Optimal storage temperature and 1-MCP treatment combinations for different marketing times of Korla Xiang pears

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Abstract

Maintenance of green color is the primary indicator of quality in the market evaluation of Korla Xiang pears at present and can generally be achieved through early harvesting and decreasing the storage temperature, but the fruit quality was reduced by early harvesting, and the decreasing storage temperature increased the risk of chilling injury. The objectives of this study were to determine the optimal storage parameters for different storage times and to find ways to preserve the green skin color of pears. Specifically, we analyzed the effects of the ethylene inhibitor, 1-methylcyclopropene (1-MCP), combined with low temperature on quality and maintenance of the green color of Korla Xiang pears during storage. We found that 1-MCP and/or low temperature reduced the loss of green color at 20°C after being removed from cold storage. In addition, 1-MCP significantly inhibited the decline of titratable acid and ascorbic acid but had no significant effect on fruit firmness and total soluble solids. Low temperature with or without 1-MCP inhibited the release of ethylene, inhibited the decline in the stalk preservation index, inhibited the increase in decay rate and weight loss rate during storage, and inhibited the increase in the core browning index after 225 days of storage. Different storage temperatures had different effects on the quality of Korla Xiang pears. Despite inhibiting ethylene release, a storage temperature of –1.5°C increased the respiration rate. Storage at –1.5°C caused core browning early during storage due to chilling injury, whereas at 2°C core browning occurred late during storage due to senescence. In late storage, 1-MCP had no significant effect on the maintenance of Korla Xiang pear quality at 2°C. Based on these results, we determined the optimal combinations of low temperature and 1-MCP treatment to maintain pear quality while avoiding chilling injury. For different marketing times, the optimal conditions for storage until New Year’s Day (a storage duration of 90 days) are 2°C or 1-MCP combined with 2°C. For storage until the Spring Festival (a storage duration of 150 days), the optimal conditions are 0°C or 1-MCP combined with 0°C, and for storage until May (a storage duration of 225 days), the best conditions are 1-MCP combined with –1.5°C.

Keywords: low temperature, 1-methylcyclopropene, Korla Xiang pear, maintenance of green color, quality

1. Introduction

Korla Xiang pear (Pyrus sinkiangensis Yu Korla Xiang), which originated from Xinjiang Uygur Autonomous Region in China, is usually harvested in mid-September. It has many valuable characteristics, such as a thin exocarp, crispy flesh, high juice and sugar content, little endocarp, and rich flavor (Gao et al. 2005). It has a high profit value, high sales, and
the longest marketing duration and is the main pear cultivar exported from China (Jia et al. 2009). According to our continuous tracking study, maintenance of green color is the primary indicator of quality in the market evaluation of Korla Xiang pears at present (Jia et al. 2014). Maintenance of green color is generally achieved by early harvesting and decreasing storage temperature, but early harvesting results in poor fruit quality and storage at a low temperature near freezing eventually results in chilling injury.

The ethylene inhibitor, 1-methylcyclopropene (1-MCP), is broadly used in the preservation of fruit and vegetables for several reasons. First, 1-MCP inhibits the decline in fruit firmness, thus extending the storage life (Sun et al. 2003; Li et al. 2004; Sisler and Serek 2010; Wang et al. 2015). Second, 1-MCP inhibits the occurrence of disorders such as superficial scald (Gago et al. 2013, 2015; Gao et al. 2015; DeEll et al. 2016; Zhou et al. 2017) and core browning (Villalobos-Acuna et al. 2011a, b; Wang et al. 2011). Third, 1-MCP induces disease resistance against fungal pathogens (Jiang et al. 2001; Zhang et al. 2012). Finally, it can slow down the degradation of chlorophyll, thus keeping the fruit surface bright (Golding et al. 1999; Cheng et al. 2012; Fernández-León et al. 2013). However, 1-MCP treatment also inhibits the production of aromatic volatile compounds, particularly esters, which is an important index used to evaluate the quality of climacteric fruits (Argenta et al. 2003; Rizzolo et al. 2005; Zhou et al. 2015; Li et al. 2016). The effects of 1-MCP in combination with other treatments such as a modified or controlled atmosphere (Anna et al. 2014), maturity (Jia et al. 2014), and Ca++ (Gago et al. 2016), etc., have also been studied. The control of fruit and vegetable ripening by 1-MCP is affected by plant-related factors, such as species, cultivar and maturity of fruit at harvest, and external factors, such as treatment temperature and duration and delays between harvest and time of treatment (DeEll et al. 2002; Watkins 2006, 2008; Jia et al. 2014).

Temperature is an important environmental factor that affects the quality of fruits during storage. Low-temperature conditions can result in the increased production of esters and fruity flavor attributes (Makkumrai et al. 2014) and inhibition of microbial growth (Yamane 1982), contrarily on the other hand it can cause many problems, mainly including superficial scald (Hu et al. 2004; Rizzolo et al. 2014), flesh browning (Kou 2001; Cantin et al. 2010), core browning (Wang et al. 2014; Zhou et al. 2014) and abnormal softening (Wang et al. 2005). The effects of 1-MCP depend on temperature; the susceptibility to some disorders that are thought to be related to chilling injury appears to be increased by 1-MCP treatment during low temperature storage (Watkins et al. 1995; Watkins 2006). Treatment with 1-MCP strongly inhibits softening, yellowing, soft scald and internal breakdown in Abate Fetel pears stored at –0.5°C, regardless storage atmosphere and time. But 1-MCP-treated pears stored at 1°C developed soft scald in a control atmosphere, although the severity was slight and the fruits were still marketable (Vanoli et al. 2016).

In this study, we analyzed the effects of 1-MCP combined with low temperature on the quality of Korla Xiang pears during storage. The research objectives included determining the optimal combination of storage temperature and 1-MCP treatment for different marketing times, and to solve issues related to the storage of Korla Xiang pears, such as poor fruit quality and chilling injury due to early harvesting and decreasing storage temperature, respectively.

2. Materials and methods

2.1. Fruit materials and treatments

Pear (Pyrus sinkiangensis Yu Korla Xiang) fruits were harvested at commercial maturity from an orchard in Korla County, Xinjiang Uygur Autonomous Region, China on 15th September 2015. After being harvested, these fruits were immediately transported to the Research Institute of Pomology, Chinese Academy of Agricultural Sciences, in Liaoning Province. It took 3 days to transport the pears by air and land transportations. Fruits were of uniform size and without physical injuries or infections. The average fruit firmness from 20 randomly selected fruits was 52.23 N as determined by a fruit texture analyzer (GS-15, GÜSS, South Africa), and the total soluble solids (TSS) content was 13.07% as determined by a digital refractometer (PR-101α, ATAGO, Japan).

The fruits were enclosed in a plastic container (500 L) and treated with 0.03125 g 1-MCP (Yuer, Hangzhou, China), which was obtained by dissolving a commercial powder in sterile distilled water to a concentration of 1.0 μL L⁻¹. An equal volume sterile water was used as a control. The fruit were treated for 20 h at 15°C and then randomly divided into three groups. The fruits (20 kg) were packed in a single unsealed plastic bag to maintain a high relative humidity (90–95%), and then put into plastic trays and stored at −1.5, 0 and 2°C, respectively. The fluctuations in temperature of the surrounding environment remained in the range from −0.3 to 0.3°C.

After storage for 90, 150 and 225 days, respectively, 15 pears per treatment (1-MCP/storage temperature) were analyzed for skin color, chlorophyll fluorescence parameters, firmness, TSS, titratable acidity, ascorbic acid content, cellular membrane permeability and malondialdehyde content. Ethylene production and respiration rate were measured for 18 fruits (6 fruits per plastic box, 3 boxes per treatment) at the 1st, 3rd, 5th and 7th day of storage at 20°C.
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