Available online at www.sciencedirect.com
ScienceDirect
Postharvest Biology and Technology 44 (2007) 101–106
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Effects of 1-MCP and hexanal on decay of d'Anjou pear fruit in long-term cold storage

Robert A. Spotts [a,*], Peter L. Sholberg [b], Paul Randall [b], Maryna Serdani [a], Paul M. Chen [a]

[a] *Oregon State University Mid-Columbia Agricultural Research and Extension Center, 3005 Experiment Station Drive, Hood River, OR 97031, USA*
[b] *Pacific Agri-Food Research Centre, Agriculture and Agri-Food Canada, 4200 Highway, 97 Summerland, BC V0H 1Z0, Canada*

Received 27 July 2006; accepted 10 December 2006

Abstract

The objectives of this study were to examine the effect of several rates of 1-MCP from 10 to 100 nL L^{-1} on stem end decay caused by *Botrytis cinerea* and to evaluate the effects of prestorage treatment with 1-MCP, hexanal, and 1-MCP + hexanal on decay of d'Anjou pear (*Pyrus communis* L.) fruit in long-term cold storage. 1-MCP at 300 nL L^{-1} reduced bull's-eye rot and Phacidiopycnis rot. Stem end gray mold also was reduced by 1-MCP at 300 nL L^{-1}, and reduction at rates from 10 to 100 nL L^{-1} was significant in one of two trials. Snow-mold rot was reduced by 1-MCP at 30 nL L^{-1}. Hexanal alone reduced snow mold but increased blue mold caused by *Penicillium expansum*. The combination of 1-MCP and hexanal affected decay similar to 1-MCP. However, hexanal in combination with 1-MCP negated the effect of 30 nL L^{-1} 1-MCP on firmness but did not counteract the effect of 300 nL L^{-1} 1-MCP. Thus, a combination of 1-MCP and hexanal at optimized rates may reduce storage decay, control superficial scald, and allow normal ripening of d'Anjou pear fruit.

Keywords: 1-Methylcyclopropene; Postharvest decay; *Pyrus communis*; *Botrytis cinerea*; *Penicillium expansum*; *Coprinus psychromorbidus*; *Phacidiopycnis piri*; *Neofabraea*

1. Introduction

1-Methylcyclopropene (1-MCP) is a synthetic cyclic olefin that inhibits ethylene by blocking access to the ethylene-binding receptor (Sisler and Serek, 1997). 1-MCP has been used extensively in the apple industry since 2002 to retain fruit firmness in cold storage and extend shelf life. It is marketed as SmartFresh^{SM} by AgroFresh, Inc. (Springhouse, PA).

Pear fruit have been used in studies on the effects of 1-MCP on ethylene biosynthesis, fruit softening, and superficial scald (Ekman et al., 2004; Hiwasa et al., 2003a,b; Kubo et al., 2003; Trinchero et al., 2004). Only one pear study includes the effect of 1-MCP on decay (Argenta et al., 2003). In this research, decay of d'Anjou pear fruit was reduced after 8 months storage at 1 °C by preclimacteric treatment with 100 and 1000 nL L^{-1} 1-MCP but not by 10 nL L^{-1}. The pathogens causing decay in this study were not identified.

When apple fruit were inoculated with *Penicllium expansum* or *Colletotrichum acutatum* then treated with 400–500 nL L^{-1} 1-MCP and placed in controlled atmosphere storage at 0.5 °C for up to 4 months, followed by an additional 2 weeks at ambient temperature, blue mold and bitter rot increased (Janisiewicz et al., 2003). However, decay caused by *P. expansum, C. acutatum*, and *Botrytis cinerea* in apple fruit treated prestorage with 1000 nL L^{-1} 1-MCP decreased when fruit were inoculated after 5 months of storage at 0 °C (Saftner et al., 2003). Poststorage 1-MCP treatment had no effect on decay severity.

Several studies have been done on the effects of 1-MCP on decay of nonclimacteric fruit. On strawberry, 1-MCP at 5–15 nL L^{-1} doubled postharvest life at 5 °C but reduced storage life at concentrations of 50–500 nL L^{-1}. Deterioration was primarily related to decay, but pathogens were not specified (Ku et al., 1999). 1-MCP at 150 and 250 nL L^{-1} slowed disease (mainly Rhizopus rot) of strawberry but increased rot at 500 and 1000 nL L^{-1} (Jiang et al., 2001). In another study with strawberry, the rate of rot (pathogen not identified) development increased after exposure to 10, 100 and 1000 nL L^{-1} of 1-MCP (Bower et al., 2003). Both stem-end rot and mold rot (pathogens not identified) of oranges increased after exposure to 100 nL L^{-1}

* Corresponding author. Tel.: +1 541 386 2030x15; fax: +1 541 386 1905.
E-mail address: robert.spotts@oregonstate.edu (R.A. Spotts).

0925-5214/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.postharvbio.2006.12.003

of 1-MCP (Porat et al., 1999). 1-MCP fumigation of grapefruit infected with *Penicillium digitatum* did not induce any change in disease susceptibility of the fruit (Mullins et al., 2000).

Hexanal is a naturally occurring volatile C-6 aldehyde formed via the lipoxygenase pathway in plants and is a precursor to the formation of alcohols and esters that operate in production of aroma (Hildebrand, 1989). The pathway operates when the plant is wounded and could be important for its defense against natural enemies such as decay-causing fungi. The related volatile, (*E*)-2-hexenal, was first used in postharvest studies for control of *B. cinerea* (Archbold et al., 1999; Fallik et al., 1998; Hamilton-Kemp et al., 1992). However, hexanal was also shown to suppress mold development in early studies conducted on apple slices (Song et al., 1996). Recently Fan et al. (2006) showed that hexanal vapor applied continuously over 48 h reduced decay in apple fruit inoculated with conidia of *P. expansum*. Previously, Sholberg and Randall (2005) had shown that hexanal applied in a manner similar to 1-MCP could also reduce decay in stored apples and pears.

In a preliminary trial with 300 nL L^{-1} 1-MCP, stem end gray mold of d'Anjou pear fruit was significantly reduced from 5.4% in the control to 0.8% (R. Spotts, unpublished). Later, we showed that d'Anjou fruit treated with 50 and 300 nL L^{-1} 1-MCP did not develop superficial scald but also failed to ripen normally. Fruit treated with 10 and 20 nL L^{-1} 1-MCP developed unacceptable scald but ripened normally (Chen and Spotts, 2005). No in-depth studies have been done to examine the effects of the combination of 1-MCP and hexanal on decay of pear fruit.

The objectives of this study were to (1) examine the effect of several rates of 1-MCP from 10 to 100 nL L^{-1} on stem end decay caused by *B. cinerea* and (2) evaluate the effects of prestorage treatment with 1-MCP, hexanal, and 1-MCP + hexanal on decay of d'Anjou pear fruit in long-term cold storage.

2. Materials and methods

2.1. Effect of low rates of 1-MCP on stem end gray mold

d'Anjou pear fruit were surface sterilized with 100 mg of sodium hypochlorite per L and rinsed with tap water. Fruit were stem end inoculated with 2.0×10^6 spores L^{-1} of *B. cinerea* isolate 62 by dipping the stem ends into the inoculum to a depth of about 3 mm. Four replicate boxes containing 19 kg each were treated with 0, 10, 30, 50, 70, and 100 nL L^{-1} 1-MCP. The source of 1-MCP was Smartfresh™ that was formulated as a 0.14% a.i. powder that liberates 1-MCP when added to 40 °C water. Fruit were treated inside a sealed cold storage room or sealed plexiglass chambers inside a controlled temperature storage room. Treatment was at 15 °C for 24 h. The atmosphere inside the room was circulated constantly with a fan. The ability of Smartfresh™ to release the stated amount of 1-MCP was confirmed for higher concentrations by flame ionization gas chromatography as described previously (Chen and Spotts, 2005). However, concentrations below 100 nL L^{-1} could not be verified accurately by this method, and the release rate was assumed to be linear at lower as well as higher concentrations. Treated fruit were stored in wooden boxes with perforated polyliners at −1 °C and evaluated after 3 and 6 months for stem end gray mold. The experiment was repeated with three replicate boxes of fruit per 1-MCP concentration, *B. cinerea* concentration of 4.0×10^6 spores L^{-1}, and fruit evaluated after 3, 6, and 8 months of storage. Disease incidence data were transformed to square root values and analyzed with linear regression analysis using Minitab release 12.1 (Minitab software, Minitab, Inc., State College, PA).

2.2. Semicommercial trials at Hood River, OR, USA and Summerland, BC, Canada

At Hood River, d'Anjou pears were harvested on 7–9 September 2004 and treated the same day, one trial per day. Conidia of *B. cinerea* isolate 62 were harvested from a 14-day-old culture growing on potato dextrose agar acidified with lactic acid, 1.5 mL L^{-1}. Eight milliliters of spore suspension at 1×10^7 CFU L^{-1} were sprayed on the fruit in each replicate box using an airbrush (Paache Airbrush Company, Harwood Heights, IL). Fruit were sealed in 0.35 m^3 plexiglass chambers at 15 °C and treated with (1) 944 μl L^{-1} of hexanal, (2) 300 nL L^{-1} of 1-MCP, and (3) a combination of hexanal and 1-MCP. 1-MCP was generated from Smartfresh powder as described above. Control fruit were inoculated and placed in a plastic chamber but received no 1-MCP or hexanal. After 18 h, fruit were placed in wooden boxes and stored at −1 °C. Each treatment consisted of 3 replications of 19 kg of fruit. A fourth box per treatment of noninoculated fruit was included for measurement of flesh firmness. Flesh firmness was measured using a fruit texture analyzer (Model GS-14, Guss Manufacturing Ltd., Strand, South Africa). Ten fruit per box were tested with an 8-mm plunger that penetrated 9 mm in 0.9 s. Two measurements were obtained per fruit from opposite sides at the equator, where 20 mm-diameter peel discs had been removed. Visual decay and firmness were evaluated immediately after treatment (firmness only) and after 4, 6, and 8 months of storage. After each evaluation, decayed fruit were removed to prevent secondary spread.

At the Pacific Agri-food Research Centre (PARC), Summerland, BC, d'Anjou pears were harvested on 21–23 September 2004 and treated the same day. Fruit were inoculated and treated similarly to Hood River with a few differences. Fruit were inoculated with *B. cinerea* isolate B-27and treated in a 1 m^3 chamber as previously described (Sholberg et al., 1996). The 1-MCP concentration was 30 nL L^{-1}. After treatment, fruit were placed into polylined cardboard boxes with a top pad and lid, and stored at 1 °C. Each treatment consisted of five replications of 18 kg of fruit. One additional box per replicate was used for analysis of fruit firmness. Flesh firmness was determined with a pressure tester (Lake City Technical Products, Model Ept-1, Kelowna, BC, Canada) equipped with a 7.9 mm tip. Fruit firmness was measured immediately after treatment and after 2, 4, 6, and 8 months of storage. Decay was evaluated visually only once after 8 months of storage.

At both locations, each experiment was done three times. Decay and firmness data were transformed to square root values.