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采前喷施1-MCP对贮藏期巴梨果实品质和后熟性的影响

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摘　要：【目的】分析采前喷施1-甲基环丙烯(1-methylcyclopropene，1-MCP)对贮藏期巴梨果实褐变、品质和后熟性的影响，为延长西洋梨贮藏期的适宜采前处理措施的制定提供参考。【方法】果实成熟前12 d(2016年7月29日)喷施300 mg·L^{-1} 1-MCP，处理果实分别在8月10日(1-MCP)和8月17日采收(1-MCP +后采)。以喷施清水为对照，对照果实8月10日采收，采后果实放入冷库中贮藏(−1.1℃)。【结果】贮藏前3个月，3个处理果实均无褐变发生。贮藏4个月，对照处理果实果心褐变率为33.33%，1-MCP和1-MCP+后采处理果实无褐变发生，3个处理果实均能正常后熟；贮藏5个月，对照果心和果肉褐变率达66.67%，果实不能正常后熟；1-MCP处理果实无褐变发生，1-MCP+后采处理果心褐变率为21.74%，显著低于对照处理，2个处理果实均能正常后熟。贮藏4个月和5个月，2个采收期的1-MCP处理果实硬度、果皮叶绿素含量和可滴定酸含量显著高于对照，可溶性固形物含量显著低于对照，而且二者之间除果实硬度差异显著外，其余果实品质无显著差异。同时，采前1-MCP处理显著降低了贮藏期果实的乙烯释放量、呼吸强度、多酚氧化酶(polyphenol oxidase，PPO)活性、多酚和丙二醛含量。【结论】采前喷施1-MCP推迟了果实成熟，降低了贮藏期巴梨果实褐变发生程度、推迟褐变发生时间，提高了贮藏期果实品质。

关键词：梨；果实褐化；果实品质；后熟；1-甲基环丙烯(1-MCP)

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Effect of pre-harvest 1-methylcyclopropene application on internal browning and storage quality of Bartlett pear

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Abstract:【Objective】Storage life of European pear (*Pyrus communis* L.) fruits is restricted by loss of eating quality and occurrence of storage disorders. Eating quality of the pear fruits is mainly dependent on the development of ripening degree, sugar and acid content. Internal browning is a major storage disorder influencing the postharvest management of Bartlett pears. The storage life is affected by cultivation techniques such as irrigation, fertilizing, fruit maturity and harvest date. Labor shortages would lead to fruit over-maturity on trees, therefore, developing strategies to slow on-tree fruit maturation would be economically valuable for growers and industries by retaining high quality fruits for delivering to the market. 1-Methylcyclopropene (1-MCP), an inhibitor of ethylene action, can reduce ethylene production and delay fruit ripening. The purpose of this study was to investigate the effects of pre-harvest 1-MCP application on the fruit maturation, internal browning, storage quality and ripening of Bartlett pear.【Methods】A proprietary formulation of 1-MCP for spraying of fruits (3.8% a.i.; HarvistaTM; AgroFresh Solution Inc., PA) was applied at 300 mg·L^{-1} using an application volume of 1350 L·hm^{-2} on July 29. All application was made with a sprayer to the point of runoff. The non-1-MCP treated Bartlett fruits were harvested on August 10 (Control), and the 1-MCP treated fruits were harvested on August 10

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(the treatment labeled as “1-MCP”) and August 17 (the treatment labeled as “1-MCP & delayed harvest”), respectively. The non-damaged fruits were stored immediately after harvest at −1.1 ℃ and 90%–95% relative humility. The internal browning was assessed visually on 1 d, 3 d, 5 d after transferring from cold storage to 20 ℃ condition. On 1, 3 and 5 days at 20 ℃ after 4 or 5 months of cold storage, the ethylene production rate was measured by gas chromatograph (GC-8A; Shimadzu, Kyoto, Japan), and the respiration rate was measured using a CO_2 analyzer (Model 900161; Bridge Analyzers Inc., Alameda, CA). The peel chlorophyll content was determined on the opposite sides of the equator of each fruit using a DA meter (Sinteleia, Bologna, Italy). After removal of the peel, fruit firmness was measured on the opposite sides of the equator of each fruit with the fruit texture analyzer (Model GS-14, Guss Manufacturing Ltd., Strand, South Africa). The titratable acidity and soluble solid content were measured using a commercial titration system (Model DL15, Mettler-Toledo Inc., Columbus, OH, USA) and a digital refractometer (Atago, Tokyo, Japan), respectively. On the 5th day at 20 ℃,100 g of flesh tissue was grounded for 3 min using a juice extractor with uniform strip of milk filter and measured with 100 mL graduated cylinder. The extractable juice was measured in a 100 mL graduated cylinder. Meanwhile, the activity of polyphenol oxidase (PPO), the content of polyphenol and malondialdehyde (MDA) in the fruit flesh were determined.【Results】The internal browning in all fruit samples was not found in the end of 3 months of cold storage at −1.1 ℃. After 4 months of cold storage, the browning of the fruit cores of the control (harvest date 10th August) occurred, and the browning incidence was 33.33%. However, the browning symptoms in the fruits treated with 1-MCP (harvest date 10th or 17th August) was not found. After 5 months of cold storage, the browning of the core and flesh tissues of the control fruits were increased, and the browning incidence was 66.67%. The browning symptoms only occurred in the cores of fruits treated with 1-MCP & delayed harvest and the browning incidence was 21.74%, which was significantly lower than that of the control. The browning symptom of fruits treated with 1-MCP was not found. At harvest, the firmness of the fruits treated with 1-MCP (87.37 N) was significantly higher than that of the control (84.56 N) and the firmness of the fruits treated with 1-MCP & delayed harvest was 85.31 N, indicating that pre-harvest 1-MCP application could delay the fruit maturation on-tree. Compared with the control, the ethylene production rate and respiration rate were inhibited by pre-harvest 1-MCP application regardless of harvest date. The activity of polyphenol oxidase (PPO), the content of polyphenol and MDA were significantly inhibited, and the decrease of fruit firmness and peel chlorophyll content was retarded. The fruit firmness of the control was 32.55 N on the 5th day at 20 ℃ after 5 months of cold storage, indicating the fruits could not normally ripen. But the fruit firmness of 1-MCP and 1-MCP& delayed harvest was 23.33 N and 24.14 N, and the extractable juice was 536 $mL \cdot kg^{-1}$ and 585 $mL \cdot kg^{-1}$, respectively, indicating pre-harvest 1-MCP application did not affect the fruit ripening.【Conclusion】In conclusion, the pre-harvest 1-MCP treatment could delay the maturation on-tree, delay the onset of the internal browning for about 1 or 2 months and improve the storage quality of Bartlett fruits.

Key words: Pear; Browning; Storage quality; Ripening; 1-methylcyclopropene (1-MCP)

巴梨是西洋梨优良品种，后熟时果肉细腻、多汁、香味浓郁，逐渐受到我国消费者的喜爱。巴梨贮藏过程中易发生果肉或果心褐变，是限制其长期贮藏的主要因素之一。研究表明，巴梨果实褐变与质膜过氧化和多酚氧化酶（polyphenol oxidase，PPO）活性有关[1-3]。细胞中存在两种形态的PPO，一种以游离态形式存在细胞质中，具有催化活性；另一种以结合态形式存在细胞膜上，无催化活性。逆境下细胞膜发生过氧化、细胞结构遭到破坏时，结合态PPO转化成游离态PPO，PPO活性增强；酚类物质从液泡

流入细胞质中，被PPO氧化为醌类物质，从而引起果实褐变[4]。已有研究表明，采收过晚、成熟度过高以及果实的膜脂过氧化作用增强，都会提高果实褐变发生程度[5]。目前，随着劳动力的缺乏，延缓果实成熟、延长采收期已成为缓解劳动力短缺的有效措施之一。

气调贮藏或采后1-甲基环丙烯（1-methylcyclopropene，1-MCP）处理可有效减少贮藏期果实褐化的发生[6-9]，但气调贮藏易发生CO_2伤害[1]，而采后1-MCP处理效果受剂量[10]、贮藏温度[11]、采收期[12]、容器材质[13]等因素的影响且需要密闭环境。Harvista™是美国AgroFresh公司研制发明的一种1.3-悬浮剂型1-MCP，采前喷施，操作简便。笔者所在的课题组前期研究表明采前14 d喷施300 mg · L^{-1}的Harvista™可降低贮藏期果实虎皮病的发生率和质膜过氧化程度，抑制果实硬度、果皮叶绿素含量和可滴定酸含量的下降[14]。但是，关于采前喷施1-MCP和不同采收期对贮藏期巴梨果实褐变的影响尚不清楚。本研究旨在探讨采前喷施1-MCP处理结合不同采收期对巴梨贮藏中果实褐变、PPO活性和果实品质的影响，为今后延长巴梨果实贮藏期提供一定的参考依据。

1　材料和方法

1.1　试验材料与处理

本试验地点选自美国俄勒冈州Parkdale商品果园（45°30′N，121°36′W），海拔610 m。试验品种为20 a生巴梨（*Pyrus communis* L.），砧木为榅桲（*Cydonia oblonga* Miller），南北行向，栽植密度为3 m×5 m。

试验于2016年7月29日（成熟前12 d）进行，利用CO_2压力喷雾机喷施300 mg · L^{-1} 1-MCP（Harvista™，AgroFresh Solution Inc.，PA）溶液，以喷清水为对照，施用量为1350 L · hm^{-2}，生产上以果实硬度作为采收期确定依据，巴梨适宜采收时果实硬度为80~89 N。对照处理的果实于8月10日采收（CK），果实硬度为84.56 N。1-MCP处理的果实分别在8月10日采收、果实硬度87.37 N（1-MCP）和8月17日采收、果实硬度85.31 N（1-MCP+后采）。采收时选取生长势和负载量相近的梨树作为取样树，完全随机设计，每个处理6株树，3次重复。将树冠外围无机械损伤和病虫害的果实，放入衬有微孔聚乙烯袋的木箱内，每个木箱70个果实，然后立即送到位于Hood River的俄勒冈州立大学农业研究与推广中心冷库中，冷库温度控制在（−1.1±0.5）°C，相对湿度为90%~95%。

1.2　相关指标的测定

1.2.1　果实褐变率、乙烯释放量和呼吸强度的测定　果实褐变率测定参考何近刚等[15]的方法，贮藏后每隔1个月，每个处理取180个果实放置在室温（20.0±1.0）℃和相对湿度50%~60%环境下。放置1、3、5 d，用水果刀沿果实赤道线切开，观察果实褐变情况，统计果实褐变率。果实褐变率(%)=果实褐变数/果实总数×100。完全随机设计，每个处理20个果实，3次重复。

乙烯释放量和呼吸强度的测定参照Li等[16]的方法。

1.2.2　PPO活性、总酚和丙二醛（malondialdehyde，MDA）含量的测定　PPO活性测定参考Yazdani等[17]的方法，略有改动。取1.0 g冷冻果肉粉末加入3 mL醋酸缓冲液中，混匀4 ℃ 10 000×*g*下离心15 min，取1 mL上清液加入50 mmol · L^{-1}邻苯二酚反应液1 mL，立即在420 nm下测定OD值，每隔1 min记录1次OD值，酶活性以每min变化0.01个OD值为1个单位。

多酚含量的测定参考Yazdani[17]的福林比色法，MDA含量测定参照郝再彬等[18]的硫代巴比妥酸比色法。

1.2.3　果实贮藏品质的测定　参考Xie等[11]的方法，贮藏第4和5个月，将果实放置在室温（20.0±1.0）℃、相对湿度50%~60%，放置后第1天，测定果皮叶绿素含量、果实硬度、可滴定酸含量和可溶性固形物含量。果皮叶绿素含量采用DA测定仪测定，测定果实赤道线正反面的果皮，单位用I_{AD}表示。果实硬度采用GS-14水果质地分析仪测定，探头直径为8 mm，单位用N表示。可滴定酸含量测定采用DL15全自动酸度仪，单位用含苹果酸mmol · L^{-1}表示。可溶性固形物含量采用PAL-1数显糖度测定仪测定，单位用%表示。每个处理10个果实，3次重复。

1.2.4　果实后熟性的测定　参考Xie等[11]的方法，贮藏第4和5个月室温放置后第5天，测定果实硬度和出汁量。每个处理10个果实，3次重复。

1.3　数据统计与分析方法

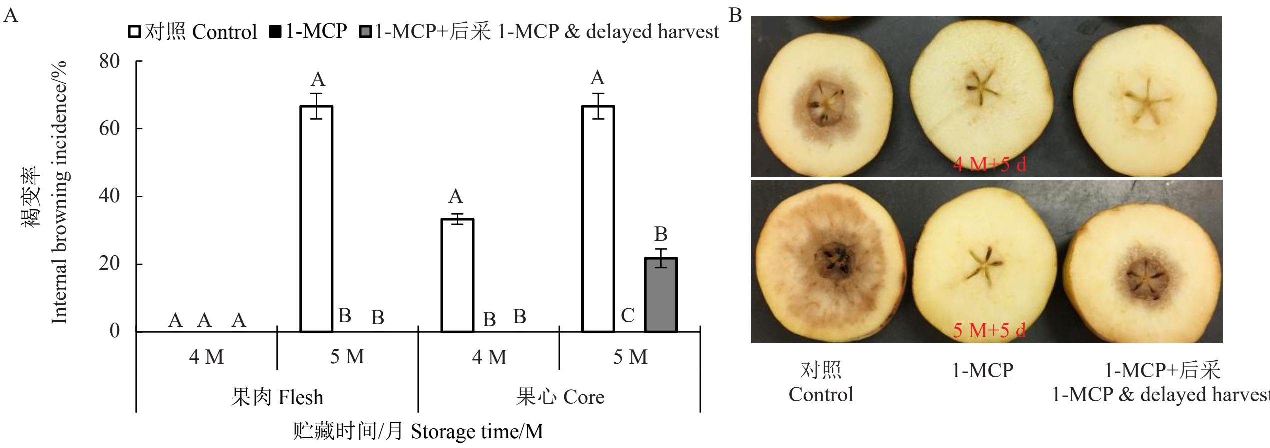
数据在Office 2010中统计和作图，运用SPSS

17.0软件进行方差分析，应用Duncan's多重比较进行显著性分析。

2　结果与分析

2.1　采前喷施1-MCP对巴梨果实褐变的影响

研究发现贮藏(-1.1 ℃)前3个月，无果实褐变的发生。随着贮藏时间的延长，褐变率呈现上升的趋势，褐变症状均在室温5 d时出现(图1-A~B)。贮藏4个月，对照处理果心褐化，褐变率33.33%；1-MCP和1-MCP+后采处理的果实均无褐变的发生，极显著低于对照处理。贮藏5个月，对照果肉和果心褐变率上升到66.67%；1-MCP+后采处理仅果心褐化，褐变率为21.74%，极显著低于对照处理；1-MCP处理的果实没有发生褐变。



A. 贮藏(-1.1 ℃)4个月和5个月，室温放置5 d不同处理巴梨果实褐变率，不同大写字母表示同一贮藏时间不同处理差异极显著($p \leqslant 0.01$)；B. 贮藏(-1.1 ℃)4个月和5个月，室温放置5 d不同处理巴梨果实褐变症状。

A. The internal browning of the 'Bartlett' fruit on 5 days after 4 and 5 months storage (-1.1 ℃), different capital letters indicate significant differences of the treatments at same storage time at $p \leqslant 0.01$ levels; B. The browning symptom of the fruit on 5 days after 4 and 5 months storage (-1.1 ℃).

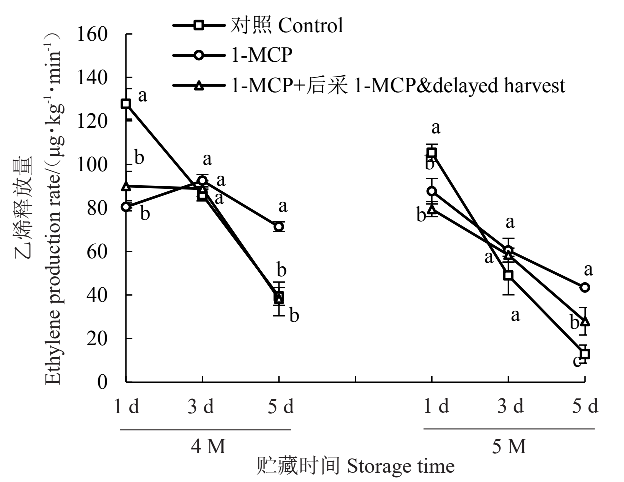
图1　采前1-MCP处理对巴梨果实褐变的影响

Fig. 1　Effect of 1-MCP treatment on the internal browning of Bartlett fruit

2.2　采前喷施1-MCP对巴梨果实乙烯释放量和呼吸强度的影响

从图2中可以看出，采前喷施1-MCP降低了贮藏期巴梨的乙烯释放量。贮藏4个月室温1 d，对照处理果实乙烯释放量显著高于1-MCP处理和1-MCP+后采处理；室温3 d，对照处理乙烯释放量显著下降，1-MCP处理的乙烯释放量呈现上升，1-MCP+后采处理无显著变化，3个处理之间无显著差异；室温5 d，3个处理乙烯释放量均呈下降趋势，但1-MCP处理显著高于对照和1-MCP+后采处理。贮藏5个月，3个处理果实的乙烯释放量均呈下降趋势：室温1 d对照处理的乙烯释放量均显著高于1-MCP和1-MCP+后采处理，随后迅速下降；室温5 d对照处理乙烯释放量最低，而且2个采收期之间差异显著。

从图3中可以看出，采前喷施1-MCP降低了贮藏期巴梨果实的呼吸强度。贮藏4个月 室温1 d和3 d，采前喷施1-MCP显著降低果实呼吸强度，



不同小写字母表示同一贮藏时间不同处理差异显著($p \leqslant 0.05$)。下同。

Different lowercase letters on same column indicate significant differences of the treatments at the same storage time at $p \leqslant 0.05$ levels. The same below.

图2　采前1-MCP处理对巴梨果实乙烯释放量的影响

Fig. 2　Effect of 1-MCP treatment on the ethylene production rate of Bartlett fruit

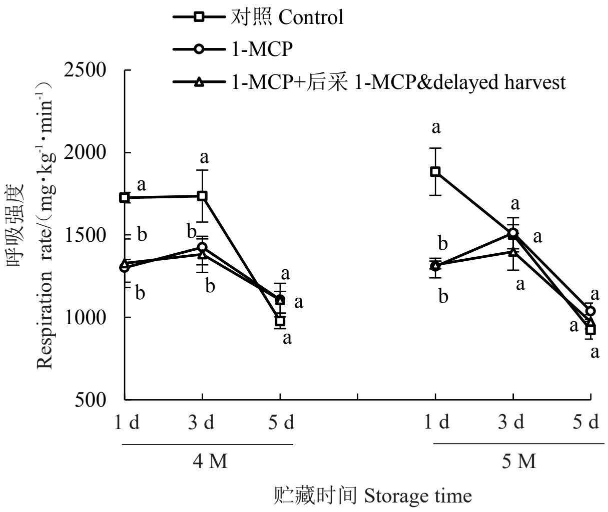


图3　采前1-MCP处理对巴梨果实呼吸强度的影响

Fig. 3　Effect of 1-MCP treatment on the respiration rate of Bartlett fruit

而且2个采收期的1-MCP处理之间无显著差异；温室5 d，3个处理果实的呼吸强度迅速下降，且处理之间无显著差异。贮藏5个月室温1 d，对照处理的果实呼吸强度显著高于采前1-MCP处理，随后迅速下降，3 d和5 d与1-MCP和1-MCP+后采差异不显著。

2.3　采前1-MCP处理对果实MDA含量的影响

从图4中可以看出，随着贮藏时间的延长，果肉中MDA含量呈现增加的趋势，贮藏5个月3个处理的MDA含量均显著高于4个月同时期水平。贮藏4个月室温放置1 d，3个处理的果肉MDA含量处于较低水平，处理之间无显著差异；随后，MDA含量迅速增加，室温3 d和5 d对照的MDA含量均显著高于1-MCP和1-MCP+后采处理。贮藏5个月室温3 d和5 d，对照MDA含量显著高于1-MCP和1-MCP+后采处理。除贮藏5个月室温5 d时1-MCP+后采处理MDA含量显著高于1-MCP处理外，其余贮藏时间2个处理之间MDA含量均差异不显著。

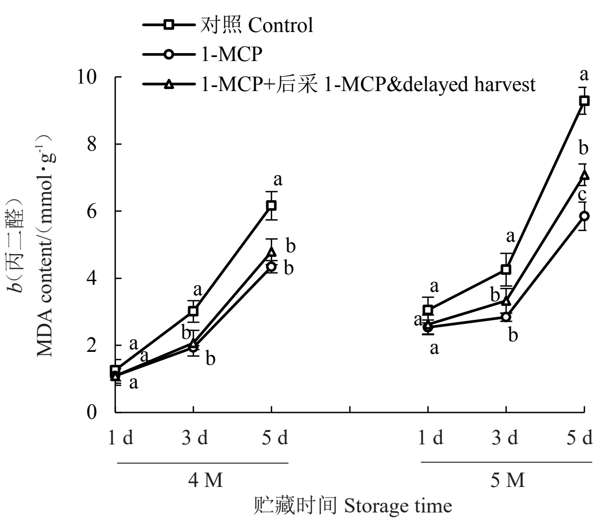


图4　采前1-MCP处理对巴梨果实MDA含量的影响

Fig. 4　Effect of 1-MCP treatment on the MDA content of Bartlett fruit

2.4　采前1-MCP处理对果实PPO活性和多酚含量的影响

从图5中可以看出，随着贮藏时间的延长，果肉PPO活性整体呈现增加的趋势。贮藏4个月后，室温下3个处理果实PPO活性均呈现先升高后下降的趋势，而且对照果实PPO活性均显著高于1-MCP和1-MCP+后采处理。贮藏5个月，3个处理PPO活性呈现不同的变化趋势：室温1 d对照PPO活性显著高于其余2个处理，随后迅速下降，室温5 d显著低于其余2个处理；1-MCP处理PPO活性呈现先升后降的趋势，室温3 d PPO活性显著高于对照和1-MCP+后采处理；1-MCP+后采处理PPO活性呈现增加趋势，室温5 d显著高于对照和1-MCP处理。

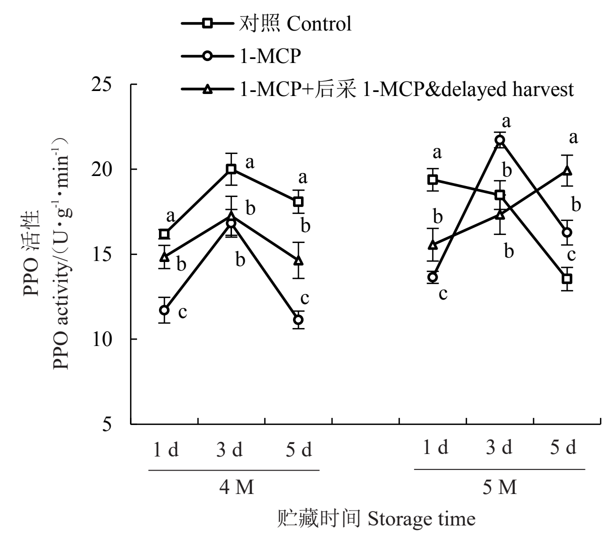


图5　采前1-MCP处理对巴梨果实PPO活性的影响

Fig. 5　Effect of 1-MCP treatment on the PPO activity of Bartlett fruit

从图6中可以看出，随着贮藏期的延长，果肉中的多酚含量呈增加趋势，采前1-MCP延缓了贮藏期果实中酚类含量的增加。贮藏4个月和5个月，对照果实多酚含量均显著高于1-MCP和1-MCP+后采处理。延迟果实采收提高了室温后期果实中酚类物质含量。贮藏4个月和5个月室温5 d，1-MCP+后采处理果实中酚类含量显著高于1-MCP处理。

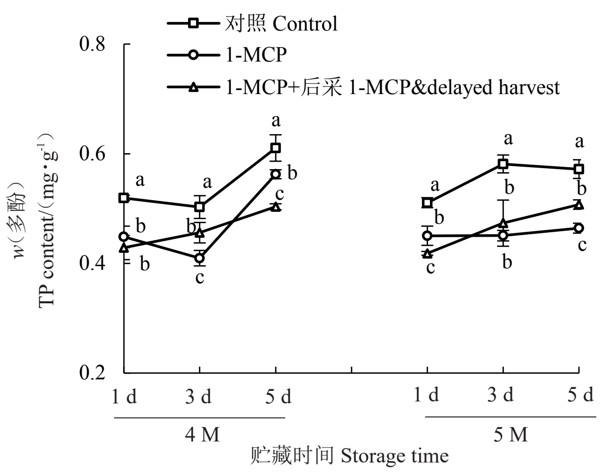


图 6 采前 1-MCP 处理对巴梨果实多酚含量的影响

Fig. 6 Effect of 1-MCP treatment on the TP content of Bartlett fruit

2.5 采前 1-MCP 对贮藏品质的影响

从表1看出，随着贮藏时间延长，果实硬度、果皮叶绿素含量、可滴定酸含量和可溶性固形物含量均呈下降趋势。但是，1-MCP 和 1-MCP+后采处理的果实硬度和果皮叶绿素含量显著高于对照。贮藏4个月和5个月，3个处理果实可滴定酸含量无显著差异，但不同处理之间的降幅不同。对照下降了 37.50%，其降幅显著高于 1-MCP 22.22% 和 1-MCP+后采 28.57%，这说明采前 1-MCP 处理对可滴定含量无影响，但抑制了可滴定酸含量的下降。除贮藏4个月 1-MCP+后采处理果实硬度显著低于 1-MCP 处理外，其余贮藏时间的2个处理之间果实硬度、果皮叶绿素含量、可滴定酸含量和可溶性固形物含量均无显著差异。

表 1 采前 1-MCP 处理对巴梨贮藏品质的影响

Table 1 Effect of preharvest 1-MCP application on the storage quality of Bartlett fruit

处理 Treatment	硬度 Fruit firmness/N		果皮叶绿素含量 Peel chlorophyll content/(I_{AD})		c(可滴定酸) Titratable acidity content/(mmol·L^{-1})		w(可溶性固形物) Soluble solids content/%	
	4 M	5 M	4 M	5 M	4 M	5 M	4 M	5 M
对照 Control	73.52±2.17 Ac	64.27±3.01 Bb	1.58±0.14 Ab	1.23±0.08 Bb	1.58±0.06 Aa	1.03±0.14 Ba	12.93±0.15 Aa	12.40±0.43 Aa
1-MCP	83.23±1.02 Aa	73.24±2.57 Ba	1.88±0.02 Aa	1.68±0.03 Ba	1.84±0.15 Aa	1.38±0.02 Ba	12.00±0.17 Ab	11.23±0.11 Ab
1-MCP+后采 1-MCP&delayed harvest	77.89±1.01 Ab	71.91±0.72 Ba	1.93±0.08 Aa	1.63±0.09 Ba	1.38±0.10 Aa	0.96±0.01 Ba	11.77±0.10 Ab	11.10±0.20 Ab

注：同行不同大写字母表示同一处理不同贮藏时间差异显著($p \leq 0.05$)，同列不同小写字母表示相同贮藏时间不同处理之间差异显著($p \leq 0.05$)。下同。

Note: Different capital letters in the same row indicate significant differences of the same treatment at different storage time at $p \leq 0.05$ levels. Different lowercase letters in the same column indicate significant differences among 3 treatments at the same storage time at $p \leq 0.05$ levels. The same below.

2.6 采前 1-MCP 处理对果实后熟的影响

多数西洋梨果实需经过后熟才能食用，室温(20.0±1.0) ℃下，果实硬度＜24 N、出汁量＜650 mL·kg⁻¹ 时果实达到最佳可食性[19]。从表2中可以看出，贮藏4个月室温5 d，3个处理的果实硬度为17.56~20.91 N、出汁量456~507 mL·kg⁻¹，均达到了最佳食用性。随着贮藏时间的延长，果实后熟加快，出汁量增加。果实冷藏5个月室温5 d，对照果实硬度显著上升，达32.55 N，果实软化受到影响；1-MCP 和 1-MCP+后熟处理果实硬度分别为 23.33 和 24.16 N，显著低于对照，出汁量为 536 和 585 mL·kg⁻¹，这表明采前 12 d 喷施 1-MCP，2个采收期的巴梨果实均能正常软化。

表 2 采前 1-MCP 处理对巴梨果实后熟的影响

Table 2 Effect of preharvest 1-MCP application on the ripening of Bartlett fruit

处理 Treatment	硬度 Fruit firmness/N		出汁量 Extractable juice/(mL·kg^{-1})	
	4 M	5 M	4 M	5 M
对照 Control	20.91±0.43 Ba	32.55±2.06 Aa	507±26 Ba	587±20 Aa
1-MCP	17.56±0.57 Bb	23.33±2.89 Ab	456±15 Ba	536±11 Aa
1-MCP+后采 1-MCP& delayed harvest	18.46±1.19 Bb	24.16±2.03 Ab	496±17 Ba	585±7 Aa

3 讨 论

梨果实贮藏过程中易发果肉或果心褐变(黑心病)等生理病害，是限制长期贮藏的主要因子之一。贮藏前期低温和后期衰老均引起梨果实黑心病发生[20]。普通贮藏(−1.1±0.5) ℃条件下，巴梨果实贮藏期为1~3个月[21]。本研究表明，贮藏前3个月，巴梨果实无褐变的发生；贮藏4个月对照果实

果心部位出现褐化，贮藏5个月褐变症状扩展到整个果肉，褐变率为66.67%，失去了商品性 。这说明，贮藏期间巴梨果实褐变主要是由后期果实衰老引起的。

1-MCP通过与乙烯受体结合或抑制乙烯合成，阻碍乙烯信号的传递，从而延缓果实衰老进程[22-24]。本研究表明，采前12 d进行1-MCP处理，采收时（8月10日）果实硬度为87.37 N，显著高于对照84.56 N，推迟了果实成熟，这与Villalobos-Acuña等[25]的研究结果相一致。同时，采前1-MCP处理显著降低了贮藏期间乙烯释放量和呼吸强度，果实硬度和果皮叶绿素含量显著高于对照，延缓了果实的衰老，从而降低了巴梨果实衰老引起的果实褐变率。同时，采前喷施1-MCP显著降低了贮藏中巴梨果实质膜过氧化程度，避免了由于细胞结构破坏引起的PPO活性增加、液泡中多酚被氧化成醌类，从而减少了果实褐变的发生。

多数西洋梨属于软肉梨，后熟时果实硬度低于24 N和出汁量低于650 mL·kg^{-1}时更受消费者的青睐[19]。贮藏时间的延长影响西洋梨果实的正常后熟，表现为果实硬度增加。本研究表明，巴梨果实贮藏4个月室温5 d，3个处理果实均能正常后熟；随着贮藏时间的延长，果实后熟受到影响。巴梨果实贮藏5个月室温5 d，对照处理果实硬度上升到32.55 N，果实软化受到影响。Dong等[26]研究表明，Comic梨果实贮藏（−1.1±0.5）℃超过4个月，果实硬度呈现增加趋势，果肉呈败絮状，这与长期贮藏抑制果胶甲酯酶活性有关。本试验还表明贮藏5个月，2个采收期的1-MCP处理果实均能正常软化，这可能与采前1-MCP处理抑制果实软化后期乙烯释放率下降有关。温室5 d，1-MCP和1-MCP+后采处理高水平的乙烯释放率促进细胞壁中果胶的分解，加速果实的软化。

4 结 论

贮藏（−1.1±0.5）℃期间巴梨果实褐变主要是由后期果实衰老引起的，采前12 d喷施300 mg·L^{-1} 1-MCP延缓了果实成熟、降低了贮藏期果实褐化率、推迟果实褐化发生，不影响果实的正常后熟。

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