Use of a potassium permanganate ethylene absorbent to maintain quality in 'Golden Delicious' apple during ULO cold storage

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Abstract

Apple (*Malus domestica*) is a well-known climacteric fruit and it is generally accepted that ethylene plays a crucial role in apple fruit ripening and senescence. Even though the ethylene inhibitor 1-MCP is a well-stablished and effective tool to prevent the negative effects of ethylene accumulation in apple cold storage, the development of alternative technologies is of great interest, especially those usable in organic fruit and able to keep high eating quality. This paper assessed the use of a potassium permanganate ethylene absorbent (Bi-On®, Bioconservacion SA, Spain) in maintaining quality of apple (cv. 'Golden Delicious') held under ULO cold storage (0.5ºC, 1.5% O_2, 1% CO_2, 85-90%HR) for 6 months. The obtained results show that the inclusion of the potassium permanganate absorbent significantly reduced ($p<0.05$) the fruit ethylene production, the loss of firmness, the loss of sugar content and the development of senescence scald. Hence, this system can be regarded as an effective method to maintain apple quality during cold storage. The high rate of ethylene production of apple is a challenge for the practical application of potassium permanganate absorbents, but it can be overcome using already existing innovative air filtration equipment.

Key words: firmness, senescence scald, sugar content, air filtration equipment.

Introduction

Apple (*Malus domestica*) is a well-known climacteric fruit. Ethylene plays an important role in regulating fruit ripening and senescence and directly influences the development of the eating quality of fresh apples, including appearance, colour, texture, and flavour.

The ethylene inhibitor 1-MCP is a well-stablished and effective tool to prevent the negative effects of ethylene accumulation in apple cold storage. However, despite its considerable benefits, this technology has also some weaknesses and it is not allowed in organic fruit (Watkins, 2006). In addition, 1-MCP treated apples have been shown to retain volatiles and develop less fruity, ripe and aromatic than untreated apples (Song *et al*, 1997; Kondo *et al*, 2005). Therefore, the development of alternative technologies usable in organic fruit and able to keep high eating quality, such as potassium permanganate ethylene absorbents, is of great interest.

A reduction of ethylene with a potassium permanganate absorbent was reported to significantly maintain firmness and prolong the storage period of 'Gala' apple stored in CA conditions (3%CO_2-1%O_2 at 1ºC), while keeping the fruit crisp, juicy and with greener ground colour and excellent appearance and taste (Brackmann & Saquet, 1999). In 'McIntosch' apples, a reduction of ethylene with a potassium permanganate absorbent was reported to maintain firmness and reduce the incidence of core browning (Forsyth *et al*, 1969). The use of potassium permanganate to remove ethylene during storage in static controlled atmosphere conditions retarded softening, accumulation of α-farnesene and earlier onset of superficial scald in 'Bramley's Seedling' apple kept in 5%CO_2-3%O_2 and in 9%CO_2-12%O_2 (Knee & Hatfield, 1981). Stow & Genge (1990) reported that the effects on the retention of flesh firmness by both, ethylene removal and storage in 0.75% O_2, were generally additive in apples cv 'Cox´s Orange Pippin'.

The aim of this research was to assess the efficacy of a reduction of ethylene with a potassium permanganate absorbent on the quality of 'Golden Delicious' apple held under ULO conditions (1.5%O_2-1%CO_2, at 0.5ºC) for 5 months followed by 14 days at normal air (0.5ºC) and 7 days at 18°C to simulate marketing.

Materials and Methods

Materials. 1 bin of apples (cv. 'Golden Delicious') was harvested on 16th September 2015 from a plantation belonging to *La Morinière* Experimental Station located in Saint Epain, France. The fruit was transported immediately to the Experimental Station. All fruit were harvested at the same time and had the following characteristics: 4.5 (starch regression), 3.5 (back ground colour), 7.1 kg*cm^{-2} (firmness), 11.4% Brix (sugar content) and 6.6 g*L^{-1} (malic acid content).

Ethylene reduction was achieved with a commercial absorbent consisting of an extruded product of a clay-mineral base impregnated with potassium permanganate (Bi-On®, Biconservacion SA, Barcelona, Spain). The absorbent was applied in the cold stores by including it in a commercial air filtration machine (ETHV-425/2, Bioconservacion SA) (operating conditions: fan speed 425 m^3 h^{-1}, 240 Watts, 50kg absorbent). During the air filtration process, the absorbent does not come in contact with the stored fruit.

Experiment details. On arrival at the laboratory, the apples were randomized in 16 boxes (approximately 800 fruits) and distributed in 2 treatments with 8 replicates (8 boxes, 400 fruits approximately) per treatment. A batch of 20 randomly selected fruits was used to assess the initial quality.

8 boxes were stored in Room A ('Ethylene removal'= Treatment 1) and 8 boxes were stored in Room B ('Control'= Treatment 2). Room A and Room B were two identical cold stores (90 m^3, 20 Tn) located in the same cold room block and settled at ULO conditions (1.5%O_2 and 1 %CO_2, at 0.5ºC and 90-95%RH). The ethylene removal equipment was placed directly under the cooling unit and behind the main door in Room A.

The fruit were stored in the cold store for 5 months and a half (from 16th/September 2015 to 1st/March/2016) under ULO conditions followed by 14 days at normal air (0.5ºC) and 7 days at 18ºC. Room A was opened 3 times during the cold storage to replace the ethylene absorbent.

Fruit Quality Assessment. Fruit quality assessment was conducted at harvest, 24 hours after breaking the ULO conditions ('end-ULO'), after the 14 days of normal cold ('end-ULO+14d') and after the 7 days at 18ºC ('end-ULO+14d+7d'). Starch regression, back ground colour, firmness, sugar level and malic acid were evaluated in 4 repetitions of 15 fruits. Fruit ethylene production at room temperature was evaluated in 4 repetitions of 6 fruits. Fungal and physiological disorders were evaluated in all the fruit.

Starch regression and background colour were evaluated using Ctifl charts ('1 to 10' and '1 green to 8 yellow', respectively). Firmness (kg*cm^{-2}), content of sugar (% Brix) and acidity (g*L^{-1}, malic acid) were obtained by means of an automated fruit analyzer ('Pimprenelle', Setop Giraud Technology, Cavaillon, France).

Ethylene production by the fruit at room temperature was measured by introducing a known weight of fruit inside an airtight jar of a known volume and measuring the ethylene concentration at time 0 and after 2 hours. The results were expressed in µL ethylene per kg of fruit per hour (µL*kg^{-1}*h^{-1}).

The incidence of internal and external decay and physiological disorders was visually assessed.

Ethylene measurement. Each cold store was provided with a gas sampling port and the concentration of ethylene was measured with a portable instrument (**EASI-2** Ethylene Analyzer, Absoger, France) every 7-10 days. The limit of detection of the method was 0.01 $\mu L\ L^{-1}$ ethylene.

Statistics. R statistical programs (Statbox logiciel) were used. The variables were analysed by analysis of variance and the test of least significant difference (LSD) ($p = 0.05$) was used to evaluate differences between mean values.

Results and Discussion

The inclusion of the ethylene absorbent significantly reduced ($P<0.05$) the fruit ethylene production at room temperature (Figure 1), the loss of firmness (Figure 2), the loss of sugar content (Figure 3) and the development of senescence scald.

Analysis of variance showed a significant difference between treatments at 'end-ULO' ($P<0.05$) in firmness, at 'end-ULO+14d' ($P<0.05$) in firmness and sugar content, and at 'end-ULO+14d+7d' ($P<0.05$) in firmness, sugar content and fruit ethylene production. Firmness and sugar content were kept significantly higher ($P<0.05$) and fruit ethylene production was significantly lower ($P<0.05$) in the fruit stored with the ethylene absorbent. No significant differences were found in acidity (Figure 3) nor in background colour (data not shown).

Symptoms of senescent scald were only detected in fruit stored without the ethylene absorbent. 1.5% of the fruit of the control presented this disorder after 'end-ULO+14d+7d'. Decay was not observed in the fruit for any of the treatments.

There is no data available in the literature concerning the effects of potassium permanganate ethylene absorbents in 'Golden Delicious', but the obtained results in firmness retention are in line with those reported for other apple varieties such as Gala (Brackman & Saquet, 1999), McIntosh (Forsyth *et al*, 1969) or Bramley's Seedling (Knee & Hatfield, 1981).

Figure 4 shows the evolution of the concentration of ethylene in both cold stores during the ULO storage. In Room B (control) ethylene started to accumulate virtually immediately, whereas in Room A, the presence of the ethylene absorbent delayed the rapid build-up of ethylene during the whole conservation period. In contrast to the obtained results, Knee *et al* (1981) reported that the rapid build-up in ethylene concentration during controlled atmosphere storage ($3\%O_2$-$5\%CO_2$) of 'Golden Delicious' apple can be delayed for about 40 days by inclusion of a potassium permanganate but nevertheless it cannot be completely prevented. The difference in atmospheric conditions between these two treatments may explain the different results.

Even though ethylene did not rapidly build-up in Room A, the absorbent could not maintain, despite the 3 replacements, the concentration of ethylene at low levels (< 2 ppm) during the whole period and the level of ethylene slowly raised up to a final level of 12 ppm. It is somehow surprising that, in spite of that, a clear benefit in fruit quality was obtained. This may be due either to a higher ethylene sensitivity threshold of 'Golden Delicious' apple or to the cumulative beneficial effects of exposure to low levels of ethylene during the first months.

The high rate of ethylene production of 'Golden Delicious' apple during ULO cold storage is a challenge for the practical application of potassium permanganate absorbents due to the large amount of absorbent required. However, this challenge can be overcome (especially in other apple varieties producing less ethylene) using innovative equipment which allows either the inclusion of high amounts of absorbent inside the cold store or an easy replacement during storage. This kind of equipment is already available (Bioconservacion SA, Barcelona, Spain) and applied under commercial conditions in various apple varieties and atmospheric conditions.

Conclusion

The technology of ethylene absorption with commercially existing potassium permanganate absorbents such as Bi-On® is an effective method to maintain apple quality during cold storage. The high rate of ethylene production of apple is a challenge for the practical application of potassium permanganate absorbents, but it can be overcome using already existing innovative air filtration equipment.

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Tables and Figures

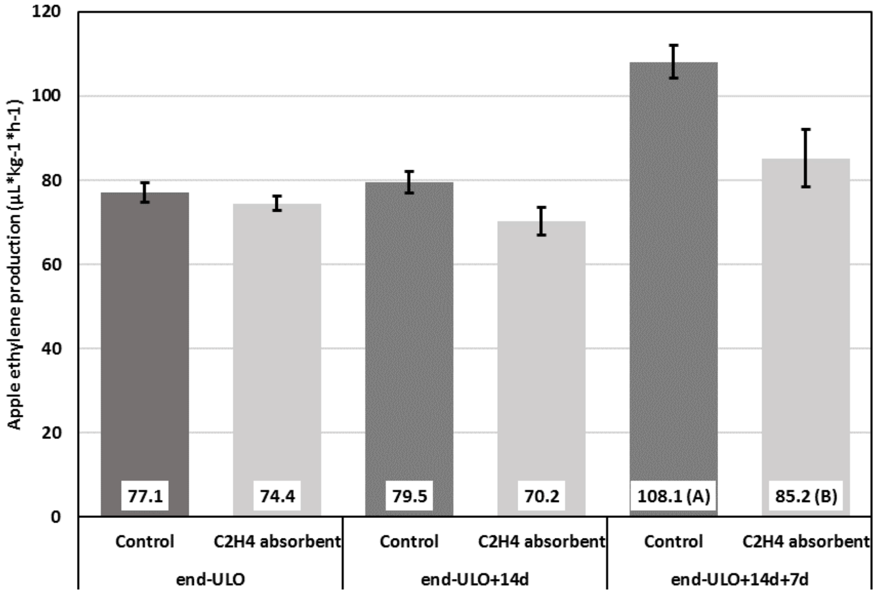

Figure 1. Ethylene production by the fruit at room temperature after cold storage in ULO, after 14 days in normal cold and after 7 days at 18ºC. Each value is the mean of 24 fruit (4 repetitions of 6 fruit). Different letters within the same column indicate significant differences at p=0.05.

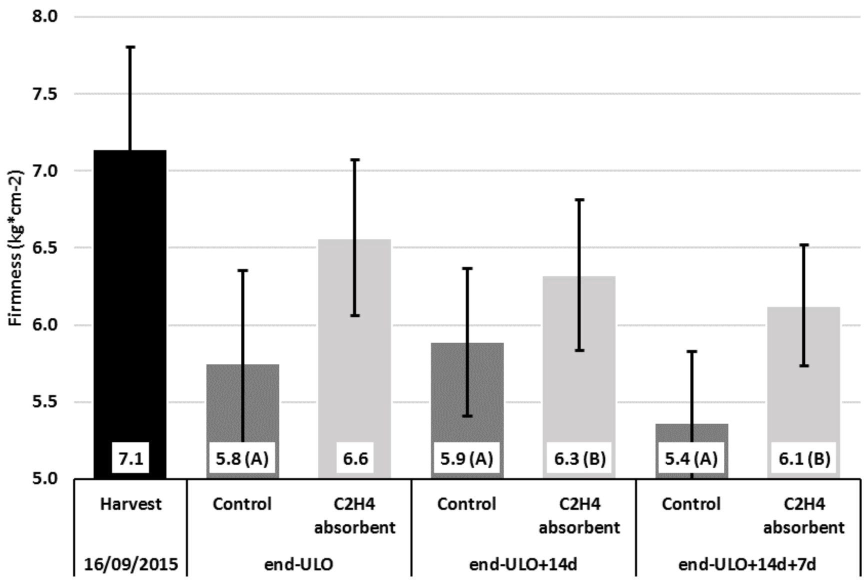

Figure 2. Fruit firmness after cold storage in ULO, after 14 days in normal cold and after 7 days at 18ºC. Each value is the mean of 80 fruit (4 repetitions of 20 fruit). Different letters within the same column indicate significant differences at p=0.05.

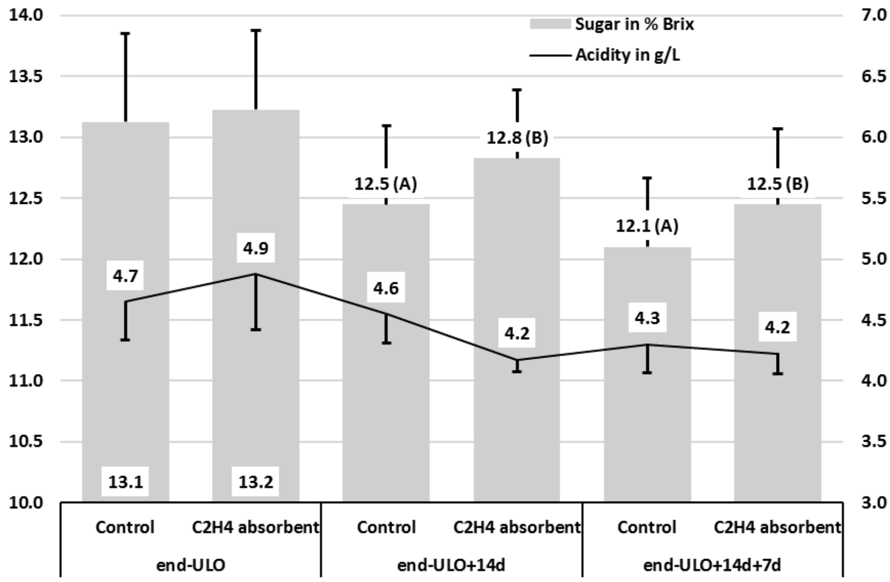

Figure 3. Sugar content and acidity (acid malic content) of the fruit after cold storage in ULO, after 14 days in normal cold and after 7 days at 18ºC. Each value is the mean of 80 fruit (4 repetitions of 20 fruit). Different letters within the same column indicate significant differences at p=0.05.

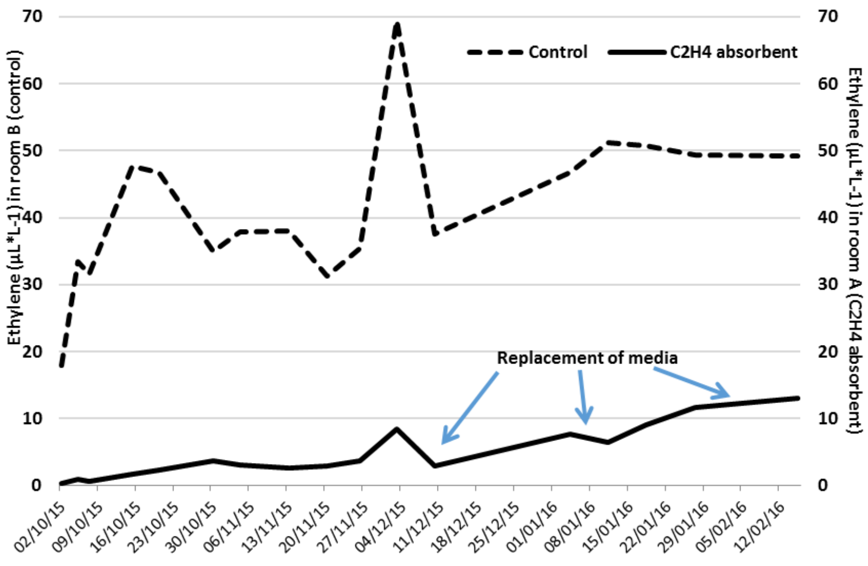

Figure 4. Concentration of ethylene in the two rooms of the assay during the ULO cold storage.