of the endogenously produced ethylene during 12 days storage at 5°C. The ethylene accumulated during storage was 18 % during 12 days storage (Fig. 1A). This ethylene accumulation was attributed to biosynthesis of ethylene after slicing. As expected, CO_2 accumulated more in containers without ethylene absorbent than in those with the absorbent (Fig. 1B). This is probably due to ethylene stimulating respiration. A maximum level of CO_2 without ethylene absorbent treatment was 7.5% during 12 days storage, whereas when ethylene absorbent was present CO_2 accumulation was 0.6%. The CO_2 concentration recorded in the present experiment was still below the 15 to 20% level of CO_2 that is known to cause injury (Kader, 1986). The reason for the low carbon dioxide levels present in the potassium permanganate treatments is unclear. It may be due to absorption of some carbon dioxide by the absorbent, or simply to lack of ethylene-stimulated respiration.

Pericarp sliced tomatoes softened more rapidly in the containers without the ethylene absorbent than those with the absorbent (Fig. 2). This is because the ethylene resulting from the physical action of slicing, could accelerate deterioration, as also shown by Brecht (1995) with 'mature-green' tomatoes. This suggests that removal of ethylene from the storage environment of fresh-cut products can retard tissue softening. In addition, during the first 4 days of storage, slight increase in tissue firmness (resistance to puncturing) was noted (Fig. 2). This phenomenon could have been the result of tissue suberization, which is a response to wounding in tomato fruit (Dean and Kolattukudy, 1976).

One aspect to consider for storage life extension of fresh-cut products is the maintenance of firmness during storage and distribution. It is well known that softening is one of the ripening processes that is most sensitive to ethylene (Lelievre *et al.*, 1997). Thus, it is likely that loss in firmness will be a practical problem during storage of sliced tomatoes, as indicated by data from these experiments if slices are stored for longer than about 8 days. By this time firmness had dropped to 8 N (Fig. 2), but in the presence of exogenous ethylene, firmness had dropped to 8 N by 5 - 6 days of storage (Fig. 4).

It is well established that ripening of intact tomato fruits is stimulated by exogenous application of ethylene (McGlasson *et al.,* 1978). This principle could also be applied to sliced tomatoes as evidenced by the data from the present experiment. Exposure of sliced tomatoes to exogenous ethylene accelerated ripening of sliced tomatoes as indicated by an acceleration of loss in firmness (Fig 4). This suggests that exogenous ethylene applied during storage has undesirable effects on quality.

Despite the quantitative increase in both ethylene production (Fig. 4A) and respiration rate (Fig. 4B) with increasing ethylene concentration, there were no major changes in soluble solids levels (Fig. 6A) and titratable acidity (Fig. 6B) in slices from all maturity stages. Similarly, ethylene absorbents did not alter the soluble solids level (Fig. 3A) and titratable acidity level (Fig. 3B). These results support the statement by Jeffery *et al.,* (1984) that the metabolism of starch, sugars and organic acids in tomatoes is independent of ethylene.

CONCLUSION

In summary, these experiments have shown that exposure to ethylene either from slicing induced-ethylene or exogenous ethylene promotes undesirable softening. While an ethylene absorbent can remove this slicing-induced ethylene and assist in quality maintenance, exogenous ethylene applied during storage produces further undesirable effects in quality. Removal of ethylene using ethylene absorbent can be an alternative strategy to manipulate the produced ethylene after slicing the tomato.

REFERENCES

Abe K and Watada AE. 1991. Ethylene absorbent to maintain quality of lightly processed fruits and vegetables. *Journal of Food Science* 56:1493-1496.

Abeles F, Morgan P, and Saltveit M. 1992. Fruit ripening, abscission, and post-harvest disorders. *In* "Ethylene in plant biology" (Abeles F, Morgan P and Saltveit M, eds.), pp. 182-221. Academic Press, San Diego.

Arpaia ML, Mitchell FG, Kader AA, and Mayer G. 1985. Effects of 2% O_2 and varying concentrations of CO_2 with or without C_2H_4 on the storage performance of kiwifruit. *Journal of the American Society for Horticultural Science* 110: 200-203.

Brecht JK. 1995. Physiology of lightly processed fruits and vegetables. *HortScience* 30:18-22.

Dean BB, and Kolattukudy PE. 1976. Synthesis of suberin during wound healing in jade leaves, tomato fruit and bean pods. *Plant Physiology* 58 :411-416.

Hong J, and Gross KC. 2000. Involvement of ethylene in development of chilling injury in fresh-cut tomato slices during cold storage. *Journal of the American Society for Horticultural Science* 125:736-741.

Jeffery D, Smith C, Goodenough P, Prosser I, and Grierson D. 1984. Ethylene-independent and ethylene-dependent biochemical changes in ripening tomatoes. *Plant physiology* 74:32-38.

Kader AA. 1986. Biochemical and physiological basis for effects of controlled and modified atmosphere on fruits and vegetables. *Food Technology* 40: 99-100,102-104.

Knee M. 1976. Influence of ethylene on the ripening of stored apples. *Journal of the Science of Food and Agriculture* 27:383-385.

Lelievre J, Latche A, Jones B, Bouzayen M, and Pech J. 1997. Ethylene and fruit ripening. *Physiologia Plantarum* 101:727-739.

Liu FW. 1977. Varietal and maturity difference of apples in response to ethylene in controlled atmosphere storage. *Journal of the American Society for Horticultural Science* 102:93-95.

Louis Russo J, Dougherty RH, Dostal HC, Wilcox GE, and Nelson PE. 1975. Quality of processed tomato products from ethephon-ripened fruit. *In* "HortScience", Vol. 10, pp. 138-139.

McGlasson WB, Wade NL, and Idato I. 1978. Phytohormones and fruit ripening. *In* "Phytohormones and Related Compounds: A Comprehensive Treatise" (Letham DS, Goodwin P B and Higgins TJV, eds.), Vol. II. Elsevier/North Holland, Amsterdam.

Mencarelli F, and Saltveit ME. 1988. Ripening of mature-green tomato fruit slices. *Journal of the American Society for Horticultural Science* 113:742-745.

Saltveit ME. 1999. Effect of ethylene on quality of fresh fruits and vegetables. *Postharvest Biology and Technology* 15:279-292.

Watada AE. 1986. Effects of ethylene on the quality of fruits and vegetables. *Food Technology* 40:82-85.

Wu T, and Abbott JA. 2002. Firmness and force relaxation characteristics of tomatoes stored intact or as slices. *Postharvest Biology and Technology* 24:59-68.

Yang SF, and Hoffman NE. 1984. Ethylene biosynthesis and its regulation in higher plants. *Annual Review of Plant Physiology* 35:55-189.