エチレン処理中の間欠換気と貯蔵温度がカキ‘西条’（Diospyros kaki Thunb.）熟柿果皮の着色に及ぼす影響
Effects of Intermittent Ventilation during Ethylene Treatment and Storage Temperature on Peel Color of Soft-Ripened ‘Saijo’ Persimmons (Diospyros kaki Thunb.)

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To obtain soft-ripened persimmons, ‘Saijo’ persimmons (Diospyros kaki Thunb.) were stored for several weeks at 0 °C, treated with 100 or 20 ppm ethylene in sealed containers for 48 h at 20 °C, and subsequently kept for 4 days at 10 °C or 20 °C. During the ethylene treatment, the containers were left open for 1 h for ventilation, and the effects of the frequency of ventilation on peel color were examined. The persimmons treated with 100 ppm ethylene with or without ventilation reached the soft-ripened stage after 4 days at 10 °C or 20 °C. Ventilation during the 100 and 20 ppm ethylene treatments markedly improved peel color of persimmons soft-ripened at 20 °C. In summary, ventilation during ethylene treatment improved peel color of persimmons soft-ripened after storage for 4 weeks at 0 °C.

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Key words: coloring, ethylene treatment, soft-ripened persimmon, storage, ventilation

Soft-ripened ‘Saijo’ persimmons have a very soft, juicy, and jelly-like flesh. The unique textural characteristics of the flesh of soft-ripened persimmons have made the fruit a popular commodity. The translucent flesh and reddish appearance of persimmons is attractive. AKAURA et al. established a procedure of obtaining soft-ripened ‘Saijo’ persimmons by cold storage and ethylene treatment of the harvested persimmons. After storage at 0 °C, persimmons were treated with 100 ppm ethylene for 48 h at 20 °C in sealed containers and then soft-ripened for 4 days at 20 °C.

Harvested persimmons normally soft-ripen at room temperature in November. Some naturally soft-ripened persimmons show brighter reddish-orange peel color than persimmons soft-ripened by ethylene treatment (48-h ethylene treatment in sealed containers). The monthly mean temperature in November in Matsue is approximately 10 °C, which is 10 °C lower than that used in the procedure proposed by AKAURA et al.

The ‘shot method’ described by KITAGAWA et al. improves the color of citrus fruit by frequent short treatments with ethylene in sealed containers. Ethylene treatment for 12 to 18 h in sealed containers was found to be the most effective treatment for improving rind color in harvested Satsuma mandarins, while ethylene treatment for 48 h was found to result in less desirable color. KITAGAWA and TARUTANI reported that ventilation after a 15-h ethylene treatment and a subsequent 15-h ethylene treatment considerably improved rind color in Satsuma mandarins. On the basis of this procedure and their findings, the current study was carried out to investigate the effects of ventilation during ethylene treatment on the color of soft-ripened ‘Saijo’ persimmons. The effect of temperature on the color of the persimmons after ethylene treatment was also examined.

Materials and Methods

Experiment 1. Effects of ventilation and temperature on peel color

‘Saijo’ persimmons were harvested at commercial maturity late in October in Matsue, Japan, and stored as described by AKAURA et al. Persimmons were packed in 26×38 cm 0.08-mm-thick polyethylene film bags (8 persimmons/bag), and stored for 4 weeks at 0 °C. At the end of the storage period, a 300-mm-long cut was made in each bag for
Six persimmons were treated with 100 ppm ethylene at 20°C in sealed plastic containers (9.5 L capacity, 12 persimmons/container). Sixty persimmons in five containers were treated with 100 ppm ethylene for 24 h at 20°C, and then the containers were left open for 1 h for ventilation. After ventilation, the persimmons were again treated with ethylene for 24 h. Another set of sixty persimmons in five containers was treated with ethylene continuously for 48 h. Fig. 1 shows a diagram of the ethylene and ventilation treatments used in Experiment 1.

After the treatments, six persimmons were transferred to stainless steel containers (265 × 153 × 84 mm) that had a polyethylene cover (390 cm² area) with a perforation of φ 5 mm. The containers were kept at 10 and 20°C for 4 days to soft-ripen the persimmons. Peel color was measured using a color chart (Kaki, Ministry of Agriculture, Forestry and Fisheries, Japan). This experiment was carried out using five replicates, with six persimmons per replicate. The removal of astringency in the soft-ripened persimmons was assessed in a sensory test by two trained male adults.

**Experiment 2. Effects of ventilation frequency on peel color**

‘Saijo’ persimmons were harvested at commercial maturity late in October in Matsue, Japan. The persimmons were stored for 1 week at 0°C and prepared for ethylene treatment as described in Experiment 1.

Six persimmons were treated with 100 ppm ethylene at 20°C in a sealed plastic container (4.5 L capacity). Ninety persimmons were used in this experiment. Thirty persimmons were treated with ethylene for 24 h and then the containers were left open for 1 h for ventilation. After ventilation, the persimmons were again treated with ethylene for 24 h. Thirty persimmons were treated with ethylene for 16 h and then the containers were left open for 1 h for ventilation. The persimmons were treated again with ethylene for 16 h and then the containers were left open for 1 h for ventilation. After the second ventilation, the persimmons were again treated with ethylene for 16 h. Thirty persimmons were treated with ethylene for 48 h. Fig. 2 shows a diagram of the ethylene and ventilation treatments used in Experiment 2.

After the treatments, six persimmons were transferred to stainless steel containers as described in Experiment 1. The containers were kept at 20°C for 4 days. This experiment was carried out using five replicates, with six persimmons per replicate.

The peel color of the intact persimmons during soft ripening was measured with a color chart. L*a*b* was measured to examine differences in peel redness. Peel discs (11 mm diameter, 1 mm thick) were cut from the equatorial zone of the soft-ripened persimmons with a borer, placed on a white plastic plate, and covered with a coverglass. The color of the discs was measured with a color-difference meter (Konica Minolta Inc., Color Reader CR-10).

**Experiment 3. Effect of ethylene concentration on peel color**

‘Saijo’ persimmons were harvested at commercial maturity late in October in Matsue, Japan. The persimmons were stored for 2 or 4 weeks at 0°C and prepared for ethylene treatment as described in Experiment 1.

Ninety persimmons were used for each storage period. Six persimmons were treated with 20 or 100 ppm ethylene at 20°C in a sealed plastic container (390 cm² area) with a perforation of φ 5 mm. The containers were left open for 1 h for ventilation. After ventilation, the persimmons were again treated with ethylene for 24 h. Another set of sixty persimmons in five containers was treated with ethylene continuously for 48 h. Fig. 3 shows a diagram of the ethylene and ventilation treatments used in Experiment 3.
Effects of Ventilation on Peel Coloring

6 h at 20°C storage at 0°C

20 ppm ethylene² treatment for 24 h

20 ppm ethylene treatment for 24 h

for 4 weeks

for 2 weeks

100 ppm ethylene treatment for 24 h

100 ppm ethylene treatment for 24 h

Ventilation for 1 h³

for 4 days

for 4 days

Fig. 3 Diagram of ventilation and ethylene treatment in Experiment 3

Z : Persimmons were treated with ethylene at 20°C in sealed containers.

Y : The containers were left open for 1 h at 20°C for ventilation.

ppm ethylene at 20°C in a sealed plastic container (4.5 ℓ capacity). Thirty persimmons were treated with 20 ppm ethylene for 24 h and then the containers were left open for 1 h for ventilation. After ventilation, the persimmons were again treated with 20 ppm ethylene for 24 h. Thirty persimmons were treated with 100 ppm ethylene for 24 h and then the containers were left open for 1 h for ventilation. The persimmons were treated again with 100 ppm ethylene for 24 h. Thirty persimmons were treated with 100 ppm ethylene for 48 h.

After the treatments, six persimmons were transferred to stainless steel containers as described in Experiment 1. The containers were kept at 20°C for 4 days. This experiment was carried out using five replicates, with six persimmons per replicate. The peel color of the persimmons during soft ripening was measured with a color chart, and fruit cracking ratio was calculated for the soft-ripened persimmons. The removal of astringency in the soft-ripened persimmons was evaluated in a sensory test by two trained male adults. Fig. 3 shows a diagram of the ethylene and ventilation treatments used in Experiment 3.

Results

Experiment 1. Effects of temperature and ventilation on peel color

The color chart values of the persimmons in all treatments increased in 6 days. Persimmons treated with ethylene continuously for 48 h and subsequently stored for 4 days at 10°C (no ventilation and 10°C : NV 10) showed the lowest increase in color chart value (1.9). The value increased from 3.6 to 5.5. The greatest increase in color chart value was 4.2 (from 3.5 to 7.7), which was observed in the persimmons that were ventilated and subsequently stored at 20°C (ventilation and 20°C : V 20). The increase in the color chart value of the persimmons that were ventilated and subsequently stored at 10°C (ventilation and 10°C : V 10) was 3.1 (from 3.5 to 6.6), and that of persimmons treated with ethylene continuously for 48 h and subsequently stored at 20°C (no ventilation and 20°C : NV 20) was 2.8 (from 3.6 to 6.4) (Fig. 4).

There were significant differences among the color chart values of the persimmons subjected to the different treatments 6 days after the beginning of the ethylene treatments. The ventilation treatment applied between the two 24-h ethylene treatments significantly increased the color chart value of the persimmons kept for 4 days at 10 and 20°C after the ethylene treatments. The color chart values of the V 20 soft-ripened persimmons were significantly higher than those of the V 10 persimmons, and the color chart values of the NV 20 soft-ripened persimmons were significantly higher than those of the NV 10 persimmons. The color chart values did not differ significantly between the

Fig. 4 Effects of ventilation and temperature on color of 'Saijo' persimmons during soft ripening

The persimmons were stored for 4 weeks at 0°C before the ethylene treatment.

Z : Different characters indicate that the means are significantly different at 1% level with the Tukey-Kramer test.
NV 20 and V 10 soft-ripened persimmons. Astringency was removed in the soft-ripened persimmons treated with ethylene and subsequently kept at 10°C or 20°C for 4 days (data not shown).

Experiment 2. Effects of ventilation frequency on peel color

Color chart value increased in all the treatments within 6 days. The smallest increase in color chart value was 1.7 (from 3.4 to 5.1), which was observed in the persimmons that received no ventilation. The highest increase in the color chart value was 2.4 (from 3.3 to 5.7), which was observed in the persimmons that received two ventilations. The increase in the color chart value of the persimmons that received one ventilation was 2.1 (from 3.4 to 5.5). The two ventilations significantly increased the color chart value 6 days after the beginning of the ethylene treatment (Fig. 5).

There were no significant differences in L*, which represent the lightness of peel color, or in positive b*, which represents yellow colors, among the treatments. However, red colors (a* values) differed significantly among the treatments (Table 1).

Experiment 3. Effect of ethylene concentration on peel color

In all the treatments, color chart value increased within 6 days in the persimmons stored for 2 weeks at 0°C prior to the ethylene treatment. The persimmons treated with 100 ppm ethylene continuously for 48 h (no ventilation and 100 ppm: NV 100) showed the lowest increase in color chart value (2.1). The value increased from 3.6 to 5.7. The persimmons that received ventilation and two 24-h 20 ppm ethylene treatments (ventilation and 20 ppm: V 20) showed the highest increase in color chart value of 3.1 (from 3.7 to 6.8). The persimmons that received ventilation and two 24-h 100 ppm ethylene treatments (ventilation and 100 ppm: V 100) showed an increase in color chart value of 2.6 (from 3.6 to 6.2). There was no significant difference in color chart value among the persimmons in all the treatments 6 days after the beginning of ethylene treatment (Fig. 6).

In all the treatments, the color chart value increased within 6 days in the persimmons stored for 4 weeks before the ethylene treatment. The NV 100 persimmons showed the lowest increase in color chart value of 2.4 (from 3.9 to 6.3). The increases in the color chart value of the V 20 and V 100 persimmons were significantly different (Table 1).
persimmons were 3.6 (from 3.8 to 7.4) and 3.4 (from 3.9 to 7.3), respectively. The 24-h 20 and 100 ppm ethylene treatments with ventilation significantly increased color chart value 6 days after the beginning of the ethylene treatment (Fig. 7).

There was no significant difference in fruit cracking ratio among the ethylene treatments for the persimmons stored for 2 and 4 weeks at 0°C (Table 2). Astringency was removed from the soft-ripened persimmons treated with 20 ppm ethylene and subsequently kept at 20°C for 4 days (data not shown).

**Fig. 7** Effects of ventilation and ethylene concentration on color of ‘Saijo’ persimmons during soft ripening

The persimmons were stored for 4 weeks at 0°C before the ethylene treatment.

Z, Y, X: See Fig. 3.

W: Different characters indicate that the means are significantly different at 1% level with the Tukey-Kramer test.

**Table 2** Effects of ventilation and ethylene concentration on fruit cracking of soft-ripened ‘Saijo’ persimmons

<table>
<thead>
<tr>
<th>treatments</th>
<th>fruit cracking ratio(%)²</th>
<th>storage for 2 weeks at 0°C</th>
<th>storage for 4 weeks at 0°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>no ventilation and 100 ppm</td>
<td>26.7</td>
<td>36.7</td>
<td></td>
</tr>
<tr>
<td>ventilation and 100 ppm</td>
<td>16.7</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>ventilation and 20 ppm</td>
<td>20.0</td>
<td>23.3</td>
<td></td>
</tr>
</tbody>
</table>

Z: Fruit cracking ratio was expressed as the number of cracked persimmons divided by the total number of persimmons in a container.

Y, X, W: See Fig. 3.

V: ns indicates that the means are not significantly different with the Tukey-Kramer test.

**Discussion**

Akaura et al.² reported that 24-h ethylene treatment is insufficient for soft-ripening ‘Saijo’ persimmons, but that 48-h ethylene treatment ensured uniform soft-ripening. In this study, the 48-h ethylene treatment was divided into two or three equal time periods to determine whether ventilation could improve peel color.

Astringency was removed in the persimmons treated with ethylene and subsequently kept at 10°C. This result was consistent with the observation that harvested ‘Saijo’ persimmons often soft-ripen at room temperature in Matsue. The monthly mean temperature in November in Matsue is approximately 10°C. ‘Saijo’ persimmon appears to soft-ripen at temperatures above 10°C.

The peel color of soft-ripened ‘Saijo’ was more desirable in the persimmons kept at 20°C compared with the persimmons kept at 10°C. Nukawa et al.² reported that the peel color of harvested ‘Fuyu’ persimmons is enhanced by storage at 25°C compared with storage at 15.6 or 10°C. Lower temperatures appear to inhibit the coloring of harvested persimmons. With respect to peel color, the storage of ‘Saijo’ persimmons at 20°C after ethylene treatment is preferable to storage at 10°C.

Experiments 1, 2, and 3 showed that ethylene treatment alone improved the peel color of soft-ripened ‘Saijo’ persimmon. However, ventilation during ethylene treatment further improved peel color. The peel of soft-ripened ‘Saijo’ persimmons was reddish color at a color chart value of 6 or more. Because this cultivar does not normally have a reddish peel color at harvest, the improvement in peel color is a particularly desirable attribute. The soft-ripened persimmons showed satisfactory peel color after combined ventilation and ethylene treatment and subsequent storage at 20°C.

In Experiments 1 and 3, the ventilation and two 24-h ethylene treatments significantly improved the peel color of persimmons soft-ripened after storage for 4 weeks at 0°C. On the other hand, a similar treatment had no effect on the peel color of persimmons soft-ripened after storage for 1 or 2 weeks at 0°C in Experiments 2 and 3. Although the relationship between the length of cold storage prior to ethylene treatment and the peel color of the soft-ripened persimmons is unclear, ventilation during ethylene treatment appears to have a greater effect.
on the peel color of persimmons stored for a longer period.

The combination of two ventilations and three ethylene treatments effectively improved the peel color of ‘Saijo’ persimmons soft-ripened after storage for 1 week at 0°C. However, this procedure is laborious, and is therefore costly. ‘Saijo’ persimmons soft-ripened after storage for 1 or 2 weeks could compete with the naturally soft-ripened persimmons commonly sold in October and November. From a practical point of view, the lack of effect of ventilation in ethylene treatment on the peel color of ‘Saijo’ persimmons soft-ripened after storage for 1 or 2 weeks at 0°C is trivial.

Akaura et al. obtained soft-ripened persimmons by treating stored persimmons with 100 ppm ethylene for 48 h, then storing them for 4 days at 20°C. This was adopted as the standard procedure for producing soft-ripened ‘Saijo’ persimmons. The results in Experiment 3 showed that two 24-h 20 ppm ethylene treatments and ventilation successfully produced soft-ripened persimmons. Although this new procedure for ethylene treatment requires additional work, there is a significant improvement in peel color, and less ethylene gas is used. Fruit cracking is a serious problem in ‘Saijo’ persimmons, so this should be evaluated in any new ethylene treatment for producing soft-ripened persimmons. In this study, two 24-h 20 ppm ethylene treatments and ventilation did not result in fruit cracking. Therefore, this new ethylene treatment can be used as another standard procedure for producing soft-ripened ‘Saijo’ persimmons.

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References


エチレン処理中の間欠換気と貯蔵温度が
カキ‘西条’（Diospyros kaki Thunb.）
熟柿果皮の着色に及ぼす影響
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カキ‘西条’果実は熟柿となる過程で着色が進み赤味が増加することが認められている。筆者は収穫し低温貯蔵した‘西条’果実をエチレン処理して得た熟柿より、収穫果を室温で自然放置して得た熟柿のほうが着色がやや優れていることを観察している。エチレン処理は20°Cの温度条件下48時間密封容器内で行うが、この密封条件と温度が自然放置の場合の条件と異なると考え、柑橘における着色促進を参考に、エチレン処理における換気が‘西条’熟柿の着色に及ぼす影響を調べる目的で実験を行った。あわせてエチレン処理後の温度条件の影響も調査した。

カキ‘西条’果実は数週間0°Cで貯蔵後、20°Cで48時間密封容器内でエチレン100ppm処理を行い、処理後10または20°Cで4日間貯蔵し熟柿を得た。エチレン処理において容器を1時間間隔して換気し、換気が果実の着色に及ぼす影響について調査した。エチレン100ppm処理果実は換気にかかわらず10および20°Cいずれの温度条件においても4日間で完熟し熟柿となった。10および20°Cいずれの温度条件においても、エチレン処理における換気による着色の改善が認められた。エチレン100および20ppm処理における換気は、処理後20°Cで貯蔵した果実の着色を著しく改善した。エチレン処理における換気は、エチレン処理前0°Cで4週間貯蔵した果実から得た熟柿の着色改善に効果があった。

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