Original article

Effects of 1-methylcyclopropene on postharvest quality of white- and yellow-flesh loquat (*Eriobotrya japonica* Lindl.) fruit

Giorgia LIGUORI[1]*, Vittorio FARINA[1], Giuseppe SORTINO[1], Agata MAZZAGLIA[2], Paolo INGLESE[1]

[1] Dep. Agric. For. Sci., Univ. Palermo, viale delle scienze, Palermo, Italy, giorgia.liguori@unipa.it

[2] Dep. Agric. Food Sci., Univ. Catania, via S. Sofia 98, Catania, Italy

* Correspondence and reprints

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Effects of 1-methylcyclopropene on postharvest quality of white- and yellow-flesh loquat (*Eriobotrya japonica* Lindl.) fruit.

Abstract – Introduction. The effects of 1-methylcyclopropene (1-MCP) were evaluated on white-flesh cv. Claudia and yellow-flesh cv. Nespolone di Trabia loquat fruit. **Materials and methods**. Application of 1-MCP [(0.5 to 1) μL·L^{-1} for 20 h)] was monitored at 20 °C (7 days) and 0 °C (7 days at 0 °C and then 7 days at 20 °C). **Results**. Treatments with 1-MCP slowed fruit softening, depending on the concentration. Softening inhibition was greatest in fruit treated and held at 20 °C. The optimum concentration for softening inhibition at 20 °C was 1 μL·L^{-1} of 1-MCP, while 0.5 μL·L^{-1} of 1-MCP was more effective at 0 °C. **Conclusion**. Treatments with 1-MCP inhibited titratable acidity loss in both cultivars. 1-MCP extends the shelf life of rapidly softening, perishable fruits such as loquat fruit.

Italy / *Eriobotrya japonica* / fruits / postharvest losses / postharvest physiology / keeping quality

Effets du 1-méthylcyclopropène sur la qualité post-récolte des fruits de néfliers du Japon à chair blanche et jaune (*Eriobotrya japonica* Lindl.) fruits.

Résumé – Introduction. Les effets du 1-méthylcyclopropène (1-MCP) ont été évalués sur les fruits de néfliers du Japon à chair blanche (cv. Claudia) et jaune (cv. Nespolone di Trabia). **Matériel et méthodes**. L'application du 1-MCP [(0.5 à 1) μL·L^{-1} pendant 20 h)] a été contrôlée à 20 °C (7 jours) et 0 °C (7 jours à 0 °C et 7 jours à 20 °C). **Résultats**. Les traitements effectués avec du 1-MCP ont ralenti le ramollissement des fruits en fonction de la concentration du produit. L'inhibition du ramollissement a été la plus forte pour les fruits traités et maintenus à 20 °C. La concentration optimale pour ralentir le ramollissement à 20 °C a été de 1 μL·L^{-1} de 1-MCP, tandis que la concentration de 0.5 μL·L^{-1} de 1-MCP a été la plus efficace à 0 °C. **Conclusion**. Les traitements effectués avec du 1-MCP ont inhibé la perte d'acidité titrable dans les fruits des deux cultivars Claudia et Nespolone di Trabia. Ce produit permet de prolonger la durée vie de fruits périssables tels que les fruits de néfliers sujets à un rapide ramollissement.

Italie / *Eriobotrya japonica* / fruits / perte après récolte / physiologie après récolte / aptitude à la conservation

1. Introduction

Loquat (*Eriobotrya japonica* Lindl.) has been classified as a non-climacteric fruit [1] with a short postharvest life. The fruit decays quickly after harvest, and losses in titratable acidity, taste and juiciness and internal browning occur rapidly during postharvest life [2].

Ding *et al.* showed that low temperatures extend loquat postharvest performance, reducing respiration, ethylene production, weight loss and slow changes in chemical components associated with fruit quality [3]; although cold storage may extend loquat storage life, internal browning and flesh leatheriness (mainly manifested as increased fruit firmness and decreased extractable juice rate) are frequent problems during storage at 1 °C [4]. However, a lack of information persists about loquat fruit postharvest physiology during cold storage, and in particular it is still not clearly understood how chilling injury symptoms occur on yellow- and white-flesh fruit.

Although ripening of non-climacteric fruit may be ethylene-independent, several studies have shown that ethylene has some effects on non-climacteric fruit such as cherries, citrus and strawberries [5]. Several authors demonstrated that ethylene is involved in ripening and senescence regulation of non-climacteric fruits such as citrus [6].

One way of extending the storage life of fruit is to control ethylene production and perception.

1-Methylcyclopropene (1-MCP) is a cyclic alkene that interacts with the receptor and competes with ethylene for binding in the plant cell [7], thereby inhibiting ethylene signal transduction and action [8].

The ethylene action inhibitor 1-MCP was found to delay ripening and improve postharvest quality of climacteric fruit [9–11]. Treatments with 1-MCP were also useful in non-climacteric fruit such as strawberry fruit, maintaining firmness and color, and extending postharvest fruit life [12]. Zheng *et al.* [4] and Cai *et al.* [5] showed that 1-MCP fruit treatments reduced internal browning and maintained quality in cold-stored loquat fruit (more than 39 days at 0–5 °C). However, different aspects remain unclear such as the different behavior of white- and yellow-flesh cultivars and the use of 1-MCP for short cold storage periods and at temperatures higher than 0 °C.

Our study was conducted to evaluate the positive effect of 1-MCP treatment on fruit of two cultivars of loquat: Claudia and Nespolone di Trabia. The effects of slower ripening and preventing negative effects of short cold storage, such as internal browning, were monitored.

Our aim was to understand how 1-MCP treatments affect fruit senescence at 20 °C and prevent chilling injury symptoms in short cold storage periods in white- and yellow-flesh loquat fruit.

2. Materials and methods

2.1. Fruit treatments

Loquat white-flesh (cv. Claudia) and yellow-flesh (cv. Nespolone di Trabia) fruit were harvested from commercial orchards, located in Palermo (38°04' N, 13°22' E, 150 m a.s.l.). Fruit were hand-picked at the ripe stage (light orange peel), suitable for the fresh fruit market. Immediately after harvest fruit quality parameters were analyzed on 30 fruits of each cultivar.

One hundred and twenty fruits (120) for each treatment and cultivar, placed in a 30-L plastic jar, were treated with 1-MCP at either 20 °C or 0 °C. The 1-MCP formulation (Smartfresh, Italy), a.i. of 0.14%, was weighed into a test tube and capped. Just before treatment, five mL of 40 °C water were added to the test tube. The tube was immediately closed, vortexed, placed in the jar with the fruit, and opened. The 30-L plastic jar was immediately sealed. The cvs. Claudia and Nespolone di Trabia fruit were placed at 20 °C in closed containers and treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP for 20 h. At the end of the treatment the containers were opened and the fruit held at 20 °C for 7 days. At 0 °C, cvs. Claudia and Nespolone di Trabia fruit were treated for

20 h with (0.5 and 1) μL·L^{-1} of 1-MCP. After 1-MCP treatment, fruit were held at 0 °C for 7 days and then transferred to 20 °C for 7 days. A sample of fruit of each cultivar was held untreated for control at 0 °C and 20 °C.

The experiment was conducted at 0 °C and 20 °C to understand if 1-MCP treatments could be used by the grower during cold storage and on the way to the market if fruit should be marketed immediately.

2.2. Quality parameters: firmness, soluble solids, titratable acidity and flesh disorders

Fruit were analyzed:

– (2, 3 and 6) days after harvest when treated with 1-MCP and held at 20 °C,

– (0, 2 and 5) days after transfer from 0 °C to 20 °C when treated with 1-MCP and held at 0 °C for 7 days.

Firmness was measured on opposite pared cheeks of each fruit (30 fruits per sample, three replicates of 10 fruits each) with a digital penetrometer (TR model 53205, Turoni, Forlì, Italy) incorporating an 8-mm-diameter probe, after removal of a small piece of peel.

A wedge-shaped slice of flesh was taken longitudinally from each fruit and ten fruit wedges were peeled and juiced. Total soluble solids (TSS) were determined by digital refractometer (Palette PR-32, Atago Co., Ltd., Japan) and titratable acidity (TA) by titration of 10 mL juice with 0.1 N NaOH to pH 8.1 and expressed as % malic acid (model S compact titrator, Crison Instrum., Barcelona, Spain).

Ten fruits for each cultivar and treatment were weighed every 2 days to observe their weight loss.

After measurement of firmness and sampling for total soluble solids and titratable acidity, fruits were halved and examined visually for flesh disorders and browning. The internal browning (IB) was evaluated as the percentage of browning area to the total flesh area. Fruit were considered unsuitable for the consumer at 40% of browning area. Data were submitted to analysis of variance (ANOVA) and means were separated with the Tukey test at $P \leq 0.05$. The statistical analysis was carried out using Systat 10 (Systat, USA).

2.3. Sensory evaluation

At the end of each shelf life period (20 °C), ten fruits for each treatment were subjected to sensory evaluation. To define the sensory differences among the loquat samples, the sensory profile method [13] was used. The sensory profile was constructed by using a trained panel of ten judges [14], consisting of students of the Department of Agricultural and Food Science (DISPA, Univ. Catania, Italy). In a few preliminary meetings, by using commercial loquat, the judges generated a list of descriptors based on the percentage of citations referring to appearance, olfactory, gustative and mouthfeel attributes. The final set consisted of 17 descriptors. The different descriptors were quantified using a nine-point intensity scale where the digit 1 indicates the descriptor's absence and the digit 9 the full intensity. Evaluations were carried out in single boxes at the DISPA sensory analysis laboratory. The order of presentation was randomized among judges. Water was provided for rinsing between samples. All data were acquired by a direct computerized registration system (FIZZ Biosystemes, version 2.00 M, France).

The sensory data for each attribute were submitted to one-way analysis of the variance (ANOVA) by the software package Statgraphics® Centurion XVI using samples as factors. To differentiate the samples the mean values were submitted to the multiple comparison test using the Least Significant Difference (LSD) procedure.

3. Results

3.1. Effects of 1-MCP on fruit quality at 20 °C

Firmness of white-flesh cv. Claudia fruit significantly decreased 2 days after treatment

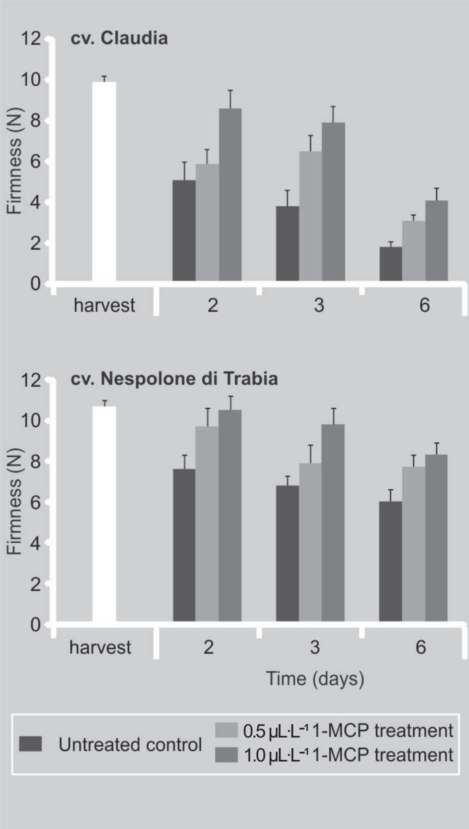

Figure 1
Firmness of cvs. Claudia and Nespolone di Trabia loquat (*Eriobotrya japonica* Lindl.) fruit treated at harvest for 20 h at 20 °C with (0.5 and 1) µL·L^{-1} of 1-MCP and then held at 20 °C for 2 days, 3 days and 6 days after harvest. Data are means ± standard error (n = 30). Different letters between histograms indicate significant differences at P < 0.01 by Tukey's test.

at 20 °C in fruit treated with 0.5 µL·L^{-1} of 1-MCP and untreated (control) fruit (*figure 1*); in contrast, only untreated cv. Nespolone di Trabia fruit lost firmness after 2 days at 20 °C (*figure 1*).

3.1.1. For cv. Claudia fruit

Two days after harvest, untreated cv. Claudia fruit were around 50% softer than at harvest, while fruit treated with (0.5 and 1) µL·L^{-1} of 1-MCP were 40% and 13% softer, respectively. Three days after harvest 1-MCP-treated cv. Claudia fruit retained firmness, while untreated fruits were 62% softer than at harvest (*figure 1*). At the end of the experiment (6 days after harvest), untreated fruit were considered unmarketable (82% softer than at harvest), while cv. Claudia fruit treated with 1-MCP were considered suitable for the consumer (around 65% softer than at harvest) (*figure 1*). Six days after harvest, both treated and untreated cv. Claudia fruit were softer than at harvest and 1 µL·L^{-1} of 1-MCP was the most effective treatment in retaining firmness.

Treatments with 1-MCP did not affect weight loss or total soluble solids content but titratable acidity decrease was delayed at both concentrations (data not shown).

Internal browning (IB) appeared at 20 °C six days after harvest, with an incidence of 30% in untreated cv. Claudia fruit, while IB was almost absent in 1-MCP-treated fruit (5%) (data not shown).

3.1.2. For cv. Nespolone di Trabia fruit

The cv. Nespolone di Trabia yellow-flesh fruit showed excellent postharvest performance. Indeed, at 20 °C, two days after harvest, untreated fruit were 30% softer than those observed at harvest and fruit treated with (0.5 and 1) µL·L^{-1} of 1-MCP were 9% and 2% softer, respectively (*figure 1*). Three days after harvest, untreated fruit and fruit treated with 0.5 µL·L^{-1} of 1-MCP were 36% and 26% softer than at harvest, respectively; while fruit treated with1 µL·L^{-1} of 1-MCP lost only 8% firmness compared with that observed at harvest. Six days after harvest, untreated fruit were softer than 1-MCP-treated fruit, 44% *vs.* 28% and 22% for fruit treated with (0.5 and 1) µL·L^{-1} of 1-MCP, respectively (*figure 1*). At the end of the experiment (6 days after harvest), untreated and 1-MCP-treated cv. Nespolone di Trabia fruit were considered suitable for the consumer (*figure 1*).

Treatments with 1-MCP did not affect weight loss or total soluble solids content but titratable acidity decrease was delayed during the experiment in both cultivars.

At 20 °C, six days after harvest, internal browning was almost absent in cv. Nespolone di Trabia fruit, with an incidence of 2% in control fruits and 0% in 1-MCP-treated fruit (data not shown).

In cv. Nespolone di Trabia fruit, the treatment with 1 µL·L^{-1} of 1-MCP was also the most effective for retaining firmness and reducing internal browning.

3.2. Effects of 1-MCP on fruit quality at 0 °C

3.2.1. For cv. Claudia fruit

Fruit firmness decreased immediately after transfer from 0 °C (7 days) to 20 °C in treated and untreated white-flesh cv. Claudia fruit (*figure 2*).

At day 0 of transfer from 0 °C to 20 °C, untreated cv. Claudia fruit were around 65% softer than those studied at harvest; while fruit treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP were 40% and 48% softer, respectively.

Two days after transfer from 0 °C to 20 °C, untreated cv. Claudia fruit were very soft: 77% softer than at harvest, while fruit treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP were 59% and 67% softer, respectively (*figure 2*).

Five days after transfer from 0 °C to 20 °C, untreated cv. Claudia fruit (85% softer than at harvest) and fruit treated with 1 $\mu L \cdot L^{-1}$ of 1-MCP (78% softer than at harvest) were considered unmarketable, while fruit treated with 0.5 $\mu L \cdot L^{-1}$ of 1-MCP retained firmness in treated fruit (68% softer than at harvest) (*figure 2*).

Five days after transfer from 0 °C to 20 °C, the internal browning (IB) incidence was 50% in untreated cv. Claudia fruit, while in fruit treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP, the IB incidence was 10% and 15%, respectively (data not shown).

Treatments with 1-MCP at 0 °C were more effective in terms of firmness loss and internal browning incidence at a concentration of 0.5 $\mu L \cdot L^{-1}$.

3.2.2. For cv. Nespolone di Trabia

The cv. Nespolone di Trabia yellow-flesh fruit also showed excellent postharvest performance after 7 days at 0 °C. Indeed, at day 0 of transfer from 0 °C to 20 °C, both control and 1-MCP fruit were around 35% softer than at harvest (*figure 2*).

Two days after transfer from 0 °C to 20 °C, untreated fruit and fruit treated with 1 $\mu L \cdot L^{-1}$ of 1-MCP were softer than those studied at harvest, 50% and 48%, respectively, while fruit treated with 0.5 $\mu L \cdot L^{-1}$ of 1-MCP lost only 31% firmness compared with at harvest (*figure 2*). Five days after transfer from 0 °C to 20 °C, untreated fruit were softer than 1-MCP-treated fruit, 63% *vs.* 48% and 57% in fruit treated with (0.5 and 1) μL of 1-MCP$\cdot L^{-1}$, respectively (*figure 2*) .

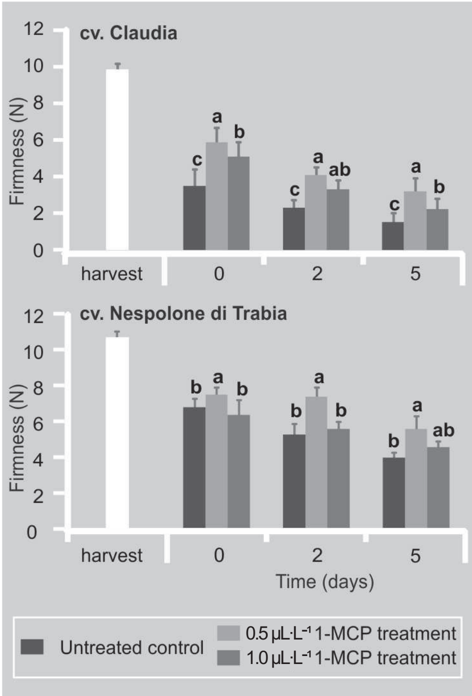

Figure 2
Firmness of cvs. Claudia and Nespolone di Trabia loquat (*Eriobotrya japonica* Lindl.) fruit treated at harvest for 20 h at 20 °C with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP and stored at 0 °C for 7 days and then moved to 20 °C for the shelf life: firmness was measured at 0 days, 3 days and 5 days. Data are means ± ES (n = 30). Different letters between histograms indicate significant differences at $P < 0.01$ by Tukey's test.

At the end of the experiment (5 days after transfer from 0 °C to 20 °C), untreated and 1-MCP-treated cv. Nespolone di Trabia fruit were considered suitable for the consumer.

Five days after transfer from 0 °C to 20 °C, internal browning (IB) was 25% in untreated cv. Nespolone di Trabia fruit, while in fruit treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP, the IB incidence was 8% and 5%, respectively (data not shown).

In cv. Nespolone di Trabia fruit, treatment with 0.5 $\mu L \cdot L^{-1}$ of 1-MCP was also the most effective treatment for retaining firmness and reducing internal browning.

3.3. Sensory evaluation

The ANOVA results regarding the sensory evaluation did not show significant differences among the samples of the cv. Claudia fruit (*figure 3*), and only the bitter descriptor

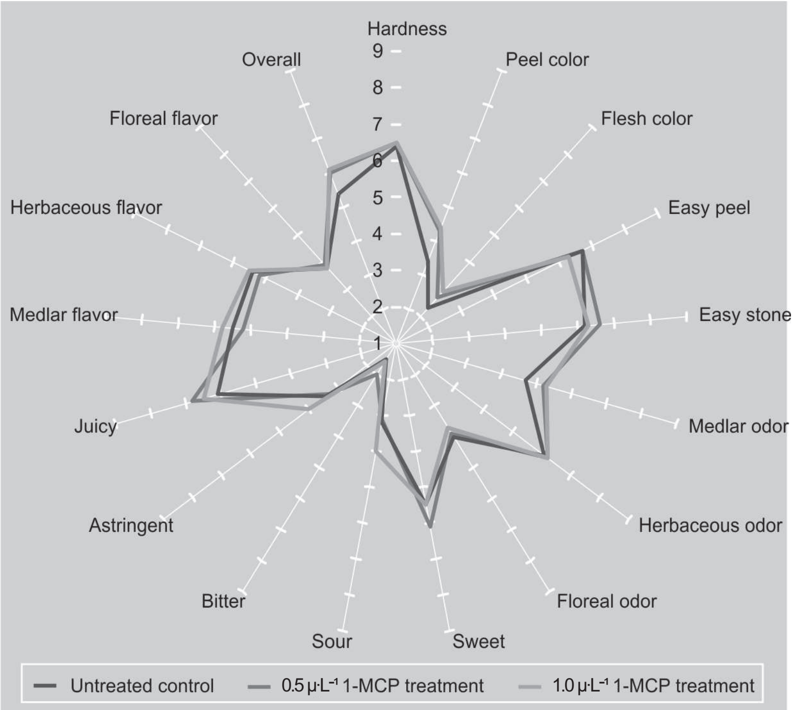

Figure 3
Sensory analysis of cv. Claudia loquat (*Eriobotrya japonica* Lindl.) fruit treated at harvest for 24 h at 20 °C with (0.5 and 1) μL·L^{-1} of 1-MCP and stored at 0 °C for 7 days and then held at 20 °C for 5 days. Comparison of untreated loquat fruit and fruit treated with (0.5 and 1) μL·L^{-1} of 1-MCP after 5 days at 20 °C.

differentiated the samples of the cv. Nespolone di Trabia fruit (*figure 4*).

Fruit of cv. Nespolone di Trabia treated with 0.5 μL·L^{-1} of 1-MCP showed a high intensity of the bitter descriptor.

4. Conclusion

Our study regarding the effects of 1-methylcyclopropene on postharvest quality of white- and yellow-flesh loquat fruit demonstrated that loquat senescence can be slowed and shelf life increased by a 20-h treatment with 1-MCP either at 20 °C or at 0 °C for 7 days. The major effect of the 1-MCP was to slow the softening process in white-flesh cv. Claudia and yellow-flesh cv. Nespolone di Trabia fruit. At 20 °C, the inhibition of softening was greater with increasing concentration of 1-MCP from (0.5 to 1) μL·L^{-1}; Liguori *et al.* showed the same trend in melting flesh peaches and nectarines treated with 1-MCP concentrations from (0.5 to 1) μL·L^{-1} [10]. In contrast, in cold storage conditions (0 °C), the treatment with 0.5 μL·L^{-1} of 1-MCP was more effective at reducing softening in both cultivars, demonstrating that relatively low concentrations of 1-MCP may also be useful to extend loquat postharvest life.

Furthermore, yellow-flesh cv. Nespolone di Trabia fruit treated with 1-MCP were not affected by storage disorders such as internal browning and flesh leatheriness; in white-flesh cv. Claudia fruit, the treatment with 1-MCP significantly reduced the internal browning manifestation and flesh disorders; similar results were shown by Zheng *et al.* in loquat fruit [4], by Selvarajah *et al.* in pineapple fruit [15] and by Pesis *et al.* in avocado fruit [16]. Fan *et al.* showed that 1-MCP treatments increased storage disorders in cv. Elberta peaches [17], while no problems were observed in the two loquat cultivars that we studied, although long-term storage was not examined.

These data suggest that 1-MCP may be used commercially to prevent chilling injury symptoms and flesh disorders during cold storage and extend loquat fruit shelf life. Sensory evaluation demonstrated that 1-MCP treatment did not affect the sensory fruit profiles at both temperatures which were tested.

The positive response of the fruit to the ethylene action inhibitor at low temperature allowed the fruit to be treated while cooling, thus making it possible to store the fruit that cannot be marketed immediately. However, if the fruit was to be marketed, it could be sorted, packed and treated on its way to the market. This allows versatile planning for the grower in marketing the crop.

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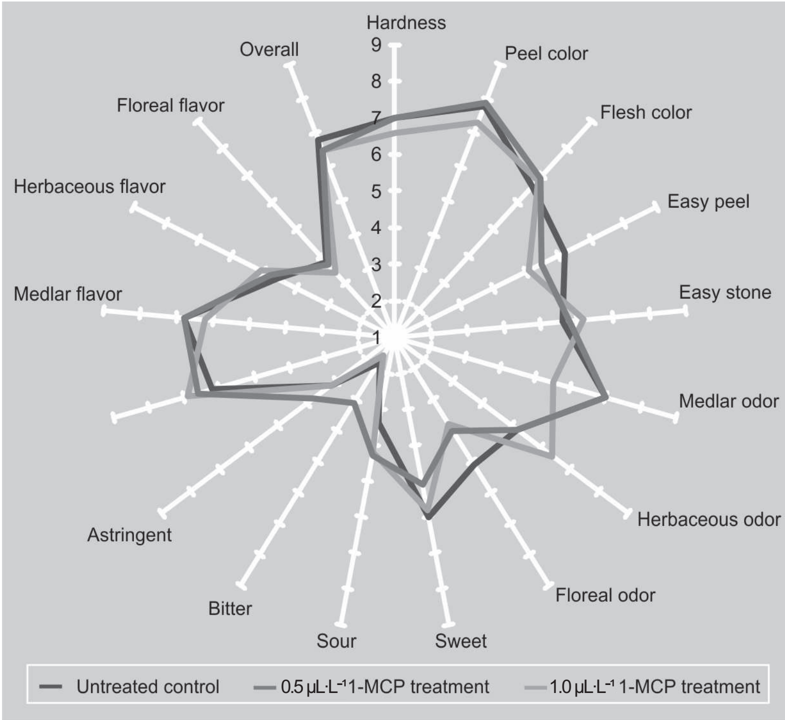

Figure 4
Sensory analysis of cv. Nespolone di Trabia loquat (*Eriobotrya japonica* Lindl.) fruit treated at harvest for 24 h at 20 °C with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP and stored at 0 °C for 7 days, then held at 20 °C for 5 days. Comparison of untreated loquat fruit and fruit treated with (0.5 and 1) $\mu L \cdot L^{-1}$ of 1-MCP after 5 days at 20 °C.

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Efectos del 1-metilciclopropeno en la calidad postcosecha de nísperos del Japón de carne blanca y amarilla (*Eriobotrya japonica* Lindl.).

Resumen – **Introducción**. Se evaluaron los efectos del 1-metilciclopropeno (1-MCP) en frutos de nísperos del Japón de carne blanca (cv. Claudia) y amarilla (cv. Nespolone di Trabia). **Material y métodos**. Se controló la aplicación del 1-MCP [(0.5 a 1) μL·L^{-1} durante 20 h)] a 20 °C (7 días) y 0 °C (7 días a 0 °C y 7 días a 20 °C). **Resultados**. Los tratamientos efectuados con 1-MCP ralentizaron el reblandecimiento de los frutos en función de la concentración del producto. La inhibición del reblandecimiento fue más fuerte para los frutos tratados y mantenidos a 20 °C. La concentración óptima para ralentizar el reblandecimiento a 20 °C fue de 1 μL·L^{-1} de 1-MCP, mientras que la concentración de 0.5 μL·L^{-1} de 1-MCP fue la más eficaz a 0 °C. **Conclusión**. Los tratamientos efectuados con 1-MCP inhibieron la pérdida de acidez valorable en los cultivares Claudia y Nespolone di Trabia. Este producto permite prolongar la duración de vida de los frutos perecederos, tales como los frutos de níspero sujetos a un reblandecimiento rápido.

Italia / *Eriobotrya japonica* / frutas / pérdidas postcosecha / fisiología postcosecha / aptitud para la conservación