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AKADÉMIAI KIADÓ

# Application of ethylene for ripening of 1-MCP treated pear after cold storage

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## SHORT COMMUNICATION

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## ABSTRACT

This work aimed to evaluate the effect of ethylene treatment on ripening of 1-MCP treated pear after 6 months of cold storage. Pear treated with gaseous 1-MCP at 625–650 ppb for 24 h at 0 °C was stored at 0 °C for 6 months with normal air, and treated groups were exposed to 100 ppm ethylene at 20 °C for 24 h. After that, samples were kept at 0, 10, and 15 °C for 2 weeks. Stiffness, chlorophyll fluorescence, ethylene and $CO_2$ production of fruit were investigated during 2 weeks. Application of ethylene resumed the ripening of pear after long term storage. The results showed that fruit treated with ethylene achieved more homogeneous surface colour in comparison with non ethylene treated pears. In addition, the ethylene and carbon dioxide production of ethylene treated pears had higher values than that of control. The ethylene treatment could accelerate the softening of pear. Temperature also has significant effect on ripening during storage. This study found that ethylene treatment could accelerate the normal ripening of 1-MCP treated pears.

## KEYWORDS

postharvest, shelf-life, storage temperature, *Pyrus communis* L.

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# 1. INTRODUCTION

Maintaining pear freshness over a long period is always challenging. Consumers expect fruit to be available months beyond harvesting period. 1-methylcyclopropene (1-MCP) treatment can block ripening for long time, sometimes resulting in the evergreen behaviour. To ensure that ripening can reboot after long storage, increased storage temperature and ethylene gas are applied (Dias et al., 2021). Many pear cultivars can be stored for months with optimal conditions such as controlled, modified, or ultra-low oxygen atmosphere combined with low storage temperature (Dias et al., 2021). The benefit of 1-methylcyclopropene (1-MCP) treatment was tested on many European pear cultivars and the result was affected by many factors including maturity stage, 1-MCP concentration, time of application, and the cultivar (Zhao et al., 2020; Dias et al., 2021). The positive role of ethylene is in ripening horticultural produces. The negative effect of ethylene is to induce rapid aging in overripe fruit.

Using an ethylene inhibitor can prevent and slow the unpleasant senescence process regarding the firmness of pear (Hiwasa et al., 2003). Extending harvested fruit quality with 1-MCP treatment has been widely studied for apple, plum, pear, and melon (Blankenship and Dole, 2003; Hitka et al., 2014; Nguyen et al., 2016).

Treatment with 1-MCP can cause storage disorders for sensitive fruit during shelf-life, such as ripening blockage and internal disorder (Saquet, 2019). Application of 1-MCP on pear (*Pyrus communis* L.) with 50 nL $L^{-1}$ at –0.5 °C for 24 h, followed by subsequent controlled atmosphere (CA) and normal atmosphere (NA) storage for 7, 14, and 22 weeks decreased ethylene production and maintained fruit firmness (Rizzolo et al., 2015). In some cases, treated pears after storage could not continue the natural ripening, since ethylene plays a critical role in regulating the fruit's biochemical processes (Hiwasa et al., 2003). Researchers investigated ripening process and physiological disorders of pears treated with 1-MCP (Dias et al., 2021). Storing pear ('Abate Fetel') in CA at −0.5 °C and NA at 1 °C showed that 1-MCP treatment was able to maintain firmness and colour, especially in CA up to 28 weeks (Rizzolo et al., 2015). Pear stored in CA showed low incidence of storage disorders and less senescence (Vanoli et al., 2016). Softening can be controlled by temperature management and application of low doses of ethylene and 1-MCP gases (Argenta et al., 2003; Ekman et al., 2004; Zhao et al., 2020). Pears of 'Comice' were able to resume ripening processes after low concentration 1-MCP treatment (0.15 μL $L^{-1}$) but failed at high concentration (0.3 μL $L^{-1}$) (Zhao et al., 2020). According to the literature, the adverse effect of 1-MCP on the fruit to resume normal ripening is highly cultivar dependent (Dias et al., 2021).

Cultivar 'Kieffer' was chosen due to the interest of growers and limited information in the literature. The main goal of this study was to investigate the effect of ethylene on the ability of pear previously treated with 1-MCP, to resume normal ripening after long term storage.

# 2. MATERIALS AND METHODS

## 2.1. Materials

'Kieffer' pears (*P. communis* L.) were collected at a green colour from an experienced grower (Soltvadkert, Hungary, at geographical coordinates 46°33′46.3″N 19°23′49.2″E) in 26th September, 2019. Fruit were selected with C2 class based on commercial colour scale (CITFL, France). Harvested fruit was transported to the laboratory of the university in Budapest, Hungary. Fruit were randomly divided into groups of 20 per group. The length and diameter of fruit were measured with a calliper. The average length was 81 mm and the diameter was 62 mm. Because non-destructive measurements were applied in the experiment, all pieces were subjected to measurement at each interval.

1-MCP (SmartFresh®, AgroFresh, Philadelphia, USA) as an application of SmartFresh® system was provided by Rohm and Haas Polska Sp.z.o.o.

## 2.2. Treatment with 1-MCP

The treatment with 1-MCP was performed according to Nguyen et al. (2018). Samples were carefully checked to be free from external damage. Fruit was cooled to 0 °C before 1-MCP treatment. Pear was treated with 625–650 ppb gaseous 1-MCP (standard commercial application rate) for 24 h in an air-tight chamber at 0 °C, and then samples were stored at 0 °C for 6 months in normal air chamber.

## 2.3. Ethylene treatment

After 6 months of storage, samples were removed from the chamber and randomly divided into 6 groups including three ethylene treated groups and three non-ethylene treated groups. Each group had 20 fruit pieces. Three groups were treated with 100 ppm ethylene at 20 °C for 24 h. During the 24 h of ethylene treatment, three non-ethylene treated groups were kept at 20 °C. The three non-ethylene treated groups served as control. All groups were stored at 3 different temperatures including 0 °C, 10 °C, and 15 °C for 14 days.

## 2.4. Measurements

The quality parameters of pear at harvest were measured according to Hitka et al. (2014).

During storage, the measurements were performed according to Nguyen et al. (2018, 2020) and Zsom et al. (2014, 2020). Measurements were carried out at 20 °C on day 0 (before ethylene treatment), 7, and 14 of storage.

***2.4.1. Ethylene production.*** Ethylene production was determined by an ICA-56 hand-held ethylene analyser (International Controlled Atmosphere Ltd., UK). Fruit were withdrawn from cold storage and measurement took place at ambient temperature. Samples were placed in a hermetically closed plastic container of 4 L for 1 h before the measurement was performed in triplicates. Results were expressed in $\mu L\ kg^{-1}\ h^{-1}$ on a fresh weight basis.

***2.4.2. Respiration rate.*** Carbon dioxide production over an hour in a closed respiratory system was measured. The system was built with hermetically closed acrylic sheet containers equipped with FY A600−CO2H carbon dioxide sensors (Ahlborn Mess-und Regelungstechnik GmbH, Germany). An Almemo 3290-8 data logger (Ahlborn Mess-und Regelungstechnik GmbH, Germany) recorded the measured data. Results were expressed in millilitre of $CO_2$ produced per kilogram of fruit for 1 s ($mL\ kg^{-1}\ s^{-1}$).

***2.4.3. Acoustic firmness (Stiffness).*** The acoustic firmness of samples was estimated using the acoustic vibration method and expressed as the parameter Stiffness (S, $g^{2/3}\ s^{-2}$). Stiffness of the samples was determined at 3 points of each fruit, using an instrument of type AWETA AFS DTF V0.0.0.105 (AWETA, Nootdorp, The Netherlands).

***2.4.4. Chlorophyll fluorescence parameters.*** Chlorophyll fluorescence parameters were determined at three points of each fruit by a PAM WinControl-3 controlled MONI-PAM multi-channel chlorophyll fluorometer (Heinz Walz GmbH, Germany). The recorded data were the minimal and maximal chlorophyll fluorescence ($F_0$, $F_m$) and potential quantum yield of the photosystem II ($F_v/F_m$).

## 2.5. Statistical analysis

Measured readings were processed using IBM SPSS Statistics (version 24, IBM Inc, New York, USA) software. Analysis of variance (Two-way ANOVA) was performed using factors treatment and time, followed by Tukey's method with significance level of $P < 0.05$. The results are presented in figures with mean and standard deviation.

# 3. RESULTS AND DISCUSSION

The initial quality parameters of pear are shown in Table 1. Samples without 1-MCP treatment served as reference. Those fruit were also measured but data are not presented or compared due to the rapid deterioration after 4 months of cold storage at 0 °C.

Figure 1 shows the ethylene production of all samples over the storage periods. Ethylene treatment increased the ethylene production of samples, the ethylene production of control samples increased gradually during 14 days of storage.

This work showed that the three groups treated with ethylene had higher values in ethylene production compared to the control groups. Storage temperature also affected the ethylene production of both ethylene treated and non-ethylene treated samples. The combination of ethylene treatment and storage at 15 °C could trigger the ripening more rapidly than other treatments. Fruit stored at low temperature had lower ethylene production in case of ethylene treated groups and non-ethylene treated group as well. 1-MCP treated pear stored at 0 °C had only minor change in ethylene production. The importance of cultivar was observed in comparison with the green and red 'Anjou' pear (Xie et al., 2016). In case of green 'Anjou' pear, the 1-MCP inhibited ethylene production and therefore inhibited ripening capacity development during long term storage. In contrast, red 'Anjou' pear was able to increase internal ethylene concentration and ethylene production rate (Xie et al., 2016). These results also confirm that response to 1-MCP treatment is highly dependent on the cultivar.

*Table 1.* Pear quality parameters at harvest

| | Flesh firmness (*N*) | Soluble solid content (%) | Black seed (%) | Ethylene production (μL kg$^{-1}$ h$^{-1}$) | Carbon dioxide production (mL kg$^{-1}$ h$^{-1}$) | Starch index | Colour index |
|---|---|---|---|---|---|---|---|
| Initial fruit | 82.45 ± 3.90 | 12.11 ± 0.66 | 5.00 ± 5.28 | 1.56 ± 0.87 | 2.35 ± 0.67 | 3.57 ± 0.48 | 2.00 |

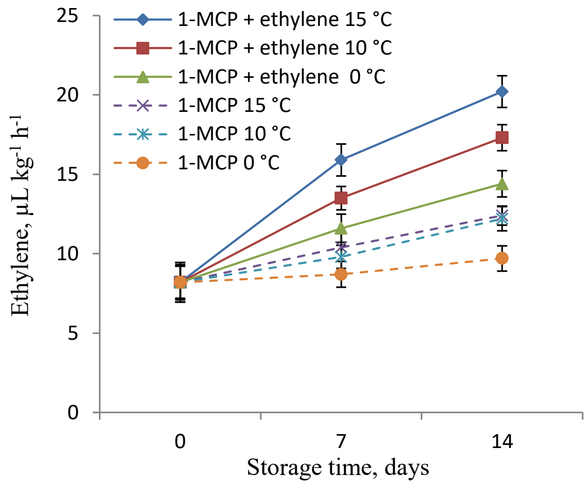


*Fig. 1.* Effect of ethylene treatment on ethylene production of pears during 14 days of storage

The results of respiration rate are shown in Fig. 2. Similarly, the carbon dioxide production was also affected by ethylene treatment.

In this work, the results showed that the respiration of ‘Kieffer’ pear treated with 1-MCP and ethylene rose rapidly over 2 weeks of storage, whereas the $CO_2$ production of 1-MCP treated fruit had minor changes. Similarly, ‘Conference’ pear treated with 1-MCP also showed constant low respiration rate (Brandes and Zude-Sasse, 2019). Other report indicated that 1-MCP treated red ‘Anjou’ pears only increased ethylene production and respiration rate after 6–7 months of

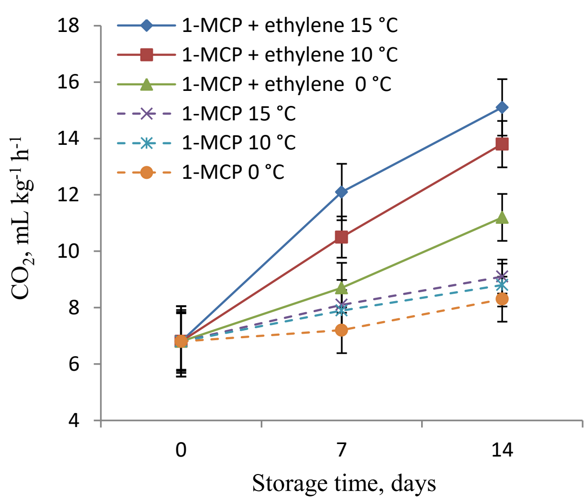


*Fig. 2.* Effect of ethylene treatment on carbon dioxide production of pears during 14 days of storage

cold storage when receiving post-storage ethylene treatment (Xie et al., 2016). Those authors also found that 1-MCP inhibited respiration of red 'Anjou' even at storage at 20 °C following the 7 months of storage at –1 °C.

Figure 3 presents the acoustic firmness of pear over the storage period. Stiffness of pears decreased during the 14 days of storage for all samples but at different rates. Storage temperature strongly affected the acoustic firmness of fruit. Samples kept at 0 °C had higher value in acoustic firmness for both ethylene and non-ethylene treated groups compared to that at 10 or 15 °C. There was a prompt decline in stiffness when fruit were kept at high temperature. At the end of the experiment, the ethylene treated pears stored at 15 °C had the lowest value. Also, 1-MCP treated 'Barlett' and 'd'Anjou' pears successfully resumed ripening with increased storage temperature of 20 °C for 10 days or 10 °C for 20 days (Bai et al., 2006). Contrasting result was obtained by Rizzolo et al. (2014), since 7 days of shelf-life at 20 °C was not sufficient to resume ripening process for 1-MCP treated 'Abbé Fétel' cultivar (Dias et al., 2021). Effectiveness of the treatment depends on cultivar and increased temperature alone cannot induce ripening in some cases.

Softening of the fruit is due to the biochemical processes during ripening (Dias et al., 2021). In this work, pear receiving post-storage ethylene application was lower in firmness compared to 1-MCP treated fruit. The application of ethylene could restart the normal ripening of fruit (Hiwasa et al., 2003), whereas non-ethylene treated samples ripened unevenly. An explanation can be that during long term storage new receptors were formed, and the ethylene combined with the new receptors induced the ripening. In addition, the ability to generate new receptors is highly cultivar dependent (Blankenship and Dole, 2003).

External ethylene fumigation was successfully used to resume ripening of 1-MCP treated 'Conference' pear, but the ethylene treatment did not significantly induce ripening in 1-MCP treated 'Bartlett' pears (Trinchero et al., 2004). In another case, exogenous ethylene treatment only showed effect after 8 months for 1-MCP treated 'd'Anjou' fruit when those began to ripen (Argenta et al., 2003). According to the review of earlier studies, the effect of ethylene application depends on cultivar. Thus, in some cases, the concominant use of 1-MCP and ethylene is recommended to maintain good quality for long term of storage with 1-MCP and ripening

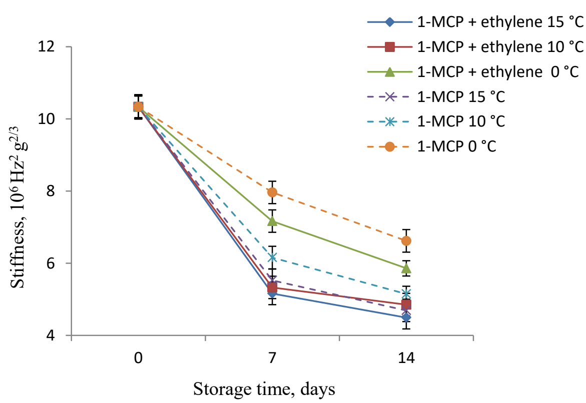


*Fig. 3.* Effect of ethylene treatment on stiffness of pears during 14 days of storage

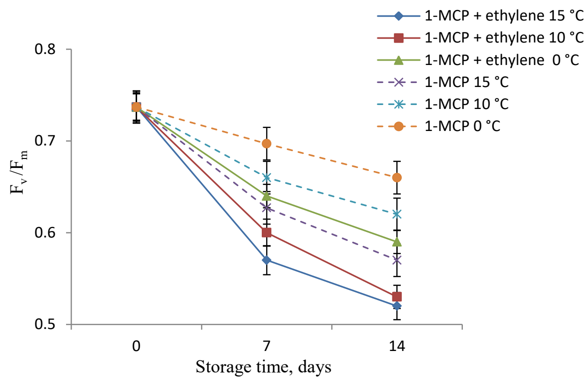


*Fig. 4.* Effect of ethylene treatment on $F_v/F_m$ of pears during 14 days of storage

recovery after removal from chamber (Dias et al., 2021). Earlier study also found that ‘Packham’s Triumph’ and ‘Conference’ pears treated with 1-MCP and ethylene gas at the same time softened slower than control fruit without treatment (Cucchi and Regiroli, 2011; Chiriboga et al., 2011). Cucchi and Regiroli (2011) also observed that 1-MCP alone inhibited the softening of ‘Packham’s Triumph’ and ‘Conference’ pears. Combined treatment of 1-MCP and exogenous ethylene showed firmness loss in ‘Conference’ pear, but the fruit were still firmer than control fruit without treatment (Chiriboga et al., 2011).

Changes of chlorophyll fluorescence parameters are shown in Fig. 4. As can be seen, the chlorophyll fluorescence parameter decreased over storage time. There was a significant decline in $F_v/F_m$ when ethylene treated samples stored at 10 °C and 15 °C were compared to other groups, while $F_v/F_m$ of samples without ethylene treatment stored at 0 °C or 10 °C changed gradually over 14 days of storage. The chlorophyll content in ethylene treated pear decreased dramatically probably due to ripening recovery. Treatment with 1-MCP slowed the chlorophyll degradation by inhibiting ethylene production and preventing the expression of chlorophyll degradation genes (Zhao et al., 2020). Post-storage ethylene application rebooted the normal ripening of ‘Kieffer’ pear. Additionally, high storage temperature also could accelerate ripening.

Pear skin lost its greenness and its yellowness increased during 14 days of storage. Turning from green to yellow skin is often the sign of ripening (Zhao et al., 2020). The combination of ethylene treatment and high storage temperature accelerated the colour change of pear over 14 days of storage. The results also showed significant loss in chlorophyll content of ethylene treated pear at the end of measurement, because fruit reached advanced ripening stage. Similar result was obtained by Chiriboga et al. (2011) for ‘Conference’ pear, as fruit treated with 1-MCP and ethylene became more yellow compared to 1-MCP treated samples. Chlorophyll fluorescence parameters measured in this study were consistent with other studies, and confirmed the effect of ethylene treatment on the ripening of ‘Kieffer’ pear.

## 4. CONCLUSIONS

Presented study evaluated the combination of increased storage temperature and exogenous ethylene to provide information about the effect of ethylene on 1-MCP treated ‘Kieffer’ pears.

The findings have practical importance, since commercial application of 1-MCP may result in completely blocked ripening and loss of value. The 1-MCP treated pears of 'Kieffer' cultivar after 6 months of cold storage could resume normal ripening more rapidly when exposed to ethylene. Ripening time after opening the long-term storage depends on temperature. The fastest ripening was observed at 15 °C with ethylene gas. However, further study is required to optimise the parameters of ethylene application by means of concentration, treatment time and temperature for specific fruits.

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