

# Influence of Prestorage Conditioning Treatment and Optimal Temperature and Humidity for Prolonged Storage of 'Kiyomi' Tangor

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## Summary

'Kiyomi' tangor (*Citrus unshiu* Marc. × *C. sinensis* Osb.) fruit held at ambient temperature and humidity for one to two weeks (prestorage conditioning) prior to storing them at various cold temperatures and humidities were compared with fruit stored directly without prestorage treatment to seek means of preventing rind injury. The conditioning treatment increased the occurrence of rind injury as brown spotting, while symptoms of chilling injury appeared as pitting on fruit stored at 1 °C. Rind injury occurred early during storage at 12 °C, whereas it developed slowly at 5–6 °C, especially under high relative humidity (RH). 'Kiyomi' fruit, stored at 6 °C and >98% RH without prestorage conditioning, remained sound with little or no rind injury for 5 months after harvest.

**Key Words:** 'Kiyomi' tangor, prestorage conditioning, rind injury, storage temperature and humidity.

## Introduction

'Kiyomi' tangor (*Citrus unshiu* Marc. × *C. sinensis* Osb.) fruit are commonly harvested in early spring and stored for several weeks before being shipped to markets. During the storage period or after shipping, rind injury sometimes develops on the fruit, thus reducing their commercial value. Maintaining citrus cultivars at particular temperatures for several days before low-temperature storage often reduced rind injury (Hatton and Cubbedge, 1982). The influence of storage temperature on rind injury of 'Kiyomi' fruit was investigated by Hasegawa and Yano (1990), but they did not include prestorage treatments in their study. Polyethylene packaging had significant effects to prevent rind injury of 'Kiyomi' (Abe et al., 1992). The occurrence of the rind injury seems to be correlated with temperature and humidity conditions, but the effect of these conditions has not been elucidated for prolonged storage periods. The objective of this study is to investigate the effect of prestorage conditioning on rind injury and to determine appropriate temperatures and humidities for prolonged storage of 'Kiyomi' tangor.

## Materials and Methods

The fruits of 'Kiyomi' tangor (*Citrus unshiu* Marc. × *C. sinensis* Osb.) were obtained from an experimental orchard of National Institute of Fruit Tree Science, Kuchinotsu, Nagasaki Prefecture in 1999 and 2000. Approximately 440 fruit were picked on April 1, 1999. Half were transferred to 5 storage rooms which were controlled at  $1.5 \pm 0.5$  °C and  $88 \pm 3\%$  RH;  $1.5 \pm 0.5$  °C and  $93 \pm 5\%$  RH;  $5 \pm 1$  °C and  $84 \pm 2\%$  RH;  $5 \pm 1$  °C and  $94 \pm 4\%$  RH;  $10 \pm 1$  °C and  $94 \pm 4\%$  RH. The remaining half were placed in a non-air-conditioned but well-ventilated shed for 7 or 15 days, a conventional prestorage conditioning method. Then they were transferred to the storage rooms as mentioned above. In the second year, 150 fruit picked on April 11 were transferred to the storage rooms directly without conditioning treatment. Storage rooms were controlled at  $1 \pm 0.5$  °C and >98% RH;  $6 \pm 0.5$  °C and  $84 \pm 3\%$  RH;  $6 \pm 0.5$  °C and >98% RH;  $12 \pm 0.5$  °C and  $86 \pm 4\%$  RH;  $12 \pm 0.5$  °C and >98% RH. At 93 and 94% RH in 1999 and at >98% RH in 2000, fruits were kept in jacketed cold storage systems with negative air ions ( $2-8 \times 10^4/\text{cm}^3$ ) and 50 to 120 ppb ozone according to Tanaka et al. (1998) to prevent mold and decay.

The fruits were weighed and assessed for rind injury during the storage period. Evaluation of rind injury including brown spotting, discolored stains with creasing, and pitting was based on the rind surface as follows: one spot of 6–20 mm (slight), 2–3 spots of 20 mm (moderate), and over 4 spots of 20 mm or one of over 40 mm (severe). Shrinkage of fruit surface, which some-

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times appears on fruit held in low humidity but unaccompanied by discoloring, is not considered as rind injury. The quantitative data on moderate and severe rind injury were combined to determine the percentage of injured fruit that have no commercial value.

### Results and Discussion

The decay in stored fruit frequently masked rind injury and prevented an accurate assessment of rind injury during the holding period. Therefore, the data in this paper were tabulated, excluding the fruit that were infected by mold, decay, and stem end rot organisms.

#### Effect of conditioning

The fruit lost approximately 3 and 6% of their fresh weight through conditioning treatment for 7 and 15 days, respectively. After 60 days in storage, most fruit preconditioned for 15 days developed rind injury, of which the most frequent symptoms were brown spotting (Table 1). A small percentage of fruit without conditioning developed rind injury after storage at 1.5 °C and

5 °C.

Relative low humidity of 70 to 85% during storage combined with conditioning treatment to decrease fruit weight 4.5 to 6.5% prevented rind puffing of satsuma mandarin (Murata, 1971). Prestorage conditioning is currently a popular method for storing them. Hatton and Cubbedge (1982) found that conditioning grapefruit for 7 days at 10 to 21 °C reduced chilling injury. However, Ogawa and Sakai (1979) concluded that conditioning had no effect against brown spotting of hassaku rind. In our experiment, longer days of prestorage conditioning resulted in higher rates of rind injury of 'Kiyomi' under any storage conditions. Thus, we conclude that the prestorage conditioning under ambient temperature and humidity promotes the development of rind injury on 'Kiyomi' fruit stored below 10 °C.

#### Appropriate temperature and humidity for prolonged storage

Data from the year 2000 tests reveal that more than 80% of 'Kiyomi' fruit without prestorage conditioning,

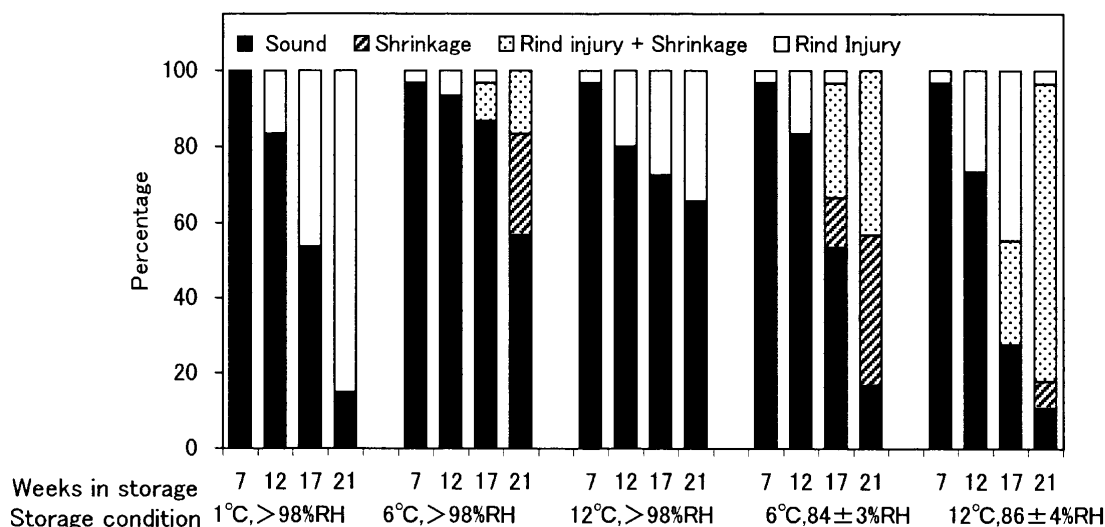
**Table 1.** Occurrence of rind injury on 'Kiyomi' tangor fruit stored with or without prestorage conditioning 60 days after harvest.

Storage temp. (°C)	Storage RH (%)	Percentage of injured fruit <sup>z</sup>		
		Days in prestorage conditioning treatment <sup>y</sup>		
		0	7	15
1.5 ± 0.5	88 ± 3	0.0	— <sup>x</sup>	71.4
1.5 ± 0.5	93 ± 5	1.8	55.0	57.8
5 ± 1	84 ± 2	5.8	40.0	92.5
5 ± 1	94 ± 4	0.0	— <sup>x</sup>	57.1
10 ± 1	94 ± 4	15.8	— <sup>x</sup>	90.9

<sup>z</sup> Each value indicates percentage of moderately (2–3 spots of 20mm) or severely (over 4 spots of 20mm or 1 of over 40mm) injured fruit.

<sup>y</sup> Holding in a non-air-conditioned but well-ventilated shed after harvest on April 1, 1999.

<sup>x</sup> Not determined.



**Fig. 1.** Changes in percentage of sound, injured, and shrunken fruit of 'Kiyomi' tangor during storage under various temperatures and relative humidities. Fruit were picked on April 11, 2000 and stored without prestorage conditioning.

stored for 21 weeks at 1 °C and 98% RH, 6 °C and 84% RH, and 12 °C and 86% RH, deteriorated with rind injury and shrinkage (Fig. 1). Fruit stored at 1 °C developed tiny pittings, whereas those stored at 1.5 °C in 1999 had similar symptoms. Pitting, observed in our study, was similar to chilling injury of ‘Valencia’ oranges stored at 1.5 °C (Wild and Hood, 1989) and low-temperature-stored grapefruit (Schiffmann-Nadel et al., 1971). ‘Kiyomi’ fruit stored at 6 °C with 84% RH or 12 °C with 86% RH developed severe rind injury during the storage period; the severity was greater at higher storage temperature. The frequent symptom was the discolored stains with minute creasing.

RH >98% greatly reduced the occurrence and the development of rind injury; the reduction was greater at 6 °C than at 12 °C. When ‘Kiyomi’ fruit were stored at 2 to 20 °C for 3 months, they developed less rind injury at the lower temperatures (Hasegawa and Yano, 1990). They also reported that ‘Kiyomi’ fruit transferred to 10 and 15 °C after storage at 5 °C showed severe rind injury incidence, while the fruit maintained at 5 °C did not. Therefore, appropriate temperatures to reduce rind injury of ‘Kiyomi’ fruit during prolonged storage seem to be about 5–6 °C. Kanlayanarat et al. (1988) reported that the development of rind injury of hassaku fruit increased under 70–85% RH as compared with 90–95% RH at temperatures ranging from 2 to 20 °C. Abe et al. (1992) demonstrated that packaging individual ‘Kiyomi’ fruit in low-density polyethylene bags delayed their deterioration after storage at 5 °C. Our results show that high RH in storage significantly reduces rind injury of ‘Kiyomi’ tangor.

Fruit stored at 6 °C with 84% RH and at 12 °C with 86% RH lost approximately 12% of fresh fruit weight after 17 weeks resulting in the rind shrinkage, while the weight losses were 9.8% and 4.2% at 6 °C with >98% RH and 12 °C with >98% RH, respectively. High humidity in storage effectively reduces fruit weight loss and delays rind shrinkage.

In conclusion, our recommendation is that to reduce rind injury, ‘Kiyomi’ tangor fruit be stored immediately after harvest at 5–6 °C and >98%RH. These conditions will enable the fruit to appear fresh for more than 17 weeks after harvest.

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### ‘清見’の長期貯蔵における予措の影響と最適温度・湿度条件

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### 摘 要

カンキツ‘清見’の貯蔵中に発生する果皮障害を防止する目的で、貯蔵前の乾燥予措処理の影響および長期貯蔵に適する貯蔵温度・湿度環境を検討した。乾燥予措の程度が強いほど、果皮が斑点状に褐色する果皮障害が著しく発生した。貯蔵温度1 °Cでは低温によるピッチングが発生し、12 °Cでは貯蔵早期から果皮障害が発生した。貯蔵温度を5, 6 °Cとした場合に障害発生が少なく、貯蔵環境を高湿度とすることにより障害は顕著に抑制された。‘清見’果実は、予措を施さず、温度6 °C、相対湿度98%以上の環境に貯蔵することにより、5ヶ月以上の長期間にわたり果皮障害を免れて貯蔵することが可能であった。

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