1-Methylcyclopropene処理がコマツナの収穫後の品質に及ぼす影響

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Effects of 1-Methylcyclopropene on the Postharvest Quality of Komatsuna (*Brassica rapa* L. Perviridis Group)

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Komatsuna (*Brassica rapa* L. Perviridis Group) rapidly turns yellow and degrades at ambient temperature after harvest. The effects of 1-methylcyclopropene (1-MCP) treatment on the postharvest quality of komatsuna were investigated. Komatsuna was treated without (control) or with 0.1, 0.5, or 1 μℓ/ℓ 1-MCP for 24 h at 20°C in the dark, and then stored in a perforated polyethylene bag at 20°C in the dark. In the control, yellowing was observed on the tops of the leaves, and the score was less than 4 on day 3. 1-MCP treatment delayed yellowing, and komatsuna treated with 0.1, 0.5, and 1 μℓ/ℓ 1-MCP started to yellow on days 4, 5, and 6, respectively. The chlorophyll a and b content was significantly higher in komatsuna treated with 1 μℓ/ℓ than in the others on day 3, and, thereafter, the decrease was retarded. The decrease in chlorophyll content reflects yellowing. 1-MCP treatment reduced weight loss and was likely to suppress carbon dioxide production to a greater extent than that observed in the control. In comparison with the control, 1 μℓ/ℓ 1-MCP treatment drastically suppressed the decrease in ascorbic acid and β-carotene content during storage. These results demonstrate that 1-MCP treatment is useful for the retention of komatsuna quality during storage.

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**Key words:** komatsuna, 1-MCP, quality

Komatsuna (*Brassica rapa* L. Perviridis Group) is a leafy vegetable, is produced throughout Japan because of its short growing period and its ability to adjust to various environments. It contains large amounts of vitamins and carotenes. After harvest, its outer leaves rapidly turn yellow at ambient temperatures. It has been reported that when it is stored at 28°C in the dark, the chlorophyll and ascorbic acid contents in the leaves decrease to 20% of their initial value in 3 days. The greenness of the leaves is an important quality index, and the retention of this quality during distribution is valuable.

Ethylene production is related to yellowing of leaves through chlorophyll degradation in some leafy vegetables after harvest. Application of an inhibitor of ethylene action or of ethylene synthesis to vegetables and fruits is an effective way to control the effect of ethylene. 1-Methylcyclopropene (1-MCP), a competitive inhibitor of ethylene, inhibits ethylene action. 1-MCP has been permitted for use towards postharvest quality retention of many horticultural crops in various countries. Many studies have been conducted on the effects of 1-MCP on fruits and flowers, but only a few have focused on leafy vegetables. So far, 1-MCP treatments have been reported to prolong the shelf life of some leafy vegetables, including coriander leaves, sweet basil, parsley, rocket, and Asian leafy vegetables. Furthermore, 1-MCP treatment delays the development of russet spotting in lettuce induced by exogenous ethylene, and increases its storage life. On the other hand, 1-MCP does not improve the shelf life of Chinese cabbage.

Therefore, this study was conducted to clarify the effects of 1-MCP treatment on the shelf life and postharvest quality of komatsuna.

**Materials and methods**

Fresh komatsuna (*B. rapa* L. Perviridis Group) was purchased from Sinkakobeseika Co., Ltd. (Kobe, Japan). Komatsuna of average size that was sound was selected for use. The roots were dipped in 1% sodium hypochlorite solution and rinsed with distilled water.

The komatsuna was treated without (control) or...
with 1-MCP (Smart Fresh™ 0.14% A.L., Rohn and Haas, Tokyo, Japan) at concentrations of 0.1, 0.5, or 1 μl/ℓ, in a 24.8 ℓ polyethylene container sealed with a rubber stopper for 24 h at 20°C in the dark. After 1-MCP treatment, the komatsuna were placed in a polyethylene bag (0.03 × 355 × 450 mm) with 4 punched holes (φ 5 mm). The bags were stored at 20°C in the dark until analysis. The day on which 1-MCP treatment was started was defined as day 0.

The quality of the leaves was evaluated visually according to changes in freshness and yellowing of leaves, as follows: 5 = fresh without any yellowing, 4 = acceptable for consumers with a slight loss of freshness, 3 = yellow at the leaf apex, 2 = one-half of the leaf blade yellow, 1 = entire leaf blade yellow.

Chlorophyll was assayed according to the method of Moran®. Leaf samples (0.5 g) were immersed in 30 ml of N,N-dimethylformamide and stored overnight at 5°C in darkness. The chlorophyll content was determined by measuring the absorbance of the solvent at 647 and 664 nm. β-Carotene content was assayed according to the method of Oyanagi and Ando®. L-Ascorbic acid (AsA) and L-dehydroascorbic acid (DHA) content was assayed, according to the method of Roe et al.®. Leaf samples (0.5 g) were taken on the day of measurement.

To measure carbon dioxide production, komatsuna were placed in a 3,360 ml container. The containers were sealed for 1 h at 20°C, and the headspace gas was withdrawn with a syringe. The carbon dioxide concentration was determined with a TCD gas chromatograph (GC-8 A, Shimadzu, Kyoto, Japan), using a Porapak Type Q column (Waters Corp., Milford, MA). The injector, column, and detector temperatures were 100, 90, and 100°C, respectively. The results of carbon dioxide production on a fresh weight basis were reported as mg·kg⁻¹·s⁻¹.

Results

1. Effects of 1-MCP treatment on the visual quality

Komatsuna was stored for 7 days at 20°C in the dark following treatment with 1-MCP for 24 h. The quality score is shown in Fig. 1, and marketability was considered lost at scores less than 4. The scores for each treatment continued to diminish during storage. In the control, yellowing was observed on the tops of the leaves, and the score was less than 4 on day 3. Treatment with 1-MCP delayed yellowing; komatsuna treated with 0.1, 0.5, and 1 μl/ℓ 1-MCP showed scores below 4 on days 4, 5, and 6, respectively. At the end of day 7, the scores were 1.5 for the control komatsuna and 2.3, 2.5, and 2.8 for those treated with 0.1, 0.5, and 1 μl/ℓ 1-MCP, respectively. These results indicate that 1-MCP treatment prolongs the shelf life, and that treatment with 1 μl/ℓ was the most effective.

2. Effects of 1-MCP treatment on chlorophyll content

Changes in the content of chlorophyll a and b during storage after 1-MCP treatment are shown in Fig. 2. Until day 2, there were no changes in chlorophyll a content in all treatments including control. After day 3, chlorophyll a levels started to decrease. However, the chlorophyll a levels were significantly higher in komatsuna treated with 1 μl/ℓ than in the others on day 3, and thereafter, the decrease was retarded. The changes seen in chlorophyll b content during storage were similar to those seen with chlorophyll a.

3. Effects of 1-MCP treatment on weight loss

The rates of weight loss during storage after treatment with various concentrations of 1-MCP are shown in Fig. 3. Progressive weight loss was observed after all treatments during the storage period. The rates of weight loss at the end of storage were 12.7, 11.4, 11.1, and 10.3% for the control and 0.1, 0.5, and 1 μl/ℓ 1-MCP-treated komatsuna, respectively. These results indicate that
1. MCP treatment tends to reduce weight loss during the storage of this vegetable in a dose-dependent manner.

4. Effects of 1-MCP treatment on carbon dioxide production

The rate of carbon dioxide production during storage after 1-MCP treatment is shown in Fig. 4. Carbon dioxide production increased from day 4 in the control. The pattern of carbon dioxide production from komatsuna treated with 0.1 μl/l 1-MCP was similar to that of control komatsuna. Komatsuna treated with 0.5 and 1 μl/l exhibited similar drifts in carbon dioxide production, and these values were more likely to be suppressed than those in the control komatsuna, except during days 3 ~ 5.

5. Effects of 1-MCP treatment on ascorbic acid content

Changes in AsA and DHA content during storage after 1-MCP treatment are shown in Fig. 5. The AsA content of the control komatsuna consistently decreased during storage, especially from day 0 to day 3. The rate of decrease in AsA during storage was progressively suppressed upon treatment with increasing concentrations of 1-MCP. There were no differences in AsA content between control and 0.1 μl/l 1-MCP-treated komatsuna, except on day 5. Treatment with 1 μl/l 1-MCP drastically suppressed the decrease in AsA content during storage, in comparison with that in the control. The DHA content, which was low compared to that of AsA,
Fig. 5 Changes in reduced ascorbic acid and dehydroascorbic acid contents of komatsuna during storage at 20°C.

Komatsuna was treated without (control [●]) or with 1-MCP at 0.1 [□], 0.5 [△], or 1 [○] μL/ℓ for 24 h. Vertical bars are the SE of 4 replications.

Fig. 6 Changes in β-carotene contents of komatsuna during storage at 20°C.

Komatsuna was treated without (control [●]) or with 1-MCP at 0.1 [□], 0.5 [△], or 1 [○] μL/ℓ for 24 h. Vertical bars are the SE of 4 replications.

Discussion

This study demonstrated that 1-MCP treatment could delay the yellowing of komatsuna during storage (Fig. 1). The decrease in chlorophyll content reflected the yellowing and reduced marketability of the leaf vegetable. While treatment with 0.1 μL/ℓ 1-MCP showed little effect compared to control, the 1 μL/ℓ 1-MCP treatment was very effective in delaying yellowing. The period of marketability of komatsuna treated with 1 μL/ℓ 1-MCP was 5 days, while that of the control was 3 days; in other words, 1-MCP treatment prolonged the period of marketability by 2 days (Fig. 1). These results show that treatment with 1-MCP at a concentration of 1 μL/ℓ is sufficient for maintaining the greenness of komatsuna.

1-MCP is an inhibitor of ethylene action and prevents ethylene effects in a broad range of fruits, vegetables, and ornaments\(^{19}\). Because of its mechanism of action, its effects on climacteric fruits have been investigated in detail\(^{16}\). The effect of 1-MCP on leafy vegetables has not been studied in depth because they generally produce very low levels of ethylene, although in some of them, endogenous ethylene is related to senescence. 1-MCP extends the shelf life of coriander leaves\(^8\), sweet basil\(^2\), parsley\(^6\), mizuna\(^1\), and tatsoi\(^7\), while in rocket\(^3\), pak choy, Chinese mustard, choy sum, and garland chrysanthemum\(^10\), 1-MCP is effective only in

was almost constant during storage and was not affected by 1-MCP treatment.

6. Effects of 1-MCP treatment on β-carotene content

Changes in the content of β-carotene during storage after 1-MCP treatment are shown in Fig. 6. The β-carotene content of the control komatsuna started to decrease at day 1, and consistently decreased thereafter. There were no differences in β-carotene content between control and 0.1 μL/ℓ 1-MCP-treated komatsuna from day 1 to day 6. The β-carotene content was significantly higher in komatsuna treated with 1 μL/ℓ 1-MCP than in the control komatsuna during storage.
the presence of exogenous ethylene. A climacteric-like peak in ethylene production has been observed in coriander leaves9 and sweet basil10 after harvest, but not in parsley11. As far as we know, there is no information about such a pattern in mizuna and tatsoi. Thus, we might not be able to attribute the effects of 1-MCP treatment to its inhibitory effect on the action of ethylene produced after harvest. However, it has been reported that the threshold level for ethylene action on non-climacteric produce is well below 0.005μl/l and that such low levels of ethylene are sufficient to exert a detrimental effect on postharvest life30. Taking this into consideration, undetectable levels of climacteric-like ethylene might be related to the senescence of some leafy vegetables. In this study, 1-MCP treatment was found to be effective in prolonging the greenness of komatsuna. Thus, we cannot exclude the possibility that endogenous ethylene might be related to senescence. Further studies on the effects of ethylene and 1-MCP treatment in the presence of exogenous ethylene, on the greenness of komatsuna, and on ethylene production during storage are required to understand the availability of 1-MCP to a greater extent.

Weight loss of vegetables during storage is an important factor that determines the quality of leafy vegetables. In this study, 1 μl/l 1-MCP had the effect of inhibiting this weight loss, a finding similar to that seen in sweet basil10. Treatment with 1 μl/l significantly reduced carbon dioxide production compared to control, except for days 3 ~ 5 (Fig. 4). These data indicate that treatment with 1 μl/l 1-MCP reduced weight loss and respiration and effectively maintained the freshness of komatsuna. Green leafy vegetables, including komatsuna, are rich in antioxidants, including ascorbic acid and carotene, and it is important to maintain their content in order to retain their quality during storage. In this study, 1-MCP treatment effectively maintained ascorbic acid and β-carotene levels during storage (Figs. 5 and 6). Although it is not known if ethylene directly regulates the amount of these antioxidants, similar results have been reported for total ascorbic acid content in lettuce31 and for DHA in spinach32. Our experiments suggest that 1-MCP treatment is useful for maintaining the quality, including vitamins and β-carotene content, of komatsuna.


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1-Methylocyclopropene処理がコマツナの収穫後の品質に及ぼす影響

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コマツナは収穫後常温下では急速に劣化し、その品質は劣化する。本研究では、1-methylcyclopropene（1-MCP）処理がコマツナの収穫後の品質に及ぼす影響を調べた。コマツナを0.1µL/ℓ, 0.5µL/ℓ, 1µL/ℓの1-MCPで24時間, 20℃暗所下で処理した。また, 1-MCP処理を行わなかったものをコントロールとした。1-MCP処理の後, コマツナを有孔ポリエチレン袋に入れ, 20℃暗所下で貯蔵した。その結果, コントロールでは貯蔵3日後に葉の先端に変色がみられ、スコアは4未満となった。一方, 0.1µL/ℓ, 0.5µL/ℓ, 1µL/ℓの1-MCP処理を行ったコマツナはそれぞれ貯蔵4日, 5日, 6日から変色がみとめられた。これらのことから, 1-MCP処理により葉の変色が遅延することが明らかとなった。1µL/ℓで処理されたコマツナのクロロフィル含量は貯蔵3日において他の処理区より有意に高く, その後の減少も遅延しており, クロロフィル含量の減少の遅延は劣化を反映していた。また, 1-MCP処理はコントロールと比べ重量減少を抑制し, 照射ガス生成量を抑制した。さらに, 1µL/ℓの1-MCP処理は貯蔵中のアスコルビン酸およびカロチン含量の減少を著しく抑制した。これらの結果から, 1-MCP処理は収穫後のコマツナの品質保持に有効であることが明らかとなった。

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