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Fruit Quality of 1-Methylcyclopropene Treated 'Formosa' Plum on the Shelf Life at Ambient Temperature

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Abstract. The effects of 1-methylcyclopropene (1-MCP) for controlling ripening processes such as weight loss, fruit softening, soluble solids content (SSC), titratable acidity (TA), and fruit skin color were investigated and also the possibility that 1-MCP can inhibit the development of brown rot was explored in 'Formosa' plum (*Prunus domestica* L.). Fruit were treated with 1 $\mu L \cdot L^{-1}$ 1-MCP on the day of harvest and one day after harvest for 16 h at ambient temperature (20℃), followed by 14 days of shelf life. 1-MCP treatment delayed fruit softening, weight loss and changes in skin color and TA during the shelf life period, but did not affect SSC. These 1-MCP effects were similar with and without delayed treatment. 1-MCP treatment inhibited the development of brown rot caused by *Monilinia laxa* during storage. Our data shows that treatment delays of ≥ 1 day before 1-MCP application had no negative effect of fruit softening, fruit skin color, and TA at ambient temperature (20℃). Overall, these results indicate that 1-MCP can be used to maintain the quality of non-refrigerated plums.

***Additional key words*:** brown rot, fruit quality, *Prunus domestica* L., skin color, storage, weight loss

Introduction

'Formosa' plums are easily perishable and have a limited postharvest life during storage. Softening is one of the serious problems resulting in losing marketable quality during postharvest handing, shipping and storage (Abdi et al., 1997). Therefore, softening should be curtailed during shelf life to maintain fruit quality. Ethylene is known to regulate physiological quality such as maintaining postharvest firmness, titratable acidity (TA), and soluble solids content (SSC) on different cultivars of plum during ripening process (Dong et al., 2002; Taylor et al., 1995), and further steps that might affect the development of brown rot (Menniti et al., 2004). To minimize postharvest softening and increase its shelf life, plum is usually maintained by low temps, often supplemented with controlled atmosphere (CA) storage (Dong et al., 2002; Menniti et al., 2006). However, its benefit is limited by the appearance of physiological disorders such as internal breakdown, gel breakdown, and brown rot by *Monilinia laxa* during the storage (Dong et al., 2002; Menniti et al., 2006); also, adequate storage facilities are not always available.

1-methylcyclopropene (1-MCP), an inhibitor of ethylene receptor, is being used as a potential tool to delay the ripening process, and to maintain fruit quality in climacteric fruit, including different cultivars of plum (Blankenship and Dole, 2003; Blankenship and Sisler, 1993; Salvador et al., 2003; Sisler and Serek, 2003; Watkins, 2006). An increased shelf life could be useful for transporting plum to commercial market without losing quality for an extended period of time. Furthermore, exposure to 1-MCP can reduce the development of physiological disorders (Menniti et al., 2006).

Menniti et al. (2006) reported that application of 1-MCP was equally effective in delaying postharvest softening of plum stored at both room and low temperatures. Its response varied with cultivars (Abdi et al., 1998; Menniti et al., 2006), concentrations (Salvador et al., 2003; Valero et al., 2003), temperatures and timing of application (Dong et al., 2002). Most studies have typically been restricted to prolonged cold storage in air, or under CA, plus stimulated shelf-life. When fruit is treated with 1-MCP soon after harvest and under ideal laboratory conditions, control of ripening and by 1-MCP can be inconsistent for some cultivars (Menniti et al., 2006). However, little information exists on the role played by the delayed 1-MCP application on quality and brown rot of 'Formosa' plum kept under this condition.

The objective of this study was to compare the effects of the delayed application of 1-MCP on the fruit quality over short periods of time (i.e., for 14 days) and on the development of brown rot under ambient temperature (20℃) during shelf life.

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Materials and Methods

'Formosa' plums (*Prunus domestica* L.) were harvested from a commercial orchard located in Yesan, Korea. The experiment was conducted using uniform sizes of fruits randomly replicated with five fruits per replicate for each treatment.

The fruit was treated with 1 $\mu L \cdot L^{-1}$ of 1-MCP in 0.6 m^3 acrylic plastic chambers for 16 h on the day of harvest and one day after harvest, respectively. All treatments were applied by adding 1-MCP powder (Smart Fresh^{TM}) to warm water at 40℃, and sealing the chamber immediately. After treatments, plums treated with or without 1-MCP were stored together at ambient temperature (20℃).

At each sampling time, five fruits from each of the three replications were used to determine weight loss, changes of flesh firmness, skin color, TA, SSC, and brown rot incidence. For color assessment, Hunter Lab System (L, a, b) in a colorimeter: CR200 model, (Minolta Camera Co., Osaka, Japan) was used and expressed as b parameter.

After weighing with the electronic balance scale, the skin was removed from the opposite side of individual fruit and then flesh firmness was measured at three equatorial points on fifteen fruits from each treatment using a hand-held pressure tester (FHM-5, Takemura Denki Manufacture Co., Japan). Then, a wedge-shaped slice (from stem end to calyx end) was removed from each fruit, pressed through cheesecloth, and the SSC of the juice was measured with digital refractor-meter at each sampling time (PR-201 Atago, Co., Japan). Juice from each replication was pooled to form a composite sample, and TA was measured with an automatic titrator (GMK-706R, G-won Hightech Co., Korea). Brown rot incidence was expressed as a percentage of infected fruit during shelf life.

Each dependent variable was statistically analyzed using the general linear model procedure (PROC GLM) of SAS (version 8.02; SAS Institute, Cary, NC, USA). Following analysis of variance, mean separation was performed by Duncan's multiple range tests (DMRT) at 0.05% level.

Results

Softening of untreated fruit was rapid, while fruit treated with 1 $\mu L \cdot L^{-1}$ 1-MCP on the day of harvest and one day after harvest did not soften until 10 days of storage when maintained at 20℃ during storage. After 7 days of storage, 1-MCP-treated plum still remained firm, while untreated fruit easily lost fruit firmness. No differences were seen between the timings of application, but all 1-MCP-treated fruits were significantly firmer than untreated fruit (Fig. 1).

A gradual weight loss was observed in both treated and untreated fruits during shelf life. The highest weight loss was obtained in untreated fruit with value of 7.2%, while those of 1-MCP treated-fruit on the day of harvest and one day after harvest reached 4.7 and 4.3% after 7 days of storage, respectively. Overall, fruit weight loss was clearly reduced in 1-MCP treated-fruit during storage. No significant differences were detected between the timing of 1-MCP treatments (Fig. 2).

The TA of 1-MCP-treated fruit was higher than those of untreated fruit through 14 days of storage. After 7 days of storage, TA of untreated fruit decreased sharply by the end of storage, while those of 1-MCP-treated fruit maintained its TA values. No significant differences in TA were detected between the timing of 1-MCP treatment. All 1-MCP-treated fruits had higher TA values than untreated fruit during shelf

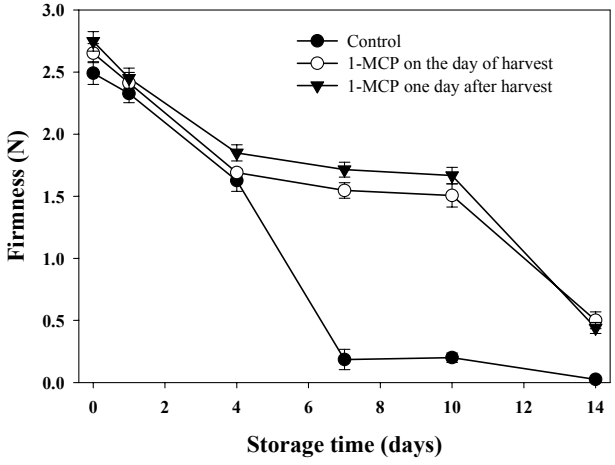

Fig. 1. Flesh firmness of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

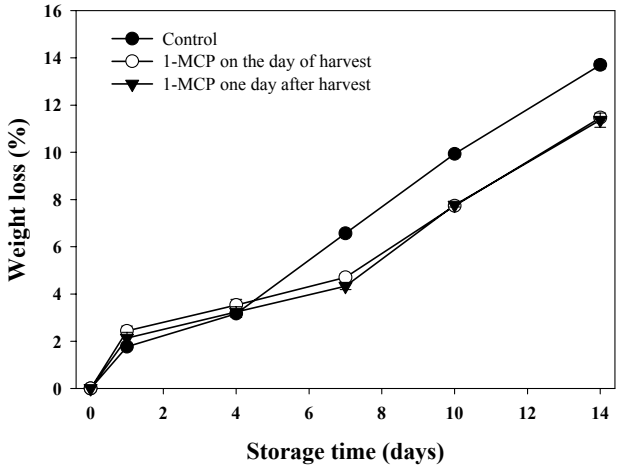

Fig. 2. Weight loss of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

life (Fig. 3).

1-MCP treatments had no effects on SSC change during shelf life, except for 7 days of storage. Even though SSC in 1-MCP-treated fruit was higher than those of untreated fruit stored for 7 days, the overall pattern of SSC in fruit treated with or without 1-MCP was inconsistent during storage (Fig. 4).

1-MCP treatment delayed skin color changes as indicated by the higher 'b' value than untreated fruit during storage. The larger differences on color 'b' values between 1-MCP treated and untreated fruit were apparent following 4 days of storage. 1-MCP-treated fruit showed light purple color, while those of untreated fruit showed dark purple color by 4 days of shelf life (Fig. 5). No significant differences were detected between untreated fruit and 1-MCP-treated fruit after 7 days of storage (Fig. 5).

Brown rot caused by *Monilinia laxa* was found on the majority of plums during shelf life. After 7 days of storage at ambient temperature (20℃), the development of brown rot on 1-MCP-treated fruit increased by 1.67%, while those of untreated fruit increased by 5%. No further development of the incidence of brown rot on 1-MCP-treated fruit was detected by the end of storage, while those of untreated fruit increased up to 18%. 1-MCP effects on the development of brown rot were similar with and without delayed treatment (Fig. 6).

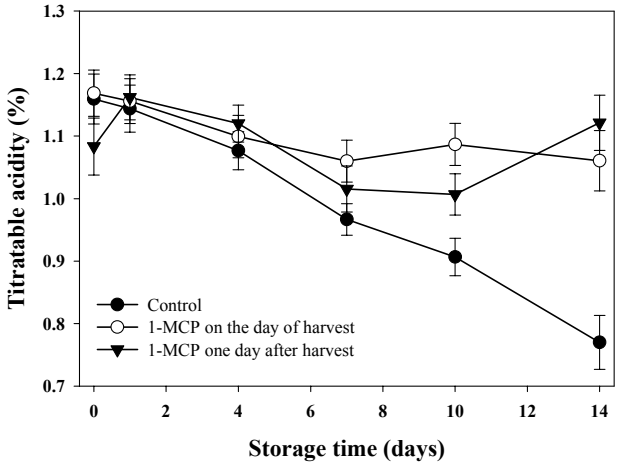

Fig. 3. Titratable acidity of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

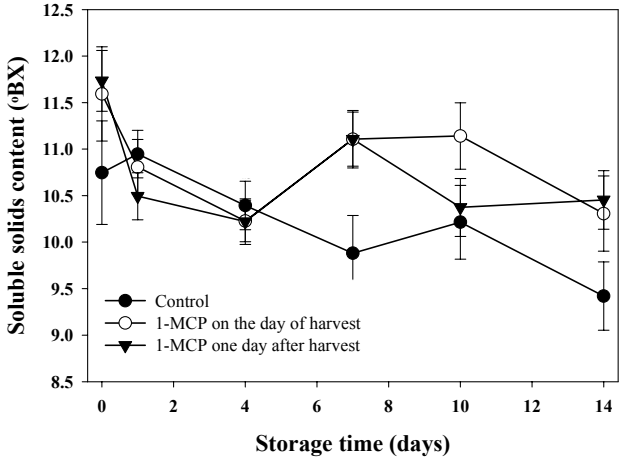

Fig. 4. Soluble solids content of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

Discussion

In present study, we showed that 1-MCP effectively delayed fruit softening, weight loss, TA, and colour changes in 'Formosa' plum and followed by additional side effects such as the occurrence of brown rot during ripening period (Abdi et al., 1998; Dong et al., 2002; Menniti et al., 2006). Those parameters such as softening, colour changes, weight loss are closely related to the ripening processes of plum.

Untreated plum easily lost marketable qualities during shelf life, while 1-MCP treatment maintained fruit firmness, weight, skin color and TA. However, 1-MCP treatments had no effects on SSC during storage and no significant differences were detected between the timings of 1-MCP application (on the day of harvest or one day after harvest). A similar observation on SSC was reported in a previous plum study (Dong et al., 2002). This physiological behavior in ripening processes seems to be affected by 1-MCP application, and

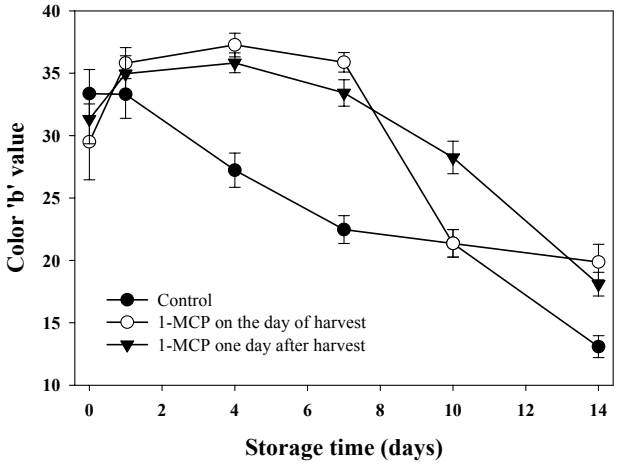

Fig. 5. Color 'b' value of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

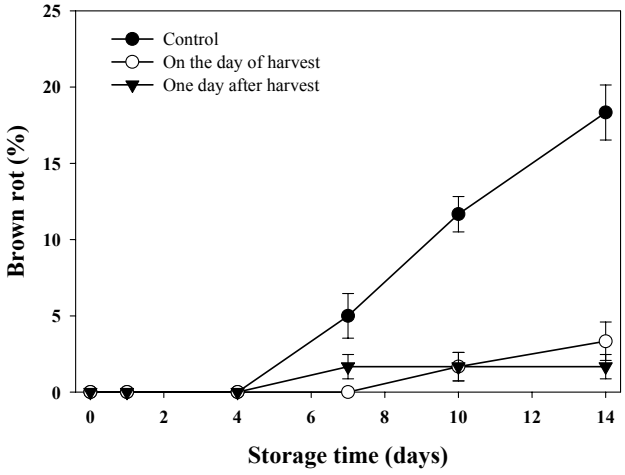

Fig. 6. Brown rot of 'Formosa' plum treated with 1-MCP on the day of harvest or one day after harvest and kept at ambient temperature for 14 days. Bars represent standard errors of the means, when larger than the dimension of the symbol (n = 15).

is related to the inhibition of ethylene production. Our present data agrees with other reports (Abdi et al., 1998; Baritelle et al., 2001; Jiang et al., 2001; Menniti et al., 2006; Watkins et al., 2000).

In our study, plums treated with 1-MCP required at least several days of storage at ambient temperature to ripen without losing marketable qualities of plum, based on fruit firmness, skin color, and TA. Furthermore, the development of brown rot on plum was reduced by 1-MCP treatment, while those of untreated fruit showed higher levels of brown rot. Our results showed additional 1-MCP application effects on reducing the incidence of brown rot in plums maintained in ambient temperature. Our study indicated that this phenomenon might be explained by ethylene sensitivity during shelf life. The data presented here were consistent with that presented in a previous report which showed the effectiveness of 1-MCP and it's effect on the development of brown rot (Menniti et al., 2006). In contrast, the response of 1-MCP on the incidence of brown rot was different by cultivars. Therefore, further study is required to confirm the effects of 1-MCP on the development of brown rot and storage disorders (Dong et al., 2002).

This study suggests that 1-MCP treatment can be used to maintain fruit quality in non-refrigerated 'Formosa' plum and reduce the occurrence of brown rot caused by *Monilinia Laxa*. Therefore, 1-MCP application can reduce fruit losses in the markets where access to cold storage is limited.

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1-Methylcyclopropene이 'Formosa' 자두의 품질과 유통기간 연장

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초 록. 본 연구는 1-MCP가 'Formosa' 자두의 저장 중 품질 변화와 유통기간 연장에 미치는 효과를 밝히고자 수행하였다. 수확한 'Formosa' 자두를 균일한 크기와 색깔로 선별한 후 수확 당일 그리고 수확 후 1일 후에 걸쳐서 각각 1-MCP를 1 $\mu L \cdot L^{-1}$ 농도로 20℃에서 16시간 동안 처리하여 대조구(무처리)와 비교하였다. 1-MCP를 처리한 후 14일 동안 상온에서 자두의 연화도, 과중감소율, 가용성고형물 함량 변화, 산도, 그리고 과실의 색깔 변화를 측정하였다. 과중감소율과 과실연화도는 1-MCP 처리구가 무처리구에 비해서 적은 변화폭을 보여주었다. 1-MCP 처리 시기(수확당일 그리고 수확 후 1일) 간에는 따른 큰 차이는 없었다. 가용성고형물 함량에는 통계적 유의성은 없었으나, 1-MCP처리구의 과실에서는 산도와 과실의 색깔 변화가 무처리구에 비해서 적게 나타났다. 또한 1-MCP는 저장 중에 발생하는 과실의 부패병 억제효과를 나타내었다. 따라서 본 연구결과, 1-MCP 처리시기(≥1일) 연장은 상온저장시 과실의 경도, 산도, 과일 색깔 변화에 큰 영향을 미치지 않았으며, 또한 과실품질 유지에 실용성이 있는 결과를 보여주었다.

추가 주요어 : 부패병, 과실품질, *Prunus domestica* L., 과피색, 저장, 과중감소