Experiments on the Sea Transportation of Papaya Fruits
( \textit{Carica papaya} L.) Produced in Ogasawara Islands

Naoto IWASAKI,* Chiaki OOGAKI,* Shigetoshi KAWAMATA,**
Min KIM* and Masayuki FUKUSHIMA*

* Institute of Agriculture and Forestry, University of Tsukuba,
Sakura, Ibaraki-ken 305
** Ogasawara sub-tropical Agriculture Research Center
Chichijima Ogasawara, Tokyo 100-21

Abstract

The present report focuses on the results of detailed experiments on sea transportation of papaya fruits at a low temperature along with studies on the determination of the optimum time of harvest of papaya fruits for transportation at a low temperature. The fruits sampled 3 days before proper ripening and transported by sea from Ogasawara islands at a low temperature and low cost processed their quality for 7 - 10 days after the transportation.

Introduction

One of the main problems associated with the fruit industry in tropical regions is the difficulty in delaying fruit ripening so that release to the market can be controlled. With regard to exports the problems of premature ripening and fungal wastage should also be considered. Wholesale traders in the importing nations prefer to receive fruits in a hard green condition so that fruit can ripen and be distributed as needed.

It is difficult to transport large quantities of tropical fruits, moreover studies on the storage and transportation at artificially low temperature and storage in the land where fruit is to be consumed are insufficient, in addition to the need to solve the problems of deterioration, decay and loss of fruits during transportation.

In 1982 and 1983, sea transportation test of papaya fruits from Ogasawara islands to Tokyo were carried out at the beginning of September at a temperature of about 25 - 28 °C and at the middle of July at a low temperature.

Male insects sterilized by radiation have been released in order to exterminate the Citrus fruit fly in Ogasawara islands. As a result it is expected that the Citrus fruit fly insects will be exterminated by March 1984. Thereafter it will not be necessary to fumigate fruits transported to mainland Japan with EDB (Ethylene Dibromide). It is considered that the harmful effects of fumigation no fruit quality will decrease and that the volume of papaya fruits transported will increase.

The purpose of this experiment was to evaluate methods for sea transportation of papaya fruits at a temperature and identify the optimum time of harvest for transportation. This information may be useful for the improvement of the methods of transportation of tropical fruits which in some countries account for a large part of agriculture production.

Materials and Methods

Test on sea transportation, September, 1982.

Fruits of the papaya cv. Higgins were harvested on the morning of Sept.10 in the orchard of the Ogasawara Sub-tropical Agriculture Research Center and in each case 10 fruits of uniform aspect were sampled on the tree, under the following conditions: greenish-yellow immature fruits, fruits about 3 or 4 days before ripening and mature fruits. Data on the fruit characteristics and quality which were determined immediately after harvest are shown in Fig. 2.

In the Ogasawara Sub-tropical Agriculture Research Center, abrasions and pittings of the fruits were recorded prior to packing, and all the fruits in a box were wrapped with wood wool and packed at 4 p.m. on the same day. Small-
sized thermorecorder (−20 °C to +40 °C) and small-sized impulse recorder (50 kHz, 5 G) were sealed in the carton boxes to register the temperature and vibration shocks to which the fruits were exposed in the boxes during the transportation.

During the sea transportation, decrease in material strength of box due to absorption of moisture is an important problem, since the carton boxes undergo changes in shape and damage fruit. Then the weight of the 100 square centimeter bottom and side boards as well as middle and upper lids of the carton boxes, respectively, was determined before packing the fruits in Ogasawara and after the fruits reached Tsukuba.

The papaya fruits packed in carton boxes at 9 a.m. on Sept. 11 were fumigated on the next day with EDB 8 grams per cubic meter for 2 hours in a fumigation chamber. Then the carton boxes were placed in a container at the ambient temperature at 11 a.m. on Sept. 12 and were loaded on the Ogasawara-maru. The ship started from Chichijima harbor at 12 a.m. and reached Tokyo harbor at 5:30 p.m. on July 13. The carton boxes were transported by truck immediately and reached the Univ. of Tsukuba at 2 p.m. on Sept. 14.

In Tsukuba, inspection of the papaya fruits which were placed at room temperature was carried out immediately after arrival and at 3 days after arrival, respectively.

\[\text{Test on sea transportation at low temperature, July, 1983.}\]

Fruits of papaya cv. Higgins were harvested at 10 a.m. (30°C) on July 12, 1983 in the orchard of the same station. Data on the fruit characteristics and quality which were obtained immediately after harvest are shown in Fig. 4. Fruit condition at harvest time corresponded to that during the 3-day period preserving the optimum time for consumption.

The fruits placed in carton boxes were wrapped with wood wool and packed at 11 a.m. on the same day. Small-size thermorecorder (−20 °C to +40 °C) were sealed in the carton boxes to register the temperature to which the fruits were exposed in the boxes during transportation. The fruits packed in carton boxes were placed at the ambient temperature on the morning of July 13. Prior to that time, the fruits subjected to low temperature were kept at a constant temperature. The fruits packed in carton boxes were fumigated with EDB (8 grams/m³) in a fumigation chamber (3 m³) at 2–5 p.m. on July 13. The carton boxes were loaded on the Ogasawara-maru and placed in a room of ambient temperature and in a constant low temperature, respectively. The ship started from Chichijima harbor at 12 a.m. on the same day and reached Tokyo harbor at 5 p.m. on July 15. The carton boxes were transported by truck immediately and reached the University of Tsukuba on the morning of the next day. In Tsukuba, inspection of the papaya fruits which placed in a room at the ambient temperature and in a low temperature cabinet (±0.5 °C) was carried out on the afternoon of July 16 immediately after and 3 days after the arrival of the materials, respectively.

In similar the last year, the weight of the 100 square centimeter bottom and side boards as well as middle and upper lids of the carton boxes, respectively, was determined before packing the fruits in Ogasawara and after the fruits reached Tsukuba.

\[\text{Results and Discussion}\]

\[\text{Test on sea transportation, September, 1982.}\]

\[\text{Ambient temperature during the period of transportation was Fig. 1. Fruits were kept at a temperature of 25–28 °C during the test period.}\]

\[\text{The characteristics and quality of papaya fruits are shown in Fig. 2. Parameters were as follows: fruit rind color, firmness and flavor of the}\]
1. Rind and fresh color

Notes:
1. Rind and fresh color were evaluated by using a 'Standard color chart which was made at the Fruit Tree Research Sta. for orange color and Japanese pear 'Nijisseki' color.

2. Fruit firmness was assessed by resistance to puncture with Fruit Pressure Tester filled to 11 mm head of Japanese pear.

3. Brix and tartaric acid of juice

Notes:
3. Brix content was determined in using a Digital refractometer.
4. Tartaric acid titration was performed with 0.01 N-NaOH, %100 ml.
5. No measurement for tartaric acid of juice in immature fruits at immediately after harvest was due to jelly condition of juice.

Fig. 2 Papaya fruit characteristics and quality before or after sea transportation, 1982.

Notes:
1. greenish-yellow immature fruits, fruits sampled prior to ripening and mature fruits, respectively.

The fruits in the carton boxes were subjected to vibration shocks of the following magnitude and frequency: maximum of 5G initially for about 10 hours, during both the sea transportation and throughout the time of transportation from Tokyo harbor to Tsukuba.

Decrease in material strength and deformation of the carton boxes due to the absorption of the moisture which evaporated from the fruits and also to the load applied on the boxes during the transportation appeared to have been responsible for the fruit damage. The moisture of the carton boxes associated with water evaporation from fruit was somehow lower during this test, because some of the carton boxes were transferred from a humid area (Ogasawara) to dry ground (Tsukuba). (Table 1).
Table 1 Moisture contents of carton boxes before or after sea transportation, 1982

<table>
<thead>
<tr>
<th></th>
<th>Bottom board</th>
<th>Side board</th>
<th>Middle lid</th>
<th>Upper lid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight before packing*</td>
<td>8.25 g</td>
<td>8.42 g</td>
<td>8.36 g</td>
<td>8.45 g</td>
</tr>
<tr>
<td>Loss of moisture contents</td>
<td>-0.18</td>
<td>-0.29</td>
<td>-0.08</td>
<td>-0.26</td>
</tr>
<tr>
<td>Loss of moisture**%</td>
<td>(2.2)</td>
<td>(3.4)</td>
<td>(1.0)</td>
<td>(3.1)</td>
</tr>
</tbody>
</table>

Notes: *Per 100 square centimeter of board.
** Loss of moisture contents/Weight of board before packing × 100

In the lst inspection, pittings 5 - 15 mm in diameter were observed on fruit rinds. The fruits with pittings above the 3rd grade (++++) were secondarily contaminated with fungi on the pitting rinds. They were deformed because of the depression of rind and had lost their marketability. Half of the mature fruits at harvest time had a decreased marketability while the marketability of the other half had decreased after 1 or 2 days. There was a close relationship between the decrease of the marketability and the weight loss of the fruits.

However, in the lst inspection, the immature fruits, maturing fruits and mature fruits at harvest time did not show any difference in the flesh color and content of Brix and tartaric acid of juice. Although the flesh appeared to have deteriorated, the flavor and taste of the mature fruits remained good. The same applied to the immature and maturing fruits. The rind color, fruit firmness and Brix content of juice of the immature fruits with juiceless flesh and poor taste appeared to have been adequate in the lst inspection (Fig. 2).

The results of the 2nd inspection 3 days after the lst one and 7 days after fruit packing are shown in Fig. 2. The maturing fruits showed numerous pittings and poor marketability whereas in the immature fruits the Brix and tartaric acid concentration of juice tended to decrease. It may be concluded that the limit period of transportation of papaya fruits is within 7 days at 20-35°C.

Except for the markedly immature fruits, the taste of immature fruits sampled 3-4 days before proper ripening had become good during the 3-4 day period of sea transportation. After a while the damage of fruits during the transportation became more evident and papaya furits distributed kept a good condition during a period of about one week.

Fig. 3 Changes in the natural ambient temperature and in the low temperature during the period of transportation, 1983.

Test on sea transportation at low temperature, July, 1983.

Changes in the natural ambient temperature and low temperature recorded during the period of transportation of fruits are shown in Fig. 3. Low temperature treatments during the period of transportation were as follows. The temperature of fruits during the short period of fumigation exceeded 20°C and the temperature of the fruits treated at a low temperature fell from 15°C to 10°C in the low temperature container of the Ogasawara-maru. In Tsukuba, the fruits were kept at about 5°C in a low temperature cabinet. As a result, the value dividing total fruit temperature each hour by the time of the experiment was 9.4°C in case of low temperature treatment and 26.5°C for the natural ambient temperature.

The fruits harvested 3 days before proper ripening were tested. The fruits transported at
the natural ambient temperature showed an appreciable loss of weight as a discoloration of rind and pitting of rind composed with the fruits transported at a low temperature, but the contents of Brix and tartaric acid of juice were not significantly different. In the fruits transported at a low temperature weight loss, discoloration of the rind, pitting of rind and softening of fruit were less pronounced and the contents of tartaric acid of juice did not change.

The papaya fruits distributed at a low temperature kept a good condition during a period of about 10 days.

The moisture of the carton boxes associated with water evaporation from fruits was increased.

There are various reports on the effect of transportation at a low temperature on fruits. It is necessary to place papaya fruits at a low temperature as soon as possible in order to preserve the fruit quality after harvest, hence the marketability of the fruits. Under these conditions of preservation the accumulation of CO₂ and C₂H₄ and respiration are less active than in fruits at the natural ambient temperature. As a result, the loss of fruit weight and damage caused by secondary diseases which develop along with the deterioration of fruit flesh and rind tend to decrease. Also at a low temperature the amount of phytoalexin substances in the fruit flesh and rind decreases. There is a danger of chilling injury if papaya fruits are kept at a temperature below 7 °C, because papaya fruits are susceptible to low temperatures since they are cultivated in a tropical and subtropical environment. Wilson⁴) reported that optimum transportation temperature to avoid chilling injury is 8 °C.

Notes:
1. Rind color was evaluated by using a ‘Standar color chart which was prepared at the Fruit Tree Research Sta. for orange color.
2. Pitting of rind was evaluated by a – (0) — (5) scale.
3. Brix content was determined in using a manual refractometer.
4. Tartaric acid titration was performe with 0.01 N-NaOH.

Fig. 4 Papaya fruit characteristics and quality before or after sea transportation at low temperature, 1983.
Table 2 Moisture contents of carton boxes before or after sea transportation, 1983

<table>
<thead>
<tr>
<th>Temperature during transportation</th>
<th>Bottom board</th>
<th>Side board</th>
<th>Middle lid</th>
<th>Upper lid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural ambient temp.</td>
<td>Weight before packing*</td>
<td>8.93 %</td>
<td>8.85 %</td>
<td>8.86 %</td>
</tr>
<tr>
<td></td>
<td>Moisture content increased</td>
<td>+1.00</td>
<td>+0.97</td>
<td>+1.06</td>
</tr>
<tr>
<td>**</td>
<td></td>
<td>(11.2%)</td>
<td>(10.9%)</td>
<td>(12.0%)</td>
</tr>
<tr>
<td>Low temp.</td>
<td>Weight before packing*</td>
<td>8.84</td>
<td>8.89</td>
<td>8.79</td>
</tr>
<tr>
<td></td>
<td>Moisture content increased</td>
<td>+1.05</td>
<td>+1.16</td>
<td>+1.25</td>
</tr>
<tr>
<td>**</td>
<td></td>
<td>(10.6)</td>
<td>(11.5)</td>
<td>(14.2)</td>
</tr>
</tbody>
</table>

Notes: 1. * Per 100 square centimeter of board.
2. ** Increased moisture contents/Weight of board before packing X 100

Summary

1. The purpose of these experiments was to define the optimum time of harvest for transportation and transportation life of papaya fruits as an index for tropical fruits.

2. The sea transportation test from Ogasawara to Tsukuba took place on Sept. 10-17, 1982 at about 25-28 °C. The fruits harvested at 3-4 days before proper ripening maintained a good condition within a week during transportation at 25-28 °C, thereafter fruit deterioration increased along with the decrease in fruit quality after a week.

3. Investigation on cold chain system have been examined to prolong the shelf life of papaya fruits during the sea transportation. The sea transportation test at low temperature from Ogasawara to Tsukuba took place on July 12-19, 1983. The value divided total fruit temperature each hour by the time of the experiment was 9.4 °C and by the time after fumigation of the experiment was 5.4 °C, respectively, in case of low temperature treatment, and 26.5 °C and 26.3 °C, respectively, for the natural ambient temperature treatment. The papaya fruits distributed at a low temperature kept a good condition during a period of about 10 days.

4. Decrease in material strength and deformation of the carton boxes due to the absorption of the moisture which evaporated from the fruits. The moisture of the carton boxes associated with water evaporation from fruits was increased.

Literature Cited

小笠原産バパイア果実の輸送に関する試験

岩崎 直人* • 大垣 智昭* • 川俣 恵利** • 金 晃* • 福島 正幸*

*筑波大学農林学系 305 茨城県土浦市桜村
**東京都小笠原亜熱帯農業センター 100-21 東京都小笠原村父島

小笠原における生物防除によるミバエ類撲滅の達成が近いことにより、同諸島産の亜熱帯性果実の大量内地輸送法を明らかにしようと試験。常温輸送に対して、低温海上輸送による果実品質の保持と、耐久性の限界、およびそのための収穫適期温度を追究した。

7月および9月において、樹上完熟状態より3日前の状態の果実を、採取〜船積〜海上輸送〜内地において、鮮度等により寸断されることがあったが、時間あたりの平均温度をほぼ9℃に維持した低温流通システムに試験。その結果、常温（時間あたり平均温度ほぼ26℃）輸送した果実の商品性が5日程度しか保持得ないのに比べて、低温輸送果実は約10日間商品性を保持することと出来た。小笠原産のものを完熟に近い熟度で収穫し、商品性で内地消費に供しうる。

なお、ダンボール箱の吸湿特性についても検討した。

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