熟柿化過程におけるカキ‘西条’の裂果
Fruit Cracking in ‘Saijo’ Japanese Persimmons (Diospyros kaki Thunb.) during Soft Ripening

AKAURA Kazuyuki*§

* Matsue College, University of Shimane, Hamanogi, Matsue, Shimane 690–0044

After storage for several weeks at 0°C, ‘Saijo’ persimmons (Diospyros kaki Thunb.) were treated with ethylene to obtain soft-ripened fruit. Fruit cracking occurred during soft ripening. There was a significant positive correlation ($r=0.707^*$) between cold storage period and the ratio of the number of cracked persimmons to the total number of treated persimmons. Shallow cracks seemed to occur in linear groups on the cuticular layer but did not reach the pericarp. Most of them were seen along the ventral suture near the fruit apex. Ruptures occurred mostly on the lateral side of the fruit. The location of shallow cracks and ruptures on the fruit were considerably close suggesting that the ruptures developed from the shallow cracks. The occurrence of ruptures was observed 2.0 to 4.5 days after the beginning of ethylene treatment. Ruptures elongated afterward and finally became 100–140mm long. Artificial deep injuries in the fruit significantly induced fruit cracking more effectively on the skin near the fruit apex than on the equatorial zone of the fruit. It was suggested that the development of shallow cracks during cold storage prior to ethylene treatment causes cracking.

(Received Sep. 19, 2007; Accepted Apr. 17, 2008)

Key words: cracking, soft-ripened persimmon, ethylene treatment, Saijo, storage

Soft-ripened ‘Saijo’ persimmons have very soft, juicy and jellylike flesh. Although the market of soft-ripened ‘Saijo’ persimmons is small, the unique characteristics of the fruit’s flesh have drawn particular attention these days. An expansion of the market of soft-ripened ‘Saijo’ persimmons would lead to an increase in the consumption of the fruit. Akaura et al. established a procedure for obtaining soft-ripened ‘Saijo’ persimmons by cold storage and ethylene treatment of the harvested fruit.

Fruit cracking is a severe problem in fruit production and is observed in grape berries, sweet cherries, tomatoes and persimmons. Cracking mostly occurs at the fruit apex in growing persimmons. Cracking in ‘Saijo’ persimmons is sometimes observed in on-tree soft-ripening fruit. Akaura et al. reported that fruit cracking occurs during the postharvest period on the lateral side of ‘Saijo’ persimmons. Thirty-three percent of ethylene-treated persimmons crack during soft ripening. Fruit cracking is a problem in the stable production of soft-ripened ‘Saijo’ persimmons.

The cause of cracking in soft-ripening ‘Saijo’ persimmons is unknown. The primary cause of cracking in sweet cherries is water absorption through the skin of the fruit. In harvested ‘Saijo’ persimmons, water comes from the dew formed in the sealed plastic bag in which persimmons are cold-stored for several weeks. ‘Saijo’ persimmons have many shallow cracks through which the fruit seems to absorb water.

To establish an effective procedure for preventing cracking in soft-ripened ‘Saijo’ persimmons, it is important to determine the mechanism of fruit cracking. In this study, the relationship between cold storage period prior to ethylene treatment and fruit cracking is studied. Also, the development of shallow cracks and ruptures is observed.

Materials and Methods

1. Experiment 1. Relationship between cold storage period and fruit cracking

‘Saijo’ persimmons were harvested at commercial maturity late in October in Matsue, Japan. Eight persimmons were sealed in 26 × 38cm polyethylene bags of 0.08mm thickness and stored for 2 to 8 weeks at 0°C. Immediately after the storage, the bag was cut about 300mm long for ventilation. The
bags containing persimmons were left at room temperature for 6 hours. Twelve persimmons were treated with 100 ppm ethylene in each sealed plastic container (capacity: 9 L) for 48 hours at 20°C. After the treatment, six persimmons each were transferred to stainless containers (265 × 153 × 84 mm³) that have a polyethylene cover with a hole (φ 5 mm, 390 cm² area). The containers were kept in a chamber to ripen the persimmons at 20°C. The number of cracked fruit was recorded 6 days after the beginning of ethylene treatment, and fruit cracking ratio was calculated. This experiment was carried out over an eight-year period. The number of persimmons used in this experiment was varied over the eight-year period from twelve to eighty-four.

2. Experiment 2. Development of cracks during soft ripening

"Saijo" persimmons were harvested at commercial maturity late in October in Matsue, Japan and stored for 6 weeks at 0°C. Ninety-six persimmons were treated with ethylene and soft-ripened at 20°C as in experiment 1. After the end of ethylene treatment, the length of ruptures was measured every 0.5 days using a piece of black string that had the same length as the verge of the rupture opening. When there were more than one rupture, the length of each rupture was summed up. Twenty-eight of the ninety-six persimmons cracked in this experiment.

3. Experiment 3. Relationship between location of cracks and that of ruptures in fruit

Twenty-eight persimmons in Experiment 2 were used in this experiment. Photographs of shallow cracks and ruptures in the persimmons were taken using a SLR camera (Nikon F3 and Micro-Nikkor 55 mm). Photographic images were digitized using a film scanner and analyzed with image analyzing software (Image-J). The relative length of shallow cracks and ruptures were calculated (Photo 1).

4. Experiment 4. Effect of wounding on fruit cracking

"Saijo" persimmons were harvested at commercial maturity late in October in Matsue, Japan and stored for 3 weeks at 0°C. After the persimmons were left at room temperature for 6 hours, the fruit’s skin was artificially injured with a small sharp razor blade. The length, width and depth of the injury were 5.2, 0.4 and 1.0 mm, respectively. The injured persimmons were treated with ethylene and soft-ripened at 20°C as in experiment 1. The number of cracked persimmons was recorded 6 days after the beginning of ethylene treatment. This experiment was carried out using five replicates, with 6 persimmons per replicate.

Results

1. Relationship between cold storage period and fruit cracking

There was a significant positive correlation (r = 0.707*) between cold storage period and the ratio of the number of cracked persimmons to the total number of treated persimmons (Fig. 1).

2. Development of cracks during soft ripening

Cumulative fruit cracking ratio increased linearly...
from 2 to 4.5 days after the beginning of ethylene treatment (Fig. 2). It showed no marked increase after 4.5 days. The force that induces ruptures seemed to occur in the early period of soft ripening.

Irrespective of their time of occurrence, ruptures extended similarly during soft ripening (Fig. 3) and became 100–140 mm long 6 days after the beginning of ethylene treatment. The force that causes the extension of ruptures seemed to persist throughout the soft ripening period.

3. Relationship between location of cracks and that of ruptures in fruit

No shallow cracks formed a reticulate network; instead they formed linear networks. Also, no cracks appeared to penetrate the pericarp; they occurred on the cuticular layer (Photo 2). Most of them were observed along the ventral suture near the fruit apex (Photo 3).

The locations of shallow cracks and ruptures as expressed by relative distances were 0.20 ± 0.11 and 0.20 ± 0.08, respectively. The shallow cracks and ruptures occurred mostly between the fruit apex and the equatorial zone of the fruit. Detailed observation showed that about 70% of the ruptures clearly developed from shallow cracks (Photo 3, 4 and 5). This observation and the considerably close locations of shallow cracks and ruptures suggest that ruptures develop from shallow cracks.

Photo 2 Shallow cracks were found in linear networks on the cuticular layer.

Photo 3 An enlarged image of the rupture in photo 1. The rupture seemed to develop from shallow cracks (arrows) that occurred along the ventral suture.

Photo 4 A rupture that extended circumferentially on the fruit.
The rupture seemed to develop from one of the shallow cracks (arrows).

Table 1 Effect of wounding on cracking of ‘Saijo’ persimmons

<table>
<thead>
<tr>
<th>Location of injury</th>
<th>Fruit cracking ratio(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between fruit apex and equatorial zone</td>
<td>73.3±19.0 a'</td>
</tr>
<tr>
<td>Equatorial zone</td>
<td>46.6± 7.4 b</td>
</tr>
<tr>
<td>Control</td>
<td>6.7± 9.1 c'</td>
</tr>
</tbody>
</table>

2 Different characters indicates that means are statistically significantly different at 5% level (Tukey HSD test).

4. Effect of wounding on fruit cracking

The wounding of the fruit skin significantly induced fruit cracking (Table 1). Artificial injury between the fruit apex and the equatorial zone induced severer induced fruit cracking.

The artificial injuries in this experiment were deeper than naturally occurring cracks. I observed cracking in 67% of the soft-ripened fruit that had naturally small deep cracks at harvest (data not shown). These results indicate that deep cracks easily develop into ruptures.

Discussion

The severer induction of cracking between the fruit apex and the equatorial zone (Table 1) suggests that the interior pressure from the changes of fruit tissues during soft ripening is higher or the fruit skin is softer at this location. Endocarp swelling was observed during soft ripening (data not shown). The central vascular bundle of persimmons that seems to reduce interior pressure does not reach the fruit apex. Shallow concentric cracks surrounding the fruit apex are observed in many Japanese persimmon cultivars. The data in Table 2 shows that shallow cracks naturally occur between the fruit apex and the equatorial zone. The persimmon skin seems to be susceptible to injury between the fruit apex and the equatorial zone.

The mechanism that induces the development of shallow cracks into deep cracks has not yet been clarified. IWANAMI et al. observed that water loss occurs in shallow cracks. MAGUIRE et al. reported that the area of cracking in the high water-vapor permanence group of apples is significantly greater than that in the low water-vapor permanence group of apples. In sweet cherries, higher soluble solids result in more cracking for a given cultivar. Mature ‘Saijo’ persimmons are high in soluble solids. Dew formation was often observed in sealed plastic bags in which harvested ‘Saijo’ persimmons were stored prior to ethylene treatment. The longer contact with liquid water during the cold storage induced severer fruit cracking (Fig. 1). Water uptake into the fruit through cracks by osmotic pressure may occur in persimmons during cold storage. Then the increased turgor pressure of the cell would form deeper cracks, which are more likely to develop into ruptures.

Fruit cracking is a severe problem in the production of soft-ripened ‘Saijo’ persimmons. Thus, the establishment of effective control methods is required. Temporarily, however, fruit cracking during soft ripening may be minimized by avoiding long cold storage, by excluding persimmons with deep cracks and many shallow cracks between the fruit apex and the equatorial zone. Also, avoiding fruit contact with liquid water in the plastic bag is effective.

Acknowledgement I thank Dr. Hiroyuki Itamura, Shimane University, for his careful reading of this draft.
References


熟柿化過程におけるカキ‘西条’の裂果
赤浦和之∗

* 島根県立大学短期大学部
（〒690-0044 島根県松江市浜乃木7-24-2）

0℃で数週間貯蔵したカキ‘西条’を100ppmで48時間エチレン処理し熟柿を得たところ、熟柿化の過程で裂果の発生がみられた。低温貯蔵期間と裂果率の間には有意な相関（r = 0.707＊）が認められた。カキ‘西条’の果実表面にはひび割れがみられ、これらのひび割れは線状にクチクラ層に発生し果皮には達していないようにみえた。またひび割れの多くは果頂部付近で傾溝に沿って発生していた。裂果、すなわち裂開の発生は果実側面で多く認められた。詳細な観察の結果裂果の多くが明らかにひび割れから発達したとみることができる、および果実におけるひび割れと裂開の位置がきわめてよく一致したことから、裂開はひび割れから生ずるものと推察された。
‘西条’果実はエチレン処理開始後6日で育一本熟柿になるが、裂開の発生はエチレン処理開始後2日から4.5日にかけて認められた。裂開は熟柿化過程の早い時期に発生することが明らかになった。また裂開は発生時期にかかわらず発生の後発達しその長さは100–140mmにも達した。果皮への深い傷つけ処理により裂果が有意に誘導されたが、その効果は果実赤道部よりも果頂部付近で大きかった。エチレン処理前の低温貯蔵期間におけるひび割れの発達が裂果の原因の一つであると推察された。

（平成19年9月19日受理、平成20年4月17日受理）