Occurrence of Rind Disorders of ‘Ootani’ Iyo (Citrus iyo hort. ex Tanaka, var. Ootani) Fruit during the Pre-harvest and Storage Periods

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Summary

Experiments were carried out to clarify the causes of rind disorders in ‘Ootani’ iyo fruit. Rind disorders were observed at a maturing stage and during storage. The disorders were classified into three types, based on visible symptoms and causal factors. The first type occurs on the fruit surface only when the fruit on the tree are exposed to solar radiation and is designated as “sunscald”. The causal factor seemed to be high temperature stress. The second type which occurs during storage at 5°C, is known as “Kohansho” by growers and shippers. The disorder is not conspicuous at harvest, but appears during storage where the fruit surface had been exposed to sunlight. The third type which is observed on the fruit exposed to −2°C during storage is called “Yakesho” which apparently differs from “Kohansho”. The latter two types of disorders do not occur when the fruit are wrapped with polyethylene film bag after pretreatment at 20°C for two days. However, the rind disorders develop after the bag is removed. The exposure of harvested fruit to 50 ppm ethylene failed to prevent the disorders.

Key Words: “Kohansho”, ‘Ootani’ iyo, rind disorders, “Sunscald”, “Yakesho”.

Introduction

In 1962, a bud sport which was found in a ‘Miyauchi’ iyo tree at Mr. Ootani’s orchard in Yoshida, Ehime Prefecture, was named and registered as ‘Ootani’ iyo in 1970. As the cultivation area increased rapidly and more trees grew to bearing age, their fruits began to exhibit rind disorders. While the disorders made the crop difficult to market, no reliable way to prevent their occurrence was known because the causal factors were not well understood.

Rind disorders of mid- and late-maturing citrus species were tentatively designated as “Kohansho” at the 1977 Annual Meeting of Evergreen Fruit Trees organized by the Fruit Tree Research Station, Ministry of Agriculture, Forestry and Fisheries. The name “Kohansho” is descriptive of these disorders in that ‘Kohan’ means tiger’s speckles and ‘Sho’ a symptom of disease. “Kohansho”, which mainly occurs in mid- and late-maturing citrus cultivars, has been attributed to both chilling and excessively high temperatures.

Studies on “Kohansho” of ‘Ootani’ iyo fruit are limited (Chikaizumi et al., 1987; Funakami et al., 1982, 1986; Hasegawa and Iba., 1986; Takahara et al., 1988). Funakami et al. (1982) showed that “Kohansho” of ‘Ootani’ iyo was significantly reduced when the fruit were stored at 8°C and 90% relative humidity (RH). Likewise, Hasegawa and Iba. (1986) found that storage of ‘Ootani’ iyo fruit at 10°C after the pretreatment of two weeks at 20°C greatly reduced the occurrence of the disorder. However, “Kohansho” appeared during storage on fruit whose peel had been exposed to the solar radiation on the tree (Chikaizumi et al., 1987), which was confirmed a year later (Takahara et al. 1988).

The purpose of this study was to examine the causal factors affecting the occurrence of rind disorders in ‘Ootani’ iyo fruit during its maturation and storage.

Materials and Methods

Experiment 1. Development of rind disorders on sunlit side of the fruit

Part A. Seven-year-old trees of ‘Ootani’ iyo top-grafted onto satsuma mandarin trees growing in a commercial grove in Yawatahama, Ehime Prefecture were used. On August 15, 1986, uniformly sized fruit were selected on the outer canopy at 1 to 2 m above the ground. After an area of the rind surface, which was exposed to solar radiation, was circled with a marking pen, the fruit was bagged with cheesecloth coated with aluminum foil. The control fruit were left unbagged and exposed to sunlight during the growing season. On December 9, 1986, the fruit were harvested and the number of disordered fruit and the total number of rind spots were counted. The unaffected fruit were stored at 5°C and 95% RH. The time course for pit development of the sunlit and shaded sides was determined visually at 15-day intervals. The number of pits was counted, and
newly pitted areas were circled with a marking pen.

Part B. Fruit on 10-year-old trees of ‘Ootani’ iyo growing in the experimental orchard, the Faculty of Agriculture, Ehime University, were selected, marked, and treated as in Part A. Daily maximum and minimum air temperatures were monitored for one month before the fruit were harvested. On October 7, 1999, fruit were harvested before the ambient air reached 12°C; all fruit were washed with water, and air-dried. One group of fruit was placed individually in a polyethylene film (0.02 mm) bag and stored at 5°C and another at 20°C; the two groups of unwrapped control fruit were stored at the same temperatures.

Experiment 2. Effects of pre-storage conditioning and low temperature treatments on the development of rind disorders

Part A. On November 27, 1985, sunlit and shaded fruit were harvested from 6-year-old trees growing in Yawatahama, Ehime Prefecture before the daily minimum temperature reached 5°C. Shaded fruit in the inner canopy were harvested and stored at −2°C for 3 and 7 days and then transferred to 8°C and 45% RH.

Part B. In this experiment, fruit were successively stored at 20°C for 5 days, −2°C for 3 days, and thereafter kept at 5°C but always at 45% RH until the end of the experiment.

Experiment 3. Effect of ethylene treatment and individual packaging with polyethylene film bag on incidence of rind disorder

Fruit which were harvested on November 29, 1985 from commercial groves in Matsuyama, Ehime Prefecture were exposed to 50 ppm ethylene at 20°C for 48 hours and then placed in the polyethylene film bag. Another lot of fruit harvested on December 18, 1986 from commercial groves in Matsuyama, Ehime Prefecture were bagged in polyethylene film after pretreatment at 20°C for 5 and 8 days. Subsequently, they were stored at 5°C. Fifty days later, they were examined for rind disorder.

Results

Exp. 1A. Development of rind disorders on sunlit side of the fruit

Two out of 45 fruit covered with cheesecloth bag coated with aluminum foil exhibited rind disorder, whereas 13 out of 45 control fruit were affected (Fig. 1, 2, 9-1). The rind surface exposed to the intense solar radiation turned yellowish green, while the shaded side of the same fruit remained normal. Temperatures of the surface of the rind within the bag were monitored on August 27, 1986 (Fig. 3). The temperatures of the surface of the sun exposed fruit were 1 to 4°C higher than that of the temperature within the bag. Light intensity, photosynthetically active radiation (PAR) and solar radiation within the aluminum coated bag were 34,000 to 35,000 Lux, 500 μE·m⁻²·sec⁻¹ and 400 Watts·m⁻², whereas without the bag, they were 60,000 - 63,000 Lux, 1,500 to 1,700 μE·m⁻²·sec⁻¹ and 780 Watts·m⁻², respectively (Table 1). Hence, light intensity in the bag was half of that in the control plot, which may account for the reduced rind disorder. It could be concluded that the pre-harvest rind disorder of ‘Ootani’

![Fig. 1. Effect of aluminum foil–coated, cheesecloth bags on the occurrence of rind disorder in ‘Ootani’ iyo fruit. Forty–five fruit were used per treatment. Bagging date: August 15, 1986. Fruit were harvested on December 9, 1986, then stored at 5°C and 95% RH.

- - Control.
- - Cheesecloth coated with aluminum foil.

![Fig. 2. Effect of aluminum foil–coated, cheesecloth bags on the occurrence of number of pits per fruit in ‘Ootani’ iyo. Forty–five fruit were used per treatment. Fruit were harvested on December 9, 1986, then stored at 5°C and 95% RH.

- - Control (shaded).
- - Control (sun-lit).
- - Cheesecloth coated with aluminum foil (shaded).
- - Cheesecloth coated with aluminum foil (sun-lit).]
iyo fruit was caused by solar radiations; accordingly, this disorder is termed “sunscald” in this report.

Furthermore, when even fruit without visible symptoms on the rind surface at harvest were stored at 5 °C, pitting developed on the exposed side of the rind, but not on the shaded side of the same fruit. Small pittings, characteristic in this disorder (Fig. 9-2) were not similar to the pre-harvest disorder. Bagging decreased the number of pits per fruit on the trees by approximately 35% of the non-bagged fruit. Raising the temperature of the storage room prevented the injury. Based on my data, this disorder is named “Kohansho”.

In Exp.1B, fruit sampled on October 7, 1999, which had not been exposed to 12 °C prior to harvest (Fig. 4) displayed no symptoms of “Kohansho” if stored at 20 °C with or without bagging or at 5 °C if bagged (Fig. 5). Fruit stored at 5 °C without bagging exhibited pitting as late as 20 days after the onset of storage.

![Fig. 3. Rind surface temperatures under aluminum foil-coated, cheesecloth bags.](image)

A: Sun-lit side of surface of cheesecloth coated with aluminum foil.
B: Sun-lit side of surface of control.
C: Air temperature.

![Fig. 9. External appearances of symptoms of rind disorders formed on the rind of “Ootani” iyo fruit.](image)

1) Light brown spots on the sun-exposed surface on the tree (“Sunscald”).
2) Small pitting spots on the sun-exposed surface during storage at 5 °C (“Kohansho”).
3) Blister-like spots on the rind surface during storage at -2 °C and 90-95% RH (“Yakesho”).

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<th>Table 1. Light intensity, photosynthetically active and solar radiation under cheesecloth coated with aluminum foil bag.</th>
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August 27, 1986, 13:40-14:30
Exp. 2. Effects of pre-storage conditioning and low temperature treatments on the development of rind disorder

Part A. Pretreatment at \(-2^\circ C\) for 3 or 7 days before storage at \(8^\circ C\) (Fig. 6) had no effect on the number of disorder fruit. However, the total number of spots were 175 and 408 for 3 and 7 days at \(-2^\circ C\), respectively. Pretreatment of fruit for 5 days at \(20^\circ C\) followed by 3 days at \(-2^\circ C\) significantly reduced the number of disordered fruit as well as the total number of spots. This disorder which exhibited neither pits nor rind spots (Fig. 9–3) originated from the collapse and death of the flavedo cells surrounding the oil glands; the ruptured areas turned red or brownish–red similar to a blister burn spots. Hence, I term it “Yakesho”, the word “Yake” means blister and “Sho”, a symptom of disease.

Exp. 3. Effect of ethylene treatment and individual packaging with polyethylene film bag on incidence of rind disorder

Ethylene was ineffective in controlling the amount of staining on affected fruit (Fig. 7). The storage at \(20^\circ C\) reduced the rind disorder, whereas ethylene treatment before storage did not. Pretreatment at \(20^\circ C\) and polyethylene bags prevented rind disorder during storage (Fig. 8). No significant differences in the rind disorder occurred between the pretreatment of 5 and 8 days at \(20^\circ C\). However, the disorder developed rapidly after the bag was removed.

Discussion

Rind disorders in ‘Ootani’ iyo fruit develop on the rind surface both on the tree and during storage after
harvest. Bagging individual fruit on the tree with cheesecloth coated with aluminum foil, which remained below 40 °C, developed little rind disorder, whereas non-bagged control fruit exposed to intense solar radiation developed "sunsclad". Hence, this disorder which seems to be closely associated with high temperature and intense solar radiation is often referred to as sunscald or sunburn in wasse satsuma mandarin fruit (Chikaizumi and Matsumoto, 1983; Chikaizumi, 1990). Accordingly, the occurrence of this disorder might be prevented by covering the tree with shade materials to protect the rind surface of fruit from solar radiation.

A second type of the rind disorder was observed when fruit were stored at 5 °C, which featured very small pittings. This type disorder was designated as "Kohansho" of 'Ootani' iyo fruit (Funakami et al., 1982, 1986; Hasegawa and Iba, 1986; Takahara et al., 1988). Because no reliable means to prevent the occurrence of this disorder is known, we also call it "Kohansho" disorder. It developed at epidermal cells during storage although there was no visible breakdown of sunlit area of the fruit surface at harvest. I found that "Kohansho" disorder occur mainly on light-exposed surface of the fruit, which indicates that a prime factor on the occurrence of "Kohansho" is intense solar radiation. The sunlight surface of the fruit on the outer canopy is more susceptible to this disorder. In this study, "Kohansho" disorder also occurred on fruit stored at 5 °C. Hasegawa and Iba (1986) reported that "Kohansho" disorder occurred at 2, 5, 10, 15, and 20 °C during storage, especially severely below 5 °C. Furthermore, Funakami et al. (1982, 1986) reported that "Kohansho" disorder was observed on the rind surface on fruit stored at 4, 5, 8, 10, and 15 °C. These results indicate that 'Ootani' iyo fruit are resistant to intense solar radiation while they are still attached to the tree. But, after the harvest, 'Ootani' iyo fruit are subject to "Kohansho" disorder during storage. Langridge (1963) suggested that if imbalance occurs at extreme temperatures, there may be an accumulation of toxic products, then metabolic disturbance, and consequently, growth inhibition. Akita et al. (1983) reported that the rate of occurrence of "Kohansho" on Hassaku fruit was the highest in fruit from the outer part of the tree canopy and those from poorly developed trees grown under poor drainage conditions. Sawamura et al. (1984) described the rind-oil spot development on seven citrus species at their ripening stage. Sawamura et al. (1987) also ascribed rind spot formation to the oxidation of ascorbic acid around oil cells. Oleocellosis is induced when the oil is released from the oil glands, even on green lemons if the fruit were injured at harvest (Eaks, 1969). However, rind disorder development in 'Ootani' iyo fruit may be unrelated to oil leakage because there is no visible breakdown of oil glands.

Hasegawa and Iba (1986) reported that pretreatment of fruit at 15–20 °C, for 20 or 40 days before the low temperature storage (5 °C), reduced the occurrence of "Kohansho". Hence, pretreatment at 20 °C may affect the aging or curing process of rind tissues.

Pretreatment at 2 °C resulted in a rind disorder which closely resembles that of 'Miyauchi' iyo fruit, stored at low temperatures called "Yakesho" (Chikaizumi et al., 1988). Because of the similarity in symptoms, this kind of disorder is also referred to as "Yakesho" in this report.

When Hasegawa and Iba (1981) treated navel oranges with ethylene before storage, the rate of "Kohansho" decreased. However, exposing 'Ootani' iyo fruit to ethylene was ineffective in preventing rind disorder during storage.

Packaging 'Ootani' iyo fruit in polyethylene film bag decreased the rind disorder, but the disorder developed after bag was removed. That transpiration rate is reduced by bagging is known, but whether it is a factor in preventing the rind disorders is unknown.

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Literature Cited


樹上および貯蔵中における‘大谷’イヨの果皮障害の発生

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摘 要

‘大谷’イヨの果皮障害の発生原因を明らかにするために、防止対策についても二三の検討を加えた。‘大谷’イヨの果皮障害は主に貯蔵中に発生するが、樹上の果実にも認められた。‘大谷’イヨの果皮障害には3種類あることが明らかになった。一つは、果実が受ける高温並びに日照が主因となった障害である。この障害は樹上の果実に発生する。そこで、この障害に対して“日焼け症”と呼称した。つぎつぎに収穫時には肉眼的には健全な果実でも、貯蔵中に果実が樹上で受けた果実の陽光部に多数の小さな斑点が発生するものである。この障害に対しては“コハン症”と呼称した。他の一つは貯蔵中に発生するが、この原因は貯蔵中の低温が主因であり、-2℃の貯蔵によって発生した。この障害は果面が赤くただれた火災れ症状を呈するため“ヤケア症”と呼称した。“日焼け症”は高温と日照を軽減する袋かけにより防止できた。20℃の予防処理とポリエチレンフィルムによる側包を組み合わせることにより、貯蔵中に発生する“コハン症”や“ヤケア症”的発生を抑制することができた。しかし、側包を開封することによってこれらの障害が発生した。