REVISTA ELETRÔNICA CIENTÍFICA DA UERGS

Evaluation of the application of 1-methylcyclopropene on the quality parameters of 'Kieffer' pears during cold storage

Rodanes Cavalli
Universidade de Caxias do Sul, Brasil
E-mail: rcavalli@ucs.br, Orcid: https://orcid.org/0009-0002-2097-0939

Wendel Paulo Silvestre
Universidade de Caxias do Sul, Brasil
E-mail: wpsilvestre@ucs.br, Orcid: https://orcid.org/0000-0002-9376-6405

ISSN 2448-0479. Submetido em: 25 out. 2024. Aceito: 20 out. 2025.
DOI: http://dx.doi.org/10.21674/2448-0479.111.22-31

Abstract

Pears are an important fruit species whose cultivation and consumption have recently grown in Brazil. Among the pear cultivars produced in Brazil, the 'Kieffer' pear, also known as 'hard pear', is prominent, particularly in Serra Gaúcha and Rio Grande do Sul. Due to their seasonal characteristics, pear production often requires storage to ensure year-round supply. However, in many situations, refrigerated storage alone is insufficient to maintain fruits quality during conservation. Consequently, the use of 1-methylcyclopropene (1-MCP) as a fruit ripening inhibitor is increasing. This study aimed to evaluate the effect of applying increasing doses of 1-MCP on the conservation and quality parameters of 'Kieffer' pears stored under refrigeration. The experiment was conducted in Caxias do Sul, RS, between April and August 2024. Treatments consisted of zero, 50%, 100%, 150%, and 200% of the 1-MCP dose recommended for the crop. Following 1-MCP treatment, the pears were stored for 120 days in a cold chamber. Subsamples from each treatment were taken monthly until the end of the storage period, and the pulp firmness, soluble solids content, titratable acidity, SS/AT ratio, and pulp pH were evaluated. Data were statistically analyzed using Analysis of Variance, and means were compared by Tukey's test at a 5% significance level. Results showed that 1-MCP application had a minimally pronounced effect on pear quality parameters, being non-significant for titratable acidity and SS/AT ratio. Thus, it can be concluded that applying 1-MCP, regardless of the dose, is not advantageous for preserving the quality of 'Kieffer' pears under refrigerated conditions.

Keywords: pears; fruit growing; postharvest; quality parameters.

Resumo

Avaliação da aplicação de 1-metilciclopropeno sobre os parâmetros de qualidade de peras 'Kieffer' mantidas sob armazenamento refrigerado

A pera é uma importante espécie frutífera, cujo interesse pelo cultivo e consumo vem crescendo no Brasil nos últimos anos. Dentre as cultivares de pera produzidas no Brasil, a pera Kieffer, também conhecida como 'pera dura', destaca-se como uma importante cultivar produzida na Serra Gaúcha e no estado do Rio Grande do Sul. Devido às suas características sazonais, a produção de pera muitas vezes precisa ser armazenada para garantir o fornecimento durante todo o ano. No entanto, em muitas situações, o armazenamento refrigerado não é suficiente para manter a qualidade de conservação dos frutos. Nesse sentido, o uso do 1-metilciclopropeno (1-MCP) como agente inibidor do amadurecimento dos frutos é crescente. Objetivou-se, com o presente estudo, avaliar o efeito da aplicação de doses crescentes de 1-MCP sobre os parâmetros de conservação e qualidade de peras Kieffer armazenadas sob refrigeração. O experimento foi realizado na cidade de Caxias do Sul, RS, entre os meses de abril e agosto de 2024. Os tratamentos consistiram em doses de zero, 50%, 100%, 150% e 200% da dose de 1-MCP recomendada para a cultura. Após o tratamento com 1-MCP,

as peras foram armazenadas por 120 dias em câmara fria. Mensalmente até o final do período de armazenamento, foram retiradas subamostras dos tratamentos e avaliados os parâmetros de firmeza da polpa, teor de sólidos solúveis, acidez titulável, relação SS/AT e pH da polpa. Os dados foram analisados estatisticamente pela Análise de Variância, e as médias foram comparadas pelo teste de Tukey ao nível de significância de 5%. Observou-se que a aplicação de 1-MCP teve efeito pouco pronunciado sobre os parâmetros de qualidade das peras, sendo não significativa para os parâmetros de acidez titulável e relação SS/AT. Dessa forma, pode-se notar que a aplicação de 1-MCP, independentemente da dose, não é vantajosa para a preservação da qualidade de peras 'Kieffer' mantidas em condições refrigeradas.

Palavras-chave: frutas de caroço; fruticultura; pós-colheita; parâmetros de qualidade.

Resumen

Evaluación de la aplicación de 1-metilciclopropeno sobre los parámetros de calidad de peras 'Kieffer' conservadas en refrigeración

La pera es una especie frutal importante, cuyo interés por el cultivo y consumo ha crecido en Brasil en los últimos años. Entre los cultivares de pera producidos en Brasil, la pera Kieffer, también conocida como 'pera dura', se destaca como un cultivar importante producido en Serra Gaúcha y en el estado de Rio Grande do Sul. Debido a sus características estacionales, la producción de pera a menudo debe almacenarse para asegurar el suministro durante todo el año. Sin embargo, en muchas situaciones, el almacenamiento refrigerado no es suficiente para mantener la calidad de conservación de las frutas. En este sentido, el uso de 1-metilciclopropeno (1-MCP) como agente inhibidor de la maduración de la fruta está aumentando. El presente estudio tuvo como objetivo evaluar el efecto de la aplicación de dosis crecientes de 1-MCP sobre los parámetros de conservación y calidad de las peras Kieffer almacenadas bajo refrigeración. El experimento se realizó en la ciudad de Caxias do Sul, RS, entre abril y agosto de 2024. Los tratamientos consistieron en dosis de cero, 50%, 100%, 150% y 200% de la dosis de 1-MCP recomendada para el cultivo. Después del tratamiento con 1-MCP, las peras se almacenaron durante 120 días en una cámara de frío. Mensualmente hasta el final del período de almacenamiento, se tomaron submuestras de los tratamientos y se evaluaron los parámetros de firmeza de pulpa, contenido de sólidos solubles, acidez titulable, relación SS/AT y pH de pulpa. Los datos se analizaron estadísticamente mediante Análisis de Varianza, y las medias se compararon mediante la prueba de Tukey a un nivel de significancia del 5%. Se observó que la aplicación de 1-MCP tuvo un efecto poco pronunciado sobre los parámetros de calidad de las peras, siendo no significativo para los parámetros de acidez titulable y relación SS/AT. Así, se puede notar que la aplicación de 1-MCP, independientemente de la dosis, no es ventajosa para la conservación de la calidad de las peras 'Kieffer' conservadas en condiciones refrigeradas.

Palabras clave: frutas de hueso; fruticultura; poscosecha; parámetros de calidad.

Introduction

Pears are among the leading fruit species cultivated worldwide. In 2022, global production was 26.3 million tons, with the primary producers being China, the United States, and Argentina (Mello; FAO, 2023; Lazzarotto; Watanabe, 2016). In the same period, Brazil was responsible for producing 17,525 t, with production concentrated mainly in the South Region, with cultivation to a lesser extent in São Paulo and Minas Gerais (IBGE, 2023).

In Brazil, the state of Rio Grande do Sul is the largest producer, with a volume of 8,385 t, corresponding to 47.8% of national production. In the state, the Serra Gaúcha region stands out for being an important producer of this fruit (Mello; Lazzarotto; Watanabe, 2016; IBGE, 2023).

Although some pears cultivars in Brazil require less than 500 chilling hours, the overall quality of these fruits is low compared to cultivars that require more chilling (Oliveira; Lopes; Silva-Matos, 2015). The European and Asian cultivars currently grown in Brazil are William's Bon Chrétien, Red Bartlett, Packham's Triumph, Abate Fetel, Housui, Kousui, and Nijisseiki, among others, whose cold requirements are between 700 and 1200 cold hours (Faoro; Orth, 2010).

The Kieffer pear, sometimes erroneously called 'Keiffer', is also known as 'stick pear' or 'hard pear', being a hybrid cultivar (*Pyrus communis x P. pyrifolia*), originating in the United States (Nakasu *et al.*, 2007). The fruit,

which is medium to large in size, has a distinctive oval shape with thick, rough skin that is yellow with greenish tones, which can acquire reddish tones as it ripens (Ayub; Gioppo, 2021; Arbor Day Foundation, 2024).

Kieffer pear is whitish, firm, and crunchy. Its flavor is mild and slightly sweet when ripe, but acidic and/or sour in immature stages (Nakasu *et al.*, 2007).

Due to its firmness and flavor characteristics, this pear variety is used for both fresh consumption and industrialization, serving as a raw material for the production of sweets, jellies, liqueurs, among other products (Ayub; Gioppo, 2021; Arbor Day Foundation, 2024).

In addition to high yields, the 'Kieffer' pear tree tends to produce relatively early, even while the plant is still young, with a reasonably long production window. Flowering occurs in late spring, with white flowers, and harvesting occurs in the summer months. The leaves are dark green and have a serrated appearance (Fioravanço; Antoniolli, 2016).

An important characteristic of this pear variety is its tolerance to warmer climates and its requirements for fewer chilling hours. It is estimated that the Kieffer pear tree requires 350 to 400 chilling hours in winter to overcome dormancy (whereas European varieties require 900 to 1100 chilling hours). In addition, this variety is resistant to several diseases that affect pear trees, which increases the interest in its use, especially by small producers (Fioravanço; Antoniolli, 2016; Nakasu; Quesada, 2021; Arbor Day Foundation, 2024).

1-methylcyclopropene (1-MCP) is a plant growth regulator that occurs in gaseous form at room temperature and pressure. It is a cycloalkene with molecular formula C_4H_6 and a molecular mass of 54 $g \cdot mol^{-1}$ (Brazil, 2024).

1-MCP has been widely used in fruit cultivation as an anti-ripening agent for fruits, especially those stored in refrigerated environments. Starting with apples, 1-MCP is currently used in the treatment of several fruit crops, such as plums, pears, persimmons, and kiwis (Krammes; Argenta; Vieira, 2005; Alves *et al.*, 2010; Antoniolli, 2011; Vieira *et al.*, 2012).

1-MCP is believed to interfere with ethylene biochemistry, more specifically by blocking cellular ethylene receptors (Barreto *et al.*, 2017). Since ethylene is the phytohormone responsible for signaling and driving fruit ripening and senescence, as well as in other plant parts, inhibition of this compound´s synthesis impedes and/or delays the ripening process (Petri *et al.*, 2016).

Some studies indicate that field application (on-plant) of 1-MCP has little or no effect on delaying fruit ripening. Nevertheless, its application can improve fruit conservation during subsequent storage, depending on the cultivar, production region, and fruit harvest season (Petri *et al.*, 2016).

On the other hand, the ripening delay caused by 1-MCP is particularly interesting to aid in the conservation of fruits stored in a refrigerated environment or under a controlled atmosphere when applied postharvest (Corrent *et al.*, 2004; Pegoraro *et al.*, 2016; Barreto *et al.*, 2017). This ripening delay, associated with maintaining the quality and physiological characteristics of the treated fruits, makes 1-MCP a valuable alternative for storing fruits for long periods, thereby avoiding substantial losses due to prolonged storage (Fante *et al.*, 2013).

Commercially, 1-MCP is sold as tablets and/or sachets, which release the product for absorption by fruits to exert its action. Several commercial brands exist for 1-MCP, with Smartfresh (AgroFresh Brasil, São Paulo) being one of the leading brands of this agricultural product sold in Brazil (Brazil, 2024).

Currently, 1-MCP has been used postharvest to slow development and extend the shelf life of pears (Antoniolli, 2011). Effects of 1-MCP exposure include a reduction in fruit respiratory activity, inhibition of ACC synthase and ACC oxidase enzymes, reduced ethylene production, delayed development of yellow epidermal coloration, and a reduction in pear pulp firmness (Antonolli, 2011; Petri *et al.*, 2016).

However, it is still necessary to more assertively determine the best combinations among the involved factors, such as the fruit ripening stage at harvest, the concentration of 1-MCP to be used, temperature and time of application, as well as the storage period after treatment. This is crucial to avoid the occurrence of physiological disorders and to adequately control the gradual softening of pears, without compromising their sensory and quality parameters and attributes (Antoniolli, 2011; Villalobos-Acuña; Mitcham, 2008).

In recent years, 1-MCP has been used commercially in several pear cultivars, such as William's, Packham's Triumph, D' Anjou, and Abate Fetel, among others. Generally, concentrations of 1-MCP in the range of 300 ppb (300 $\mu g \cdot L^{-1}$) are used. The application time depends on the maturation stage, the cultivar, and the purpose of the postharvest application to be achieved (Antoniolli, 2011; Pasa *et al.*, 2012).

Pasa *et al.* (2018) evaluated the application of 300 ppb (300 $\mu g \cdot L^{-1}$) of 1-MCP during the refrigerated

postharvest storage of 'Abate Fetel', 'Packham's', and 'Tenra' pears. According to the authors, 1-MCP application efficiently maintained the firmness of treated pears and reduced the decline in their quality compared to untreated pears.

Balkees *et al.* (2022) evaluated 1-MCP application in 'Alexander Lucas' pears at a dose of 300 ppb, stored in a refrigerated environment for six months. According to their results, 1-MCP application maintained high fruit quality even after six months of storage, suggesting that this product is beneficial for pear preservation.

Tedeschi *et al.* (2023) evaluated the use of 1-MCP at a dose of 20 $mg \cdot m^{-3}$ for the refrigerated storage of 'Abate Fetel ' pears harvested at different ripening stages. The results demonstrated that 1-MCP application promoted better conservation of the treated fruits after two months compared to the control (untreated fruits), and the product´s use led to better maintenance of the pears´ organoleptic characteristics, even with different and/or uneven ripening stages.

Hendges *et al.* (2016) evaluated 1-MCP application at300 ppb (300 $\mu g \cdot L^{-1}$) for the conservation of 'Packham's Triumph' pears at room temperature. The results showed that, even without refrigeration, pears treated with 1-MCP had a firmer pulp texture, preventing yellowing of the epidermis and indicating effective inhibition of ripening in the treated fruits.

Although studies exist concerning 1-MCP use in pears, there is very limited literature specifically on its application in Kieffer pears. This demonstrates the importance of conducting studies to elucidate the effect of this phytoregulator on the physiology and quality of Kieffer pears, which are of agronomic and economic importance for pear production in the State of Rio Grande do Sul and, consequently, in Brazil.

Thus, the objective of the present study was to evaluate the effect of applying different doses of 1-methylcyclopropene (1-MCP) on the quality characteristics and conservation of 'Kieffer' pears stored in a refrigerated environment.

Materials and methods

Plant material and experimental location

Approximately 800 'Kieffer' pears (*Pyrus communis* 'Kieffer') from the same orchard and harvested on the same day were used for this research. Only pears in good condition and suitable for commercialization were selected, avoiding fruits that were excessively large or small, or those lacking a uniform appearance.

The research was conducted between April and August 2024, in a cold chamber installed on the researcher's property, located in Caxias do Sul, RS (29°07'59.6" S, 51°04'59.9" W).

Treatments and experimental conduction

The fruits were stored in plastic boxes, with each box containing 30 fruits representing one replicate. The study also aimed to evaluate the storage time in a cold chamber for up to four months (120 days). Each treatment consisted of four boxes, totaling 120 fruits.

Increasing doses of 1-MCP were applied based on the product manufacturer's specifications. The treatments applied were:

T0 (control): without application of 1-MCP;

T1: application of 50 % (half) of the 1-MCP dose recommended by the manufacturer;

T2: application of 100 % of the 1-MCP dose recommended by the manufacturer;

T3: application of 150 % (one and a half times) of the dose of 1-MCP recommended by the manufacturer;

T4: application of 200 % (double) the dose of 1-MCP recommended by the manufacturer.

1-MCP was supplied in tablets. Following the manufacturer's recommendation (one tablet per 3.2 m^3), a plastic isolation frame with a volume equivalent to 0.8 m^3 was used for the test, housing eight boxes of fruit. The 100% dose corresponded to 10 $\mu g \cdot L^{-1}$ of 1-MCP, or approximately 150 ppb by volume.

Pears were randomly selected. The 1-MCP product was applied according to the manufacturer´s recommendations: fruits were kept in sealed plastic boxes and exposed to 1-MCP, which was generated by the reaction of a tablet at 20 °C for 24 h.

After 1-MCP application, the pears were refrigerated in a cold chamber (0±2 °C and 85±5 % RH) for up

to 120 days. Monthly (at 30, 60, 90, and 120 days), a box from each treatment was removed to perform fruit quality analyses based on storage time and applied 1-MCP dose.

Fruit quality assessment

Pulp firmness, soluble solids content, juice pH, titratable acidity, and SS/AT ratio were evaluated for each treatment. To determine firmness, approximately 2.0 cm^2 of epidermis was removed from each side of the fruits, using the peduncle axis as a reference. Pulp firmness was then determined on both sides using a digital penetrometer with an 11 mm diameter tip. The results were expressed in Newtons (N).

To determine soluble solids content, juice pH, and titratable acidity, fruits were blended in a domestic blender to produce a homogeneous, semi-liquid pulp. These parameters were then determined using this pulp.

The soluble solids content was determined by refractometry, following method 315/IV (IAL, 2008), with results expressed in degrees Brix (°Bx). Pulp pH was determined by direct reading using a benchtop pH meter with an Ag/ AgCl electrode, following method 201/IV (IAL, 2008). Fruit titratable acidity was determined by titrimetry, following methods 310/IV and 312/IV, and results were expressed as malic acid equivalents per 100 g of fruit (IAL, 2008).

The SS/AT ratio was calculated by dividing the soluble solids content (SS) by the titratable acidity (AT) (Daniels *et al.*, 2019).

Experimental design and statistical analysis

The experimental design was bifactorial, evaluating two factors: 1-MCP dose and storage time. Each treatment consisted of 30 fruits, arranged in five replicates of six fruits each. Data were evaluated for homoscedasticity (Levene's test). The normality of residuals was assessed using the Shapiro-Wilk test, and the data were subjected to Analysis of Variance (ANOVA). Means were compared by Tukey´s test at a 5% significance level ($\alpha = 0.05$) using the AgroEstat statistical program.

Results and discussion

Regarding the fruits' external appearance, no changes in the external or internal visual aspect were observed, regardless of the 1-MCP dose used. Data regarding the pulp firmness of pears treated with increasing doses of 1-MCP and different storage times are presented in Table 1.

Table 1 - Pulp firmness (N) of 'Kieffer' pears subjected to increasing doses of 1-MCP in cold storage for 120 days.

1-MCP dose	Storage time (days)			
	30	60	90	120
Zero	65.0 Aa	66.0 Aa	60.5 Ba	51.4 Cb
50 %	64.6 Aa	63.5 Aab	61.9 Aa	55.6 Ba
100 %	63.3 Aa	63.8 Aab	60.9 Aa	54.6 Bab
150 %	63.3 Aa	60.6 Ab	58.8 Ba	55.8 Ca
200 %	63.3 Aa	63.8 Aab	59.1 Ba	57.0 Ba

Source: authors (2025).
Means followed by the same letter, capitalized in row (storage time) and lowercase in column (1-MCP dose), do not differ statistically by the Tukey test at a 5 % significance level (coefficient of variation: 13.78 %).

Regarding the storage period, it can be observed that as the time in the cold chamber increased, fruit firmness decreased. This behavior may be attributed to the natural ripening process pears undergo, even under refrigerated storage, or to other physiological processes that lead to changes in fruit firmness.

Pasa *et al.* (2018) reported results differing from those in the present study. According to the authors, 1-MCP application promoted greater pulp firmness for 'Packham´s' and 'Abate Fetel' pear' varieties during cold storage, but only at 120 days, with no significant difference observed in the first 60 days of storage.

Hendges *et al.* (2016) observed that 'Packham's Triumph' pears treated with 1-MCP showed superior flesh firmness compared to the control in both refrigerated and room temperature storage. Villalobos-Acuña *et al.* (2011) reported greater flesh firmness for 'Bartlett' pears treated with 1-MCP, even after 120 h of refrigerated storage.

Melnyk and Drozd (2020) observed firmness values higher than 70 N (7 kgf) for 'Delbarau' pears treated with doses in the range of 500 - 1,000 $\mu g \cdot L^{-1}$ of 1-MCP, maintaining such firmness even after four months (120 days) of storage.

Although 1-MCP is an effective postharvest treatment for maintaining the quality of various fruit types, including pears (Antoniolli, 2011), specific studies for 'Kieffer' pears are lacking. The results obtained in the present study indicate that the applied rates may not be suitable for this pear variety, or that 1-MCP is ineffective in preserving the flesh firmness of 'Kieffer' pears.

Data related to the pulp pH of the treated fruits are compiled in Table 2.

Table 2 - pH of the pulp of 'Kieffer' pears subjected to increasing doses of 1-MCP in cold storage for 120 days.

1-MCP dose	Storage time (days)			
	30	60	90	120
Zero	4.30 Bab	4.45 Aa	4.43 Tab	4.34 ab
50 %	4.21 Bb	4.40 Aa	4.34 Tab	4.37 Aa
100 %	4.41 Aa	4.36 Aa	4.35 Aa	4.35 Aa
150 %	4.24 Bb	4.41 Aa	4.36 Tab	4.31 Ab
200 %	4.41 Aa	4.38 Aa	4.28 Ab	4.30 Ab

Source: authors (2025).
Means followed by the same letter, capitalized in row (storage time) and lowercase in column (1-MCP dose), do not differ statistically by the Tukey test at a 5 % significance level (coefficient of variation: 2.03 %).

It can be observed that 1-MCP application did not have a consistent effect related to the applied dose, varying with refrigerated storage time. In any case, it is possible to note that pulp pH was also not consistently affected by storage time in a cold chamber; thus, both factors exhibited erratic behavior.

The behavior observed in the present study aligns with that reported by Pasa *et al.* (2018), where 1-MCP application slightly increased the pH of 'Abate Fetel' (3.7 in control versus 3.8 with 1-MCP) and 'Packham's' (2.9 in control and 3.0 with 1-MCP) pears. However, it is important to note that the pear pH was higher than 4.2 in all treatments, which may be a characteristic of the 'Kieffer' variety.

Results regarding the soluble solids (SS) content are presented in Table 3.

Table 3 - Soluble solids content (°Bx) of 'Kieffer' pears subjected to increasing doses of 1-MCP in cold storage for 120 days.

Storage time (days)				
	30	60	90	120
	10.1 c	13.4 ab	13.2 b	13.9 a
1-MCP dose				
Zero	50 %	100 %	150 %	200 %
13.2 a	12.6 ab	12.4 b	12.4 b	12.6 ab

Source: authors (2025).
Means followed by the same letter in row do not differ statistically by the Tukey test at a significance level of 5 % (CV = 13.78 %).
Note: interaction between factors was not significant for this parameter.

Regarding the soluble solids content, no interaction effect was observed between 1-MCP doses and refrigerated storage time. Concerning the applied 1-MCP dose, it was noted that higher doses promoted a slight reduction in soluble solids content, ranging from 0.4 to 0.8 °Bx. This behavior indicates that the applied 1-MCP may have partially inhibited the fruit ripening process, albeit to a minor degree.

Regarding storage time, soluble solids content increased with increasing time in the cold chamber, regardless of 1-MCP application of 1-MCP. This is attributable to the natural ripening process of fruits, which is only delayed by low temperatures (Nakasu *et al.*, 2007).

Melnyk and Drozd (2020) observed similar behavior concerning soluble solids content, where higher doses of 1-MCP promoted a reduction in soluble solids content in 'Delbarau' pears, with values ranging from 10.5 to 12.8 °Bx.

On the other hand, Pasa *et al.* (2018) reported that 1-MCP application had no significant effect on the soluble solids content of 'Abate Fetel' (14.9 °Bx in control and 15.1 °Bx with 1-MCP) and 'Packham's' pears (15.3 °Bx in control and 15.6 °Bx with 1-MCP), and noted a tendency for soluble solids content to increase with increasing storage time in a cold chamber.

The titratable acidity and SS/AT ratio data for the treated pears are presented in Table 4.

Table 4 - Titratable acidity (wt.%) and SS/AT ratio of 'Kieffer' pears subjected to increasing doses of 1-MCP in cold storage for 120 days.

Parameter	Storage time (days)			
	30	**60**	**90**	**120**
Titratable acidity	0.23 a	0.19 b	0.16 c	0.14 d
CV (%)	12.28 %			
SS/AT ratio	43.9 d	70.3 c	82.6 b	100.6 a
CV (%)	15.00 %			

Source: authors (2025).
Means followed by the same letter in row do not differ statistically by Tukey's test at a significance level of 5 %. The 1-MCP dose factor was not significant for these parameters. Titratable acidity is expressed in gram-equivalents of malic acid per 100 g of fruit. CV: coefficient of variation.

For both titratable acidity and SS/AT ratio, 1-MCP application did not have a significant effect, indicating that these parameters were not affected by the product´s application. Conversely, there was a clear trend of reduction in titratable acidity with increasing storage time in the cold chamber and a corresponding increasing in the SS/AT ratio.

This behavior can be explained by the fruit ripening process. Although a potential residual effect of 1-MCP may have prevented the complete conversion of acidity into sugars, the acidity of the pulp was reduced because of ripening, a process that, while potentially delayed by refrigerated storage, is not completely inhibited.

Pasa *et al.* (2018) reported that 1-MCP application significantly affected the titratable acidity of 'Packham's' pears but had no significant effect on the titratable acidity of 'Abate Fetel' pears. Melnyk and Drozd (2020), conversely, noted a significant effect of the 1-MCP dose on the titratable acidity of ' Delbarau' pears, observing that higher 1-MCP doses resulted in higher titratable acidity of the fruits, which would indicate a delay in the pear ripening process (Nakasu; Quezada, 2021). However, it is important to note that the dose applied by these authors (500 - 1000 $\mu g \cdot L^{-1}$ of 1-MCP) was much higher than that recommended by the manufacturer of the 1-MCP tablets and used in the present study (5 - 20 $\mu g \cdot L^{-1}$ of 1-MCP).

Conclusions

Based on the observed results, 1-MCP application did not significantly affect the titratable acidity and SS/AT ratio of 'Kieffer' pears stored in cold storage. Furthermore, no consistent effect was observed for firmness, soluble solids content, and pulp pH, indicating that 1-MCP use may not be advantageous for maintaining the quality of pears stored in cold storage, and/or the applied product may not be suitable for this pear variety.

References

ALVES, E. O.; STEFFENS, C. A.; AMARANTE, C. V. T.; WEBER, A.; MIQUELOTO, A.; BRACKMANN, A. Cold storage of 'Laetitia' plums with use of 1-MCP and induction of fresh mass loss. **Ciência Rural**, v. 40, n. 1, p. 1-7, 2010. DOI: 10.1590/S0103-84782009005000251. Available at: https://www.scielo.br/j/cr/a/wzjDQydY4hsYkV5vNXdzPcP/?lang=pt. Accessed on: May 25 2024.

ANTONIOLLI, L. R. Pera: perspectivas sobre a produção e conservação pós-colheita. **Jornal da Fruta**, Dez. 2011, p. 4-5. Available at: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/909917/1/13559201lp.45.pdf. Accessed on: Jun. 25 2024.

ARBOR DAY FOUNDATION. **Kieffer Pear**. 2024. Available at: https://shop.arborday.org/treeguide/359. Accessed on: Jun. 15 2024.

AYUB, R. A.; GIOPPO, M. **A cultura da pera**. 2021. Available at: https://www2.uepg.br/labiovegetalteste/wp-content/uploads/sites/201/2021/07/Pera.pdf. Accessed on: Jun. 14 2024.

BALKEES, B. M.; SAQUET, A. A.; KLEIN, N.; PANSERA-ESPÍNDOLA, B.; SAUTER, C. K.; NEUWALD, D. A. Effect of temperature and 1-methylcyclopropene on the storability of 'Alexander Lucas' pear. **Revista Caatinga**, v. 35, n. 1, p. 216-222, 2022. DOI: http://dx.doi.org/10.1590/1983-21252022v35n122rc. Available at: https://www.scielo.br/j/rcaat/a/Ls6R3hdcg8gTjnrHBVBHcQH/?lang=en&format=pdf. Accessed on: May 14 2024.

BARRETO, C. F.; ZANDONÁ, R. R.; ACORSI, G.; COPATTI, A.; DEL AGUILA, J. S. Effect of 1-methylcyclopropene on the postharvest quality of 'Chiripá' peach. **Revista Iberoamericana de Technología Postcosecha**, v. 18, n. 1, p. 33-38, 2017. Available at: https://www.redalyc.org/articulo.oa?id=81351597005. Accessed on: Apr. 10 2024

BRAZIL. MINISTRY OF AGRICULTURE AND LIVESTOCK. Sistema fitossanitário de agrotóxicos (AGROFIT). **Registro de Ingrediente Ativo:** 1-Metilciclopropeno. 2024. Available at: https://bi.agricultura.gov.br/reports/rwservlet?agrofit_cons&ingredientes_ativos.rdf&p_id_ingrediente_ativo=&p_nm_comum_port=&p_id_grupo_quimico=199&p_id_classe=&p_id_cultura=&p_tipo_relatorio=DETALHADO&paramform=no. Accessed on: Jun. 15 2024.

CORRENT, A. R.; PARUSSOLO, A.; GIRARDI, C. L.; ROMBALDI, C. V. Effect of 1-methylcyclopropene on the preservation of ' royal gala' apples in refrigerated air and controlled atmosphere. **Revista Brasileira de Fruticultura**, v. 26, n. 2, p. 217-221, 2004. DOI: 10.1590/S0100-29452004000200009. Available at: https://www.scielo.br/j/rbf/a/xxdrGKmGzG7fntPw355HB7c/?lang=pt. Accessed on: May 12 2024.

DANIELS, A. J.; POBLETE-CHEVERRÍA, C.; OPARA, U. L.; NIEUWOUDT, H. H. Measuring Internal Maturity Parameters Contactless on Intact Table Grape Bunches Using NIR Spectroscopy. **Frontiers in Plant Science**, v. 10, p. 1517, 2019. DOI: 10.3389%2Ffpls.2019.01517. Available at: https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2019.01517/full. Accessed on: May 28 2024.

FANTE, C. A.; BOAS, A. C. V.; COSTA, A. C.; SILVA, E. P.; OLIVEIRA, M. C.; LIMA, L. C. O. 1-MCP on the physiological aspects and postharvest quality of Eva apples during cold storage. **Ciência Rural**, v. 43, n. 12, p. 2142-2147, 2013. DOI: 10.1590/S0103-84782013005000138. Available at: https://www.scielo.br/j/cr/a/BNxddJrnJG878bvYRJdNQDy/?lang=pt. Accessed on: Jun. 5 2024.

FAORO, I. D.; ORTH, A. I. Pear cultivation in Brazil. **Revista Brasileira de Fruticultura**, v. 32, n. 1, p. 1-2, 2010. DOI: 10.1590/S0100-29452010000100001. Available at: https://www.scielo.br/j/rbf/a/ff9M8f9yJMhwqGdfxFrGgJL/?lang=pt. Accessed on: May 10 2024.

FIORAVANÇO; J. C.; ANTONIOLLI, L. R. **Pera:** o produtor pergunta, a Embrapa responde. Brasília, DF: Embrapa, 2016. 229 p. Available at: https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1039296. Accessed on: May 12 2024.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). **Faostat:** Crops and livestock products. 2023. Available at: https://www.fao.org/faostat/en/#data/QCL. Accessed on: Jun. 14 2024.

HENDGES, M. V.; STEFFENS, C. A.; AMARANTE, C. V. T.; NEUWALD, D. A.; BRACKMANN, A. 'Packham's Triumph' pear response to 1-methylcyclopropene and nitric oxide treatments. **Revista Caatinga**, v. 29, n. 2, p. 283-289, 2016. DOI: 10.1590/1983-21252016v29n203rc. Available at: https://www.scielo.br/j/rcaat/a/rd4rMjW3HwVgDcXHqw83CkS/?lang=en. Acessed on: May 29 2024.

INSTITUTO ADOLFO LUTZ (IAL). **Manual de métodos físico-químicos para análise de alimentos**. 4. ed. São Paulo: Adolfo Lutz Institute, 2008. 1020 p. Available at: https://www.ial.sp.gov.br/ial/publicacoes/livros/metodos-fisico-quimicos-para-analise-de-alimentos. Accessed on: Jun. 4, 2024.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Produção de pera**. 2023. Available at: https://www.ibge.gov.br/explica/ producao-agropecuaria /pera/ rs. Accessed on: Jun. 14, 2024.

KRAMMES, J.; ARGENTA, L. C.; VIEIRA, M. J. Control of ripening and postharvest quality conservation of 'fuyu' persimmon by ethylene management. **Revista Brasileira de Fruticultura**, v. 27, n. 3, p. 360-365, 2005. DOI: 10.1590/S0100-29452005000300006. Available at: https://www.scielo.br/j/rbf/a/tj4KKg3YLcx8vkzqKrZJ9rb/?lang=pt. Accessed on: May 15 2024.

MELLO, L. M. R.; LAZZAROTTO, J. J.; WATANABE, H. S. Produção, mercado e comercialização. *In*: FIORAVANÇO, JC; ANTONIOLLI, LR (Ed.). **Pera:** o produtor pergunta, a Embrapa responde. Brasília, DF: Embrapa, 2016. p. 209-220.

MELNYK, O.; DROZD, O. Storage and quality of autumn pears, depending on the dose of postharvest treatment with ethylene inhibitor 1-MCP. **Scientific Papers Series B: Horticulture**, v. 64, n. 2, p. 67-72, 2020. Available at: https://horticulturejournal.usamv.ro/pdf/2020/issue_2/Art9.pdf. Accessed on: May 29 2024.

NAKASU, B. H.; HERTER, F. G.; CAMELATTO, D.; REISSER JUNIOR, C.; FORTES, J. F.; CASTRO, L. A. S.; RASEIRA, A.; FREIRE, C. J. S.; BASSO, C.; FAORO, I.; PETRI, J. L.; LEITE, G. B.; PEREIRA, J. F. M.; CANTILLANO, R. F. F.; VERISSIMO, V.; SIMÕES, F. **Cultura da pera**. Pelotas: Embrapa Temperate Climate, 2007. 58 p.

NAKASU, B. H.; QUEZADA, A. C. **Pera**: Evolução. 2021. Available at: https://www.embrapa.br/agencia-de-informacao-tecnologica/cultivos/pera/pre-producao/evolucao. Accessed on: Jun. 15 2024.

OLIVEIRA, I. V. M.; LOPES, P. R. C.; SILVA-MATOS, R. R. S. Phenological evaluation of the 'Triunfo' pear tree grown in a semiarid climate in northeastern Brazil in the 2012 harvest**. Revista Brasileira de Fruticultura**, v. 37, n. 1, p. 261-266, 2015. DOI: 10.1590/0100-2945-007/14. Available at: https://www.scielo.br/j/rbf/a/fbv9zvrxDYYzFW5tGrx4jBF/?lang=pt. Accessed on: May 18 2024.

PASA, M. S.; FACHINELLO, J. C.; SCHMITZ, J. D.; SOUZA, A. L. K.; FRANCESCHI, E. D. Desenvolvimento, produtividade e qualidade de peras sobre porta-enxertos de marmeleiro e *Pyrus calleryana*. **Revista Brasileira de Fruticultura**, v. 34, n. 3, p. 873-880, 2012. DOI: 10.1590/S0100-29452012000300029. Available at: https://www.scielo.br/j/rbf/a/Sp9RHTzJxsfMxTWzfmHQQQs/?lang=pt. Accessed on: May 12 2024.

PASA, M. S.; ROSA JUNIOR, H. F.; FRANCESCHI, E.; PEREIRA, R. R.; DEL AGUILA, J. S.; FACHINELLO, J. C.; SILVA, C. P. The application of 1-methylcyclopropene (1-MCP) increases the postharvest conservation of pears. **Revista de Ciências Agroveterinárias**, v. 17, n. 2, p. 206-211, 2018. DOI: 10.5965/2238117117722018206. Available at: https://www.revistas.udesc.br/index.php/agroveterinaria/article/view/9286. Accessed on: May 13 2024.

PEGORARO, C.; STORCH, T. T.; CRIZEL, G. R.; FERREIRA, W. A.; GIRARDI, C. L. Controlled atmosphere associated with 1-methylcyclopropene in preserving the quality of 'tewi' kiwifruit. **Brazilian Journal of Food Technology**, v. 19, e2014078, 2016. DOI: 10.1590/1981-6723.7814. Available at: https://www.scielo.br/j/bjft/a/PLHjmBJQ7K4nzSDrz3zC5Zc/?lang=pt. Accessed on: Jun. 1 2024.

PETRI, J. L.; HAWERROTH, F. J.; LEITE, G. B.; SEZERINO, A. A.; COUTO, M. **Reguladores de crescimento para frutíferas de clima temperado**. Florianópolis: Epagri, 2016. 141 p. Available at: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1067694/1/LIVROReguladoresdecrescimentoparafrutiferasdeclimatemperadocorrigidoOKneu.pdf. Accessed on: May 12 2024.

TEDESCHI, P.; MARZOCCHI, S.; MARCHETTI, N.; BARBA, F. J.; MAIETTI, A. Influence of Post-Harvest 1-Methylcyclopropene (1-MCP) Treatment and Refrigeration on Chemical Composition, Phenolic Profile and Antioxidant Modifications during Storage of Slaughter Fétel Pears. **Antioxidants**, v. 12, 1955, 2023. DOI: 10.3390/antiox12111955. Available at: 10.3390/antiox12111955. Accessed on: May 20 2024

VIEIRA, M. J.; ARGENTA, L. C.; AMARANTE, C. V. T.; VIEIRA, A. M. F. D.; STEFFENS, C. A. Postharvest quality of 'Hayward' kiwi treated with 1-MCP and stored under different atmospheres. **Revista Brasileira de Fruticultura**, v. 34, n. 2, p. 400-408, 2012. DOI: 10.1590/S0100-29452012000200012. Available at: https://www.scielo.br/j/rbf/a/FNhzgD3mHfkJmzYPKZd3qDJ/?lang=pt. Accessed on: May 20 2024.

VILLALOBOS-ACUÑA, M. G.; BIASI, W. V.; FLORES, S.; JIANG, C. Z.; REID, M. S.; WILLITS, N. H.; MTICHAM, E. J. Effect of maturity and cold storage on ethylene biosynthesis and ripening in 'Bartlett' pears treated after harvest with 1-MCP. **Postharvest Biology and Technology**, v. 59, p. 1-9, 2011. DOI: 10.1016/j.postharvbio.2010.08.001. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0925521410001651. Accessed on: May 25 2024.

VILLALOBOS-ACUNA, M.; MITCHAM, E. J. Ripening of European pears: The chilling dilemma. **Postharvest Biology and Technology**, v. 28, p.187-200, 2008. DOI: 10.1016/j.postharvbio.2008.03.003. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0925521408000975. Accessed on: Jun. 4 2024.