CONTROLLED ATMOSPHERE STORAGE AFFECTS QUALITY AND CHILLING SUSCEPTIBILITY OF CUCUMBERS

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ABSTRACT

Controlled atmospheres (CA) maintained the quality of cucumbers better than conventional refrigerated storage at 5°C. Elevated levels of CO₂ (3%) and decreased concentrations of O₂ (1 and 15%) also increased the tolerance of cucumbers to chilling exposure. The content of sugars, including fructose and glucose; and organic acids, particularly malic acid, were maintained at higher levels in CA-stored cucumbers than in air-stored samples. The respiration rates (measured as CO₂ production) of cucumber fruit during storage at 5°C were markedly suppressed under CA conditions. Contrary to reports in the literature, CA storage was found to be beneficial in reducing chilling injury and maintaining cucumber quality.

INTRODUCTION

Controlled atmosphere (CA) storage has been shown to affect the respiration, ethylene production and action, enzyme synthesis and activity, ripening process, and senescence of various horticultural products (Calderon and Barkai-Golan 1990; Kader 1986). Most fresh fruits and vegetables respond favorably to CA treatment in maintaining sensory and nutritional quality and in extending storage life (Blanpied et al. 1993). However, CA is not always beneficial in reducing chilling injury of chilling-sensitive horticultural crops (Forney and Lipton 1990). The effectiveness of chilling injury reduction often depends on the type of commodity, the concentrations of O₂ and CO₂, and the temperature and duration of storage (Wang 1993).

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A decrease in O₂ level and/or an increase in CO₂ concentration in the storage atmospheres have been shown to alleviate chilling injury of avocados, grapefruit, apricots, nectarines, okra, peaches, pears, pineapples, potatoes, and zucchini squash (Wang 1993). However, an atmosphere of 3 or 5% CO₂ combined with a 20% O₂ was found to increase the symptoms of chilling injury in cucumbers at chilling temperature (Eaks 1956). Elevated concentrations of CO₂ induced injury symptoms in tomatoes similar to those of chilling injury (Kader and Morris 1975). Unfavorable results in ameliorating chilling exposure by CA have also been reported in asparagus spears (Lipton 1965), lime fruit (Spalding and Reeder 1983), sweet peppers (Cappellini et al. 1984), and grapefruit (Hatton et al. 1972).

In a recent study, we found that cucumber fruit packaged in perforated or sealed low density polyethylene bags had significantly less chilling injury than nonwrapped fruit when stored at a chilling temperature of 5°C (Wang and Qi unpublished). One of the effects of film packaging is the modification of in-package atmosphere with raised CO₂ levels and decreased O₂ concentrations. This result prompted us to initiate a study to evaluate the effect of CA on quality and chilling susceptibility of cucumbers during refrigerated storage.

**MATERIALS AND METHODS**

Cucumber fruit (Cucumis sativus L., cv. Thunder) used in this study were grown on a farm in southern Maryland. Fruit that were uniform in size (18-22 cm in length) and free from blemishes were chosen for the research. Samples were washed with tap water to remove any loose soil, then were randomly divided into three lots and used for three CA treatments: air, 15% O₂ + 3% CO₂, and 1% O₂ + 3% CO₂.

Three cucumber fruit were placed in each 3.8 L glass respirometer jar and stored at 5°C. Humidified gas mixtures of air, 15% O₂ + 3% CO₂, or 1% O₂ + 3% CO₂ were passed through the respective jars at a rate of 50 mL min⁻¹. Air, CO₂ and nitrogen from a liquid nitrogen supply or from a nitrogen generator (AVIR and NA 100H5, A/G Technology Corporation) were metered and combined to obtain the desired gas mixtures. Respiration rates, based on CO₂ production from the effluents of the respirometer jars, were determined every four hours by an automated system. Respiration data were reported after each 24-h period. CO₂ was analyzed with a carbon dioxide analyzer (AMETEX Applied Electrochemistry, Model CD-3A).

Three jars in each treatment were removed from the respirometer at 3-day intervals for the evaluation of chilling injury and chemical analyses. The severity of chilling injury was evaluated 24 h after cucumbers were transferred to 20°C.
The quality of cucumber fruit as affected by controlled atmosphere storage was elevated by changes in sugar and organic acids. Sugar analysis consisted of cutting mesocarp tissue; (2.0 g) cucumber fruit was cut into small sections and homogenized with a Polytron homogenizer (Brinkmann) in imidazole buffer (20 mM, pH 7.0). The extracts were centrifuged and supernatants were dried in vacuo in derivatizing vials. Derivatization of the sugars was carried out according to procedures described by Li and Schuhmann (1980). One μL of the derivatized samples was injected for gas chromatographic separation and quantification. A Hewlett Packard 5890 gas chromatograph equipped with a flame ionization detector was used. A known amount of β-phenyl-D-glucopyranoside was included in all samples as an internal standard. A 12.5 m dimethyl silicon fluid capillary column (0.2 mm ID, 0.33 μm film thickness) was used. Chromatograph temperatures were as follows: injector 250°C, detector 275°C, and column 160 to 250°C programmed at 10°C/min.

Organic acids were analyzed after extraction with imidazole buffer and purification with a Baker-10 solid phase extraction system. Supernatants from the extracts were passed through quaternary amine column which were previously conditioned with hexane and methanol. The samples were then eluted from the columns with 0.1 N HCl. The eluates were concentrated to dryness in vacuo in derivatized vials. Procedures of derivatization and chromatography for organic acids were the same as those for sugars except that column temperatures were programmed from 100 to 230°C at 4°C/min. Separated sugars and organic acids were compared with derivatized standards for qualitative and quantitative determinations. Data were analyzed by analysis of variance and the variance components were used to calculate the expected standard errors of the means.

RESULTS AND DISCUSSION

Respiratory rates of cucumbers were markedly suppressed by CA treatments throughout storage at 5°C (Fig. 1). Reduction of respiration by low O₂ and/or high CO₂ atmospheres has been reported previously (Wang 1990). Lowering the O₂ concentration or raising the CO₂ level has been shown to delay the onset of climacteric rise in some fruits and retard the CO₂ production in nonclimacteric type of fruits and vegetables (Biale 1960; Kader 1986). In our study, cucumbers from both CA treatments (1% O₂ + 3% CO₂ and 15% O₂ + 3% CO₂) had lower rates of respiration than the air control.

One of the most significant benefits of 1% O₂ + 3% CO₂ treatment was the inhibition of mold growth in cucumber fruit during storage at 5°C. Cucumbers from other treatments, particularly the air control developed decay at the chilling temperature. The 1% O₂ + 3% CO₂ and 15% O₂ + 3% CO₂ treatments showed no difference in the degree of chilling injury. Both CA treatments
delayed the onset and reduced the severity of pitting in the chilled cucumbers. Cucumbers stored under an elevated CO₂ atmosphere (3 or 5%) combined with an ambient O₂ concentration were previously reported to have high pitting incidence at a chilling temperature (Eaks 1956). The present research indicates that low O₂ concentration is important in alleviating chilling injury in cucumbers.

![CO₂ Production vs. Days at 5°C](image)

**FIG. 1. EFFECT OF CONTROLLED ATMOSPHERES ON RESPIRATORY RATES OF CUCUMBERS STORED AT 5°C**

Fructose and glucose were the major sugars in cucumber with trace amounts of sucrose. Fructose increased during storage at 5°C for 3 or 6 days, then declined gradually (Fig. 2). Cucumbers kept in CA conditions (1% O₂ + 3% CO₂ or 15% O₂ + 3% CO₂) maintained higher fructose concentrations than those in air storage. Glucose concentrations decreased during the first 3 or 6 days of storage, then leveled off (Fig 3.). The low O₂ and elevated CO₂ atmospheres reduced glucose loss at the beginning of the 5°C storage.

Malic acid was the predominant organic acid in cucumber fruit. Malic acid decreased markedly in air storage at 5°C (Fig. 4). Cucumbers stored under CA conditions also lost malic acid in storage but to a lesser extent than fruit from...
FIG. 2. EFFECT OF CONTROLLED ATMOSPHERES ON CHANGES OF FRUCTOSE CONTENT IN CUCUMBERS DURING STORAGE AT 5°C

Error bars represent ± SE.

FIG. 3. EFFECT OF CONTROLLED ATMOSPHERES ON CHANGES OF GLUCOSE CONTENT IN CUCUMBERS DURING STORAGE AT 5°C

Error bars represent ± SE.
FIG. 4. EFFECT OF CONTROLLED ATMOSPHERES ON CHANGES OF MALIC ACID CONTENT IN CUCUMBERS DURING STORAGE AT 5°C

Error bars represent ± SE.

air storage. Citric acid was present in cucumber tissue at a much lower level than malic acid. During storage at 5°C, citric acid increased gradually in cucumber fruit; however, due to low levels and large variations, no significant differences were detected between air and CA stored fruit. Other organic acids detected in cucumbers included succinic acid and tartaric acid. These organic acids were present in minute amounts.

The reduction of losses of sugars and organic acids by CA has been reported in various fruits and vegetables (Blanpied et al. 1993; Kader 1986; Wang 1990). Sugars and organic acids are utilized as substrates and as sources of energy for respiratory metabolism. Preservation of these substances tends to maintain the desirable quality of fruits and vegetables. The keeping quality of chilling-sensitive commodities is adversely affected by the exposure to temperatures below 10°C. Abnormal utilization of sugars and organic acids in the Krebs cycle were reported to take place in the fruit of eggplant during storage at a chilling temperature (Kozukue et al. 1978). In the present study, we have also found that losses of fructose, glucose, and malic acid occurred in cucumber fruit during storage at 5°C. However, CA storage minimized these losses. Susceptibility to chilling injury and the incidence of decay were also reduced by the elevated CO₂ levels and low O₂ concentrations. The overall quality of cucumbers was better maintained when the fruit were kept in CA storage.
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REFERENCES


