Pretreatment of Greenhouse-Grown Cucumber with Aqueous 1-MCP Maintains Quality During Exposure to Ethylene

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Abstract. The efflux of solutes from plant tissues is widely used as a measure of membrane permeability in response to various stress conditions. Following harvest, hydroponically grown mini-cucumbers (cv. Manar) were immersed for 1 minute in 100 ppb, 1 ppm or 5 ppm 1-methylcyclopropene (1-MCP) solutions, air dried and stored at 15°C, 99% relative humidity in a flow-through system with continuous exposure to 13 μL·L⁻¹ exogenous ethylene or air. Color, firmness and electrolyte leakage were determined after 4 and 8 days. After 8-day storage in ethylene, non-1-MCP treated (control) cucumbers had lower hue angle, were softer and had higher electrolyte leakage compared to those stored in air. There were differences in external color between fruit stored in air or ethylene following pretreatment at 0, 1 and 5 ppm 1-MCP concentrations. Control fruit stored in ethylene was softer than those stored in air. For 100 ppb, 1 ppm, and 5 ppm 1-MCP concentrations, there were no differences in firmness of fruit stored in air and in ethylene. Regardless of 1-MCP concentrations, fruit stored in ethylene had higher electrolyte leakage than air-stored fruit. Fruit without 1-MCP pretreatment appeared visually inferior when exposed to ethylene compared to exposure to air only. The deleterious effects of exogenous ethylene exposure on the postharvest quality of stored cucumbers were reduced by immersion in aqueous 1-MCP preparations.

Cucumber fruit are classified as non-climacteric (Biale and Young, 1981). Mini and Beit Alpha cucumber types are smaller than the traditional Dutch-type or English-type cucumbers. Mini-cucumbers originate from Dutch or Israeli breeding programs, while Beit Alpha cucumbers are from Israeli breeding programs (N. Shaw, personal communication). Size, shape and dark green color of peel indicating freshness are the only maturity indices demanded by the market (Nilsson, 2005). Mini-cucumber (‘Manar’) maintained acceptable quality for up to 2 weeks at 10°C in rigid clamshells (Villalta et al., 2003). These authors also reported that ethylene (10 ppm) exposure reduced the shelf-life of Beit Alpha cucumber by more than 50% by adversely affecting pulp firmness. Exposure of vegetables to ethylene accelerates senescence, with chlorophyll loss, tissue softening and microbial growth as well as certain senescence-related events noted in many non-climacteric fruits (Vendrell et al., 2001).

1-methylcyclopropene (1-MCP) has increased the list of options for extending the life and quality of many fresh plant products (Blankenship and Dole, 2003). The use of the ethylene-action inhibitor 1-MCP has proven beneficial in attenuating the rate of ripening many climacteric fruits. It is thought to bind irreversibly to ethylene receptors at very low concentrations, blocking or delaying the process of maturation and/or senescence normally triggered by ethylene. The influence of 1-MCP has been less studied on non-climacteric than on climacteric fruits, showing variable results in the delay of fruit ripening (Blankenship and Dole, 2003). Gaseous 1-MCP pretreatment of Beit Alpha-type cucumber provided complete protection against the effects of continuous ethylene (10 μL·L⁻¹) exposure and also maintained firmness stored in air (Lima et al., 2005).

The use of 1-MCP has thus far been limited to application as a gas. In this study, we tested the efficacy of a liquid 1-MCP formulation for protecting cucumbers against the adverse effects of ethylene exposure.

Materials and Methods

Material. Mini-type cucumbers (Cucumis sativus cv. ‘Manar’) were grown hydroponically under greenhouse conditions at Beli Farms, Welborn, Fla. Fruit were harvested in the morning (20 Feb 2006), packed and transported to the Postharvest Horticulture Laboratory at the University of Florida. Cucumbers were selected for size (average length: 4.88 in (122 mm); average equatorial diameter: 1 in (25 mm)) and dark-green surface color. 1-MCP and Ethylene Treatments. Four groups (n=16) of cucumber fruit were initially dipped in deionized water for 1 min and air-dried for 5 min. After drying, three groups were treated with 1-MCP (Formulation AFxRD-300, SmartFresh®, Agrofresh, Inc., a division of Rohm and Hass Co., Philadelphia, Pa.) concentrations of 100 ppb, 1 ppm, and 5 ppm, prepared in water. Fruit were immersed in the 1-MCP solutions for 1 min and air-dried. The fourth group (control) was immersed for 1 min in deionized water. Fruits were then put in polystyrene containers, with 8 cucumbers per container (capacity: 2 lb; 0.91 kg). Containers were stored in sealed, metal chambers at 15°C ± 1 (59°F) and 99% relative humidity. Gas-chambers were connected to a mixing board using polyethylene tubing. The ethylene and compressed air mixture was humidified by bubbling through a 2-L glass jar with water. Cucumbers were continuously exposed to air or ethylene (13 μL·L⁻¹). Total gas flow was monitored using a digital ADM 1000 flow meter (J & W Scientific, Folsom, Calif.) and adjusted to ensure <2% CO₂ accumulation in the storage atmosphere. Ethylene concentrations in the gassing chambers were analyzed daily using a Tracor 540 gas chromatograph (Tremetrics Analytical Division, Austin, Texas). Fruit quality parameters were measured at 4 and 8 d of storage.

Color Evaluation. External and internal color was assessed using a CR-400 Chroma Meter (Konica Minolta Sensing Co., Japan). For external color, two measurements were taken on opposite sides of the equatorial region of individual fruit. Two internal color readings were taken per equatorial slice (n =4) and averaged to obtain a final value from each cucumber.

Fruit Firmness. Firmness was assessed on equatorial slices using an Instron® Universal Testing Instrument (Model...
Instron Corporation, Canton, Mass.) equipped with a 3.0-mm diameter probe with a crosshead speed of 50.0 mm·min\(^{-1}\), a 5-kg load cell and a 7-mm displacement. Firmness was evaluated at the mesocarp area of similarly sized, transverse, equatorial slices of fruit. Fruit slices were obtained using a double-bladed cutting instrument with 10-mm separation between blades. The slices were obtained from four cucumbers, with two firmness measurements per slice.

Electrolyte Leakage Four plugs (10 mm long by 3.4 mm wide) of mesocarp tissue were excised from transverse slices using a No. 1 brass cork borer. Samples were excised from four different cucumbers per treatment. The mesocarp plugs were cleaned of damaged tissue by rinsing gently with deionized water before placement in plastic vials containing 15 mL of 0.3 mol·L\(^{-1}\) isotonic mannitol in water. Samples were then placed in a shaker for 3 h, and the electrical conductivity of the solutions measured using a digital electrical conductivity meter (YSI, Inc., Yellow Springs, Ohio). Samples were then frozen overnight and equilibrated to room temperature before obtaining a final conductivity measurement of the solution. Electrolyte leakage was expressed as a percent of the total electrical conductivity.

Data Analysis. Data were analyzed using SAS software (SAS Institute, Inc., Cary, N.C.). All data were subjected to a Least Square Means (P < 0.05).

Results and Discussion

Since significant interactions were observed among the variables examined: time (4 or 8 d), 1-MCP concentration (0, 100 ppb, 1 ppm, or 5 ppm) and storage environment (air or ethylene), the results are discussed considering the three factors together.

Color. Most color changes in cucumber are associated with a decrease in the concentration of chlorophyll. During ripening or senescence, the chloroplasts are transformed into chromoplasts through extensive changes in their internal membranes (Kays and Paull, 2004). After 4 d of storage, there were no differences in external color between fruit stored in air or ethylene for all 1-MCP concentrations (Fig. 1). After 8 d, however, significant differences were observed in external color between fruit stored in air and ethylene in the 0, 1 and 5 ppm 1-MCP (Fig. 1). In the control group (without 1-MCP), hue angle was lower (yellowing) in fruit stored in ethylene than in fruit stored in air. However, at 1 and 5 ppm 1-MCP concentrations, hue angles in air-stored fruit were lower than ethylene-stored ones; at 100 ppb 1-MCP, there was no difference between fruit stored in air or ethylene.

Villalta et al. (2004) did not find differences in the external color of cucumbers stored under different ethylene concentrations after 3-d storage. Nilsson (2005) reported...
degreening of peel in cucumber treated with gaseous 1-MCP (1 ppm) after 9 d exposure to ethylene at 20°C. In green tissue, ethylene accelerates the degradation of chlorophyll, resulting in undesirable yellowing (Kays and Paull, 2004). The deleterious effects of exogenous ethylene exposure on the surface color of stored cucumbers were reduced by immersion in the aqueous 1-MCP formulation. Internal fruit (mesocarp) color did not vary among treatments.

Firmness. After 4 d, there was no difference in mesocarp firmness of cucumbers treated with 0, 100 ppb, and 5 ppm 1-MCP concentrations. At 1 ppm, air-stored fruit were firmer (11.1 N) than fruit exposed to ethylene (10.3 N) (Fig. 2a). After 8 d, control fruit stored in ethylene were softer (8 N) than those stored in air (9.7 N) (Fig. 2b). Ethylene within the storage environment causes a decline in quality attributes and is responsible for the induction of several physiological disorders (Kays and Paull, 2004). At 100 ppb, 1 ppm, and 5 ppm 1-MCP, there were no differences in fruit firmness stored in air and ethylene. Similar results were reported for cucumber (Lima et al., 2005) and watermelon (Mao et al., 2004) fruit treated with gaseous 1-MCP.

Electrolyte Leakage. Electrolyte leakage from mesocarp of cucumber (Fig. 3) was used as an indirect measure of membrane damage. After 4 d, fruit pretreated at all 1-MCP concentrations were not affected by exposure to ethylene (Fig. 3a). For non-treated fruit (without 1-MCP), the rate of ion leakage in fruit stored in ethylene was higher (53.8%) than in air (20.6%), whereas those treated with 1 ppm 1-MCP were similar: ethylene (23.6%) and air (19.7%). For 8-d stored fruits the ion leakage rate was independent of 1-MCP concentration. The rates for fruit stored in ethylene were 99.9% (control) and 29.1% (1-MCP treated fruit), higher than corresponding rates for fruit stored in air (26.2% and 25.1%) (Fig. 3b). Ethylene within the storage environment is known to cause a significant stress to many harvested products. The increased rates in and magnitude of electrolyte leakage are correlated to changes in membrane permeability (Knowles et al., 2000). Ethylene increases the rate of respiration, alters the activity of a number of enzymes, increases membrane permeability, and alters cellular compartmentalization and auxin transport and metabolism.

Conclusion

Aqueous solutions of 1-MCP were comparable in efficacy to corresponding concentrations of gaseous 1-MCP in that the deleterious effects of exposure of cucumber to ethylene were negated during 8 d of storage at 15°C.

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Literature Cited


