Improvementof Shelf-Life and Quality in Fresh-Cut Tomato Slices:

Ji Heun Hong
Doosan Biotech BU, PBR Team

1. Maintaining Quality of Fresh-cut Tomato Slices through Modified Atmosphere Packaging and Low Temperature Storage
2. Tomato Cultivation Systems Affect Subsequent Quality of Fresh-cut Fruit Slices
3. Involvement of Ethylene in Development of Chilling Injury in Fresh-cut Tomato Slices during Cold Storage

Abstract

Quality of fresh-cut tomato slices was compared during cold storage under various modified atmosphere packaging conditions. Chilling injury of slices in containers sealed with Film A was higher than with Film B; these films had oxygen transmission rates of 87.4 and 60.0 ml h-1 m-2 atm-1 at 5℃ and 99% RH, respectively. While slices in containers with an initial atmospheric composition of air, 4% CO2 + 1 or 20% O_2, 8% CO_2 + 1 or 20% O_2, or 12% CO_2 + 20% O2 showed fungal growth, slices in containers with 12% CO_2 + 1% O_2 did not. Low ethylene in containers enhanced chilling injury. Modified atmosphere packaging provided good quality tomato slices with a shelf-life of 2 weeks or more at 5℃.

Experiments were conducted to compare changes in quality of slices of red tomato (Lycopersicon esculentum Mill. 'Sunbeam') fruit from plants grown using black polyethylene or hairy vetch mulches under various foliar disease management systems including: no fungicide applications (NF), a disease forecasting model (Tom-Cast), and weekly fungicide applications (WF), during storage at 5℃ under a modified atmosphere. Slices were analyzed for firmness, soluble solids content (SSC), titratable acidity (TA), pH, electrolyte leakage, fungi, yeasts, and chilling injury. With both NF and Tom-Cast fungicide treatments, slices from tomato fruit grown with hairy vetch (Vicia villosa Roth) mulch were firmer than those from tomato fruit grown with black polyethylene mulch after 12 days storage. Ethylene production of slices from fruit grown using hairy vetch mulch under Tom-Cast was about 1.5- and 5-fold higher than that of slices from WF and NF fungicide treatments after 12 days, respectively. The percentage of water-soaked areas (chilling injury) for slices from tomato fruit grown

using black polyethylene mulch under NF was over 7-fold that of slices from tomato fruit grown using hairy vetch under Tom-Cast. When stored at 20℃, slices from light-red tomato fruit grown with black polyethylene or hairy vetch mulches both showed a rapid increase in electrolyte leakage beginning 6 hours after slicing. However, slices from tomato fruit grown using the hairy vetch mulch tended to have lower electrolyte leakage than those grown with black polyethylene mulch. These results suggest that tomato fruit from plants grown using hairy vetch mulch may be more suitable for fresh-cut slices than those grown using black polyethylene mulch. Also, use of the disease forecasting model Tom-Cast, which can result in lower fungicide application than is currently used commercially, resulted in high quality fruit for fresh-cut processing.

Experiments were conducted to determine if ethylene influences chilling injury, as measured by percentage of slices exhibiting water-soaked areas in fresh-cut tomato slices of 'Mountain Pride' and 'Sunbeam' tomato (Lycopersicon esculentum Mill.). Ethylene concentration in containers without ventilation significantly increased during storage at 5℃, whereas little or no accumulation of ethylene occurred in containers with one or six perforations. Chilling injury was greatest for slices in containers with six perforations, compared to slices in containers with one perforation, and was over 13-fold greater than that of slices in control containers with no perforations. An experiment was also performed to investigate the effectiveness of including an ethylene absorbent pad in containers on subsequent ethylene accumulation and chilling injury. While ethylene in the no-pad controls increased continually during storage of both 'Mountain Pride' and 'Sunbeam' tomatoes at 5℃ under modified atmosphere conditions, no increase in accumulation of ethylene was observed in containers containing ethylene absorbent pads throughout storage. The ethylene absorbent pad treatment resulted in a significantly higher percentage of chilling injury compared with the no-pad control. In studies aimed at inhibiting ethylene production using AVG during storage of slices, the concentration of ethylene in control containers (no AVG) remained at elevated levels throughout storage, compared to containers with slices treated with AVG. Chilling injury in slices treated with AVG was 5-fold greater than that of controls. Further, we tested the effect of ethylene pretreatment of slices on subsequent slice shelf-life and quality. In slices treated with ethylene (0, 0.1, 1, or 10 μL L-1) immediately after slicing, ethylene production in non-treated controls was greater than that of all other ethylene pre-treatments. However, pretreatment of slices 3 days after slicing resulted in a different pattern of ethylene production during storage. The rate of ethylene production by slices treated with 1 L L-1 ethylene 3 days after slicing was greater during storage than any of the other ethylene treatments. With slices pre-treated with ethylene, both immediately and 3 days after slicing,the rate of ethylene production tended to show an negative correlation with chilling injury. Chemical name used: 1-aminoethoxyvinylglycine (AVG).

INTRODUCTION

A major prpblem with storage and marketing of fresh-cut tomato slices is their relatively fast deterioration in quality and short shelf-life. Although

their shelf-life can be extended by cold storage, tomato tissue is sensitive to chilling injury, a term used to describe the physiological disorder caused by exposure of plants to low but non-freezing temperatures. The symptoms of chilling injury in tomato fruit are uneven ripening, surface pitting, increased susceptibility to fungal infection, loss of aroma volatiles and water-soaked areas on red tomato fruit (Hobson 1987; Morris 1982). Symptoms associated with chilling injury often develop only after transfer of chilled fruit to ambient temperature (King and Ludford 1983). The formation of water-soaked areas often occurs while tomatoes are held in cold storage, before removal of fruit to non-chilling temperatures (Hong and Gross 1998). Hobson (1987) has used extent of visible damage, ie., water-soaked areas and surface pitting, as an indicator of the degree of chilling injury.

Major benefits of plastic container or film packaging of fruits and vegetables include the ability to modify gas composition and reduce moisture loss. The accumulation of CO_2 and depletion of O_2 to beneficial levels by the application of modified atmosphere packaging (MAP) is known to prolong the shelf-life of many horticultural crops (Zagory and Kader 1988). Thus, MAP has been used as a supplement to refrigeration to extend storage of fruits and vegetables. MAP results in high humidity and changes in O_2 and CO_2 concentration, which is generally beneficial for preventing development of chilling injury symptoms (Forney and Lipton 1990). Wang (1993) has shown that the maintenance of high humidity, increase in CO_2 and decrease in O_2, reduced chilling injury of avocado, grapefruit, peaches, nectarines, pineapples and zuchini.

In tomato fruit, previous studies have focused on the effect of MAP on storage of whole tomato fruit at temperature above 12.5℃, which is the minimum temperature that can be used without danger of chilling injury (Efiuvwevwere and Uwanogho 1990; Gong and Corey 1994; Shirazi and Cameron 1992). Recently, Artés and others (1999) reported that MAP should be used for maintaining fresh-cut tomato slices when stored at 10℃, while MAP was not beneficial at 2℃ for maintaining quality and shelf-life. Although the recommended storage temperature for fresh-cut produce is at or below 5℃, 2℃ is commercially impractical.

Fresh-cut produce is an industry that has been rapidly growing, and there is a great demand for fresh-cut tomato slices. Little information is available in the literature on postharvest storage systems for fresh-cut tomato slices. The objective of the present study was to investigate the effect of various MAP conditions, films, and temperatures on quality, shelf-life and development of chilling injury symptoms in fresh-cut tomato slices.

Tomatoes (Lycopersicon esculentum) are grown conventionally either on plastic mulches or in bare soil. In particular, black polyethylene is used most commonly as a mulch commercially in the production of fresh-market field tomatoes (Hochmuth et al., 1986). Synthetic mulches, including black polyethylene, are used commonly for early production (West and Pierce, 1988), high yield (Abdul-Baki et al., 1992; Bhella, 1988), good fruit quality (Perry and Sanders, 1986) and for weed-control (Teasdale and Colacicco, 1985). However, installation and removal of polyethylene mulches require specialized equipment and involve relatively high costs.

A sustainable agricultural production system has been developed for summer vegetables, including tomatoes, in which hairy vetch (Vicia villosa) was used as a cover crop alone (Abdul-Baki and Teasdale,

1993) or in combination with other legumes and grasses (Stivers and Shennan, 1991). Many studies have been published dealing with various effects of winter legumes as cover crop mulches; they reduce soil erosion (Shelton and Bradley, 1987), improve soil organic content (Stivers and Shennan, 1991), increase soil water-holding capacity (Hoyt and Hargrove, 1986), reduce weed competition and the need for herbicides (Sloderbeck and Edwards, 1979), reduce the need for fungicides (Sloderbeck and Edwards, 1979), and provide significant amounts of N to subsequently grown non-leguminous crops (McVay et al., 1989).

Abdul-Baki et al. (1996) reported that yields were higher, fruit were heavier, and leaf necrosis was lower in plants grown using hairy vetch than with black polyethylene. They also reported that dry weight was higher and pH lower in tomatoes grown using black polyethylene mulch compared with hairy vetch, but there was no difference in soluble solids content between black polyethylene and hairy vetch mulch. In general, plastic mulches increase the range of soil temperature fluctuation compared with bare soil (Ham et al., 1993). However, organic mulches decrease the maximum and increase the minimum soil temperature (Teasdale and Mohler, 1993).

Weekly fungicide applications are used commonly to reduce disease severity in commercial production of fresh market tomato fruit. However, frequent fungicide use results in ground water contamination and increased resistance of pathogens to pesticides (Haynes et al., 1986). Thus, there exists a need to investigate alternative methods of pest-control, such as integrated pest-management (IPM) and use of disease forecasting models like Tom-Cast, that minimize fungicide and other pesticide use within conventional and sustainable production systems. Trumble et al. (1994) reported that use of IPM in fresh market tomatoes has significant benefits, such as a reduction in potential development of fungicide resistance, reduced soil compaction, less environmental contamination, and reduction in human health concerns.

While the effects of mulches and IPM in sustainable systems on plant growth, yield, and environmental impact have been studied, we were interested in the effects on sustainable systems on postharvest tomato fruit quality, particularly the quality of fresh-cut slices. Thus, the objective of this study was to compare quality during storage of fresh-cut slices from red-ripe tomato fruit grown with different mulches and fungicide applications.

Ethylene is a plant hormone that controls many aspects of plant growth and development, and its rate of production is increased dramatically by various stimuli (Yang and Hoffmann, 1984). Ethylene is synthesized naturally during specific developmental stages such as fruit ripening, seed germination, leaf and flower senescence and abscission, and root and leaf growth. Also, ethylene production is stimulated by various types of stress, including mechanical wounding (bruising and cutting), temperature (chilling, freezing, and occasionally high temperature), and chemicals (auxins, herbicides, and various pollutants). Ethylene also accumulates in response to pathogenic infection of plant tissues (Boller and Kende, 1980; Yang and Hoffmann, 1984).

Ethylene is involved in chilling injury in a number of fruits. For example, ethylene treatment increased development of chilling injury symptoms and decreased shelf life of avocado (Persea americana Mill.; Chaplin et al., 1983). Avocado fruit stored in an atmosphere with high ethylene also showed more chilling injury

than those maintained in air at the same temperature (Lee and Young, 1984).

Ethylene has also been shown to alleviate chilling injury. For example, application of ethylene significantly reduced the incidence of chilling injury in Honeydewmuskmelons (Cucumis melo L.; Lipton and Aharoni, 1979) and exposure of sweet potatoes [Ipomoea batatas (L.) Poir.] ethylene during the post-chilling period significantly reduced the severity of chilling injury (Buescher, 1977). In contrast, Kader and Morris (1975) reported that exposure of mature green tomatoes to ethylene before or following storage at chilling temperatures did not affect development of chilling injury.

Little is known about the effect of ethylene on formation of water-soaked areas during chilling injury in tomato fruit, especially with regard to fresh-cut slices. While studying storage of fresh-cut tomato at low temperatures, we observed that ethylene affected development of chilling injury in tomato slices under modified atmosphere (MA) storage. Therefore, the objective of this study was to investigate the involvement of ethylene in chilling injury of fresh-cut tomato slices.