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ScienceDirect
Postharvest Biology and Technology 44 (2007) 71–79
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Quality characteristics of fresh-cut watermelon slices from non-treated and 1-methylcyclopropene- and/or ethylene-treated whole fruit

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Received 3 July 2006; accepted 5 November 2006

Abstract

Maintaining the postharvest quality of fresh-cut fruit after processing and throughout distribution and marketing is a major challenge facing the fresh-cut fruit industry. Analytical quality characteristics of packaged fresh-cut watermelon slices from non-treated and 1-methylcyclopropene (1-MCP)- and/or ethylene-treated whole fruit were investigated. Freshly harvested seedless watermelon ('Sugar Heart') were stored 7–14 days in air before exposure to 0, 0.5 or 1.0 $\mu L\,L^{-1}$ 1-MCP for 18 h followed by 5 days exposure to 0 or 10 $\mu L\,L^{-1}$ ethylene, all at 20 °C. Following treatment, fruit were processed into wedge-shaped slices, packaged into rigid trays sealed with a high oxygen transmission rate film overlap and stored 1, 6 or 12 days at 5 °C. During storage, fresh-cut watermelon slices from non-treated and 1-MCP- and 1-MCP + ethylene-treated whole fruit maintained similar respiration rates and internal atmospheres of CO_2 and O_2 and were of similar quality with total aromatic volatile concentrations decreasing and puncture firmness, soluble solids content (SSC), cut surface pH and color remaining relatively stable. In contrast, fresh-cut slices from fruit treated with ethylene alone had higher respiration rates and modified package atmospheres containing more CO_2 and O_2; lower firmness, SSC and chromaticity values; higher pH and an altered volatile profile compared to those of slices from non-treated and 1-MCP- and 1-MCP + ethylene-treated fruit. The 22 most abundant volatiles were various aldehydes, alcohols and ketones. During storage, many individual volatiles decreased in concentration but some increased including (*Z*)-6-nonen-1-ol, a volatile having a pumpkin-like aroma. The results indicated that low dosage 1-MCP treatments prior to ethylene exposure of whole watermelons prevented ethylene-mediated quality deterioration in fresh-cut slices stored under modified atmosphere conditions at 5 °C.

Keywords: *Citrullus lanatus*; Ethylene; 1-Methylcyclopropene; Quality; Respiration rates; Volatiles

1. Introduction

The market for fresh-cut watermelon [*Citrullus lanatus* (Thunb. Matsum. and Nakai)] has increased at a rate of 20–30% annually (Fonseca et al., 2004), and the fresh-cut product now accounts for 46% of total watermelon sales and over 80% of total fresh-cut watermelon/melon sales (National Watermelon Promotion Board, 2005). Fresh-cut watermelon is marketed as halves, quarters and slices with rinds, or as rind-free chunks. Quality degradation has been associated with decreased acceptability of texture, color and sweetness (Rushing et al., 2001), with shelf-life limited by water soaking, juice leakage (Cartaxo et al., 1997), off-odor development (Fonseca et al., 2004) and increased microbial growth and spoilage (Mao et al., 2006).

Uncut freshly harvested or stored watermelons normally produce ethylene at low ($0.3\,nL\,kg^{-1}\,s^{-1}$) rates (Elkashif and Huber, 1988; Rushing, 2004) and otherwise exhibit a non-climacteric pattern of ripening (Elkashif et al., 1989). Although production rates are normally low, fruit are sensitive to exogenously applied ethylene, exhibiting softening and water soaking of the flesh accompanied by off-odor development at ethylene concentrations as low as 1 $\mu L\,L^{-1}$ (Rissi and Hatton, 1982; Shimokawa, 1973). The response of watermelons to ethylene is not associated with fruit

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doi:10.1016/j.postharvbio.2006.11.002

maturation (Karakurt and Huber, 2002) or normal ripening (Elkashif and Huber, 1988), but rather to a postharvest disorder in which phospholipid degradation and membrane deterioration are involved (Karakurt and Huber, 2004; Mao et al., 2004).

1-Methylcyclopropene, a potent inhibitor of ethylene action, maintains specific quality attributes and prolongs shelf-life of many fruits, especially climacteric fruit, but can also inhibit aromatic volatile production that contributes to the aroma (and flavor) of the fruit (Blankenship and Dole, 2003). In watermelon, 1-MCP has recently been shown to maintain the firmness of whole fruit stored in the presence or absence of added ethylene (Mao et al., 2004), but was not able to maintain firmness or extend shelf-life of fresh-cut placental pieces stored in air at 10 °C (Mao et al., 2006).

While whole melons and watermelons stored below 10 °C may develop rind and flesh damage, fresh-cut melon and watermelon products are not as chilling injury sensitive as the corresponding whole fruit (Beaulieu and Gorny, 2004). Temperatures near 0 °C generally provide optimal shelf-life by inhibiting growth of spoilage microorganisms. Fresh-cut watermelon has been stored for ≥9 days at 1–3 °C under modified atmosphere (MA) conditions (Fonseca et al., 2004). However, the flesh of chill sensitive fruit may still be chilling injured. No studies have indicated if quality-associated aromatic volatile profiles and concentrations in fresh-cut watermelon are affected by low temperature storage or by 1-MCP treatment of whole fruit.

The objective of this study was to examine the influence of 1-MCP, ethylene, and 1-MCP + ethylene applied to whole 'Sugar Heart' watermelon, on respiration and quality attributes, including aromatic volatile concentrations, of subsequently processed fresh-cut watermelon slices stored at 5 °C under modified atmosphere conditions.

2. Materials and methods

2.1. Plant material

Seedless watermelon (*C. lanatus* Thunb. Matsum. and Nakai, 'Sugar Heart') were harvested at the commercial maturity (fully ripe) stage as determined by a major grower/packer in central Delaware, placed in padded containers to avoid physical injury, and immediately transported to the ARS Agricultural Research Center in Beltsville, MD. Undamaged fruit weighing about 9 kg each were stored 7 or 14 days at 20 ± 1 °C until used for experimentation.

2.2. 1-MCP and ethylene application and whole fruit storage

At both 7 and 14 days after harvest, sets of 20 fruit were treated with 0, 0.5 or 1.0 μL L^{-1} 1-MCP (SmartFresh™, Rohm and Haas Co., Spring House, PA) for 18 h at 20 ± 1 °C as previously described (Saftner et al., 2003a). Subsets (10 fruit) of the control and the 1-MCP-treated watermelons were then treated with 0 or 10 μL L^{-1} ethylene for 5 days at 20 ± 1 °C. The watermelons were stored an additional day in air at 20 ± 1 °C. Non-treated and 1-MCP- and/or ethylene-treated fruit were kept in separate treatment/storage areas to avoid possible contamination by 1-MCP or ethylene outgassing.

2.3. Processing of watermelons and storage of fresh-cut slices

Non-treated and treated watermelons were rinsed with tap water followed by two 1-min dips with 100 μL L^{-1} sodium hypochlorite (pH 6.5). With a sharp sanitized custom-made knife assembly, four 4-cm wide rings were latitudinally cut simultaneously from the center of the fruit. Each of the four rings was then processed into six equally sized wedge-shaped slices. The 24 slices from each watermelon were randomized and 18 were placed (two per container) into 13.5 cm × 19 cm × 4 cm rigid polypropylene trays (Pactiv Corporation, Lake Forest, IL, USA) and the trays sealed with a 29.2 pmol s^{-1} m^{-2} Pa^{-1} oxygen transmission rate (OTR) film. Film OTR was determined by the film manufacturer (Package Concept Corporation, Salinas, CA, USA) at 23 °C using a MOCON apparatus to measure steady state rate of dry O_2 gas transmission through plastic films, i.e., according to ASTM International procedure D 3985-81 (ASTM International, 1986). At 5 °C in air, the film OTR was 10.5 pmol s^{-1} m^{-2} Pa^{-1}, as determined following an exponential decay method for determining OTRs through plastic films in a static cell (Moyls et al., 1992). The samples were stored at 5 ± 1 °C and examined at 1, 6 and 12 days. Three packages (six slices) from each of five watermelons (replications) per treatment per evaluation time were evaluated. Three slices from each of four watermelons from each treatment also were placed in sealed 3.8-L glass jars and respiration, as evolved CO_2, and ethylene production rates were measured every 8 h during a 12-day period at 5 ± 1 °C using an automated system (Izumi et al., 1996).

2.4. Quality assessments of packaged watermelon slices

The concentrations of O_2, CO_2 and ethylene in the atmosphere of the sealed trays on day 6 and 12 were measured using gas chromatography (GC) as previously described (Saftner et al., 1999). Gas concentrations are the means of 15 measurements (three trays per replicate × 5 replicates) per treatment.

Texture, cut surface color and pH, SSC, and aromatic volatile concentrations were measured using six slices of each replicate sample from each treatment following 1, 6 and 12 days storage at 5 ± 1 °C under modified atmosphere conditions.