Postharvest Practices for Managing the Quality of Longans and Rambutans

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Abstract
Research was conducted to integrate preharvest disease control methods and postharvest practices to manage diseases, improve fruit quality, and extend the shelf-life of longans and rambutans exported from Hawaii. The main pathogens of longan and rambutans were isolated and identified as Lasmenia, Colletotrichum, Pestalotiopsis and Phomopsis. In vitro sensitivity of these pathogens to registered fungicides was established, and Serenade® (a patented strain of Bacillus subtilis) was 100% effective at all test concentrations. However, when Serenade® was applied as a preharvest field treatment, it did not control postharvest diseases or improve quality of rambutans or longans. In postharvest studies, optimum storage temperatures and packaging systems were established. Package treatments included microperforated bags, clamshell containers, Peakfresh® film, and Lifespan® film. For longans, the sensory quality was maintained, overall disease incidence minimized, and shelf-life extended when microperforated packages or clamshell containers were stored at 10°C. The modified atmospheres (15% CO2 and 7% O2) inside Peakfresh® packages adversely affected longan flavor. Rambutans stored in the clamshell, microperforated bag, or Peakfresh® packages had higher visual quality ratings and lower disease incidences when stored at constant 10°C compared to simulated shipping temperatures. Rambutans held under simulated shipping temperatures in microperforated bags or clamshells had disease incidences that were 2-3 times higher than when stored at constant 10°C. Rambutans stored in Peakfresh® packages had the best overall quality ratings and lowest disease incidence, but lowest flavor ratings.

INTRODUCTION
Longan (Dimocarpus longan) and rambutan (Nephelium lappaceum) are two of the most important specialty fruit crops grown in Hawaii. Increased export of these fruits to U.S. mainland markets is necessary to accommodate a rapid expansion in production. Consumer acceptance of these high value crops requires that fruit arrive at their final destination in excellent condition with minimal external and internal defects.

Currently, postharvest diseases limit the successful export and marketing of specialty tropical fruit. In addition to postharvest disease symptoms, fresh rambutans dehydrate and skin color darkens during postharvest storage, limiting shelf-life (Landrigan et al., 1996). Longan pericarps also dry and darken in color. These factors may be minimized through modified atmosphere packaging (MAP) in which high humidity, high CO2 and low O2 levels are created inside semipermeable films through fruit respiration and transpiration (Kader et al., 1989). Enhanced CO2 (9-12%) can retard color loss and increase shelf-life by 3-4 days for rambutans (O’Hare et al., 1994). Although packaging reduces water loss (the main cause of spintern blackening for rambutans), the humid atmosphere can cause greater postharvest diseases, especially at higher temperatures that may occur during retail marketing. Knowledge of O2 and CO2 concentrations within a package is important because concentrations beyond those...
tolerated by a commodity can induce physiological disorders or anaerobic respiration and off-flavor development (Kader et al., 1989). Optimum temperatures must be maintained during postharvest handling to maximize shelf-life and fruit quality, especially when MAP is used. Recommended postharvest conditions are 8 to 15°C at 90-95% RH for rambutans (Mendoza et al., 1972; O’Hare, 1995), and 4 to 7°C at 90-95% RH for longans (Paull and Chen, 1987). However, cultivars can differ in sensitivity to chilling injury, modified atmospheres, and disease susceptibility, and the spectrum of fungi associated with diseased fruit can vary with storage temperature. Also, temperature fluctuations are common during shipping and retail handling and can impact the effectiveness of packaging.

The objectives of this work were 1) to identify fungal pathogens associated with rambutan and longan fruits and establish the baseline sensitivity (in vitro) of the major fungal pathogens to registered fungicides, 2) to determine the effectiveness of preharvest fungicide applications on postharvest disease development and fruit quality, and 3) to develop packaging strategies to extend the shelf-life of rambutans and longans.

MATERIALS AND METHODS

A survey was conducted on Hawaii Island to determine the causal agents of diseases affecting rambutan and longan production. Leaves and fruit were collected from representative samples of symptomatic plant material. Fungi were isolated on artificial media using a tissue dissection method in which three small pieces of tissue from the advancing margin of a lesion were cut, surface sterilized with 0.5% sodium hypochlorite, and plated onto potato dextrose agar (PDA) or water agar (WA). Plates were incubated at 26°C and examined after 7 d of incubation. Fungi were identified using morphology, physiology and molecular techniques. Pure cultures were obtained by hyphal tip transfer from plate cultures.

Fungal isolates were evaluated for sensitivity to fungicides registered for use in Hawaii (Abound®, Trilogy® and Serenade®) by growing them on PDA plates amended with label-approved concentrations of fungicides. Abound® is a broad spectrum, systemic azoxystrobin fungicide. Trilogy® is an extract from neem oil, and Serenade® is a patented strain of Bacillus subtilis. Mycelial plugs (5-mm) were cut from the margin of fungal colonies, transferred to three replicate plates, and maintained at ambient temperatures (23 to 25°C) under fluorescent lighting (12 h/day). Colony diameter after 7 d was measured across two axes, averaged, and the diameter of the mycelial plug subtracted from the average. Fungal growth was compared to PDA plates containing no amendments to determine the percent inhibition. Each experiment was conducted at least twice.

In-field applications were made at commercial orchards of rambutan (‘Jit Lee’) and longan (‘Biew Kiew’) with Serenade®, the registered fungicide shown to be most effective in laboratory tests on fungi isolated from fruits. Applications were made according to label specifications and to simulate grower practices. Each experiment was a randomized complete block design with single trees as replications. Four replications were used for each treatment per crop (rambutan or longan). Approximately 20 kg of fruit were randomly harvested from each tree for disease incidence, postharvest quality and shelf-life evaluations. Untreated trees served as controls.

Rambutans were harvested in Dec. 2007 from fungicide-treated and untreated trees, removed from the panicles, and sorted. Fruit (500 g) were placed into fiberboard boxes, microperforated bags (MP), clamshells (CL), Lifespan® bags (LS), or Peakfresh® bags (PF). Each package type was placed into fiberboard boxes and stored at 10°C. A further packaging study was conducted in Feb. 2009 using fruit harvested from a commercial orchard (untreated trees). Rambutans (‘R167’; 1800 g) were packaged in MP bags, CL, PF bags, or LS bags and stored at 1) constant 10°C (control) or 2) held at 20°C for 2 days (simulated harvest, packing, quarantine treatment, and air transport), transferred to 10°C for 5 days (simulated wholesale storage and distribution), and removed to 20°C for 2 days (simulated retail conditions).

For longans, a packaging experiment was conducted in Oct. 2008 in which fruit
(1500 g) were placed into fiberboard boxes, MP bags, LS bags, or PF bags and stored at 10°C. In the next experiment, longans were harvested in Jan. 2009 from the Serenade® field trial using 2 application rates (low dose: 4.7 L/ha; high dose: 14 L/ha). Fruit were removed from the panicles in small clusters, and longans (1500 g) were packaged in MP bags, CL containers, or PF bags. Packages were placed into fiberboard boxes and stored at 10°C.

For all experiments, CO₂ and O₂ concentrations were analyzed in each package using an Illinois Instruments 6600 headspace analyzer. Fruit were evaluated for disease incidence, soluble solids content, total acidity, weight loss, aril firmness, pericarp color, external appearance, internal quality, and percent marketable fruit. Aril firmness was measured with a digital force gauge, surface color with a colorimeter, soluble solids with a refractometer, and acidity with titration. Isolations were made from any diseased fruit to identify the causal organisms of fruit decay. A trained sensory panel evaluated fruit flavor and texture for the most promising MAP treatments in 2009.

RESULTS AND DISCUSSION

The main pathogens of longans and rambutans were isolated and identified as Lasmenia, Colletotrichum, Pestalotiopsis, and Phomopsis. In vitro fungicide assays using Trilogy®, Abound®, and Serenade® against these four fungal pathogens showed that Trilogy® was least effective, with percent inhibition ranging from 14 to 26% for Pestalotiopsis, Colletotrichum and Phomopsis and 61% for Lasmenia. Abound® treatments had percent inhibition ranging from 30 to 52% for Pestalotiopsis, Colletotrichum and Phomopsis and 78% for Lasmenia. Serenade® showed the most promise in the laboratory and was 100% effective at all concentrations tested. However, when Serenade® was applied as a preharvest field treatment, it did not reduce fruit drop, control postharvest diseases, or improve quality for rambutans or longans (data not shown). Also, there were no interactions between preharvest fungicide treatment and postharvest package type (P<0.05). Therefore, results for the packaging treatments were combined for fungicide-treated and untreated trees.

In the first packaging experiment, rambutans stored in PF bags for 10 d at 10°C had lower weight loss and higher soluble solids content than fruit in other package types (Table 1). Respiring fruit created modified atmospheres inside the PF and LS packages, with steady state gas concentrations ranging from 4-5% CO₂ and 16% O₂. As a result, fruit packaged in PF or LS bags had better visual quality and lower disease incidence than fruit stored in MP or CL packages (Table 1). In a study by Mendoza et al. (1972), rambutans stored at 10°C remained marketable for 12 d inside polyethylene bags, 10 d inside perforated bags, and <4 d when not bagged.

In a subsequent study, rambutans were tested in four package types stored at constant 10°C or under simulated shipping conditions with fluctuating temperatures. Rambutans stored in different packages had similar soluble solids contents and titratable acidity regardless of temperature treatment (data not shown). Fruit packaged in PF bags had the lowest weight lost (<0.4%) among all package types, and this difference became more pronounced under the simulated shipping treatment (Fig. 1A). Aril firmness was higher (P<0.05) for rambutans stored at constant 10°C, compared to simulated temperatures, especially for fruit stored in CL containers or PF bags (Fig. 1B). Fruit in the PF bags also had the best visual quality (Fig. 1C) and lowest disease incidence (Fig. 1D) among all package types under both temperature regimes. Simulated shipping temperatures affected disease incidence the most in CL and MP bags (Fig. 1D), with incidences 3 times higher (68% versus 20%) and 2 times higher (60% versus 30%), respectively, than when storage was at constant 10°C. Only rambutans in the LS bags were not affected by temperature, however, disease incidences were 43 to 45% (Fig. 1D).

Modified atmospheres reached about 12% CO₂ and 5% O₂ inside the PF packages, and about 3% CO₂ and 18% O₂ inside the LS packages. Although rambutans packaged in PF had superior visual quality and reduced disease incidence compared to the other treatments, the sensory analysis revealed adverse affects on fruit flavor (Fig. 2).
flavor scores were significantly lower for rambutans packaged in PF, but were similar and acceptable for fruit in MP, CL or LS packages. Results suggest that threshold concentrations for CO₂ and O₂ were exceeded in the PF packages. However, others have reported that 9 to 12% CO₂ reduced color loss and extended rambutan shelf-life by 4 d without affecting edible quality (O’Hare et al., 1994).

For longans, fruit packaged in MP bags or CL had the longest shelf-life (23 d) when compared to PF bags, LS packages, or boxes (Table 2). Longans packaged in PF bags had the lowest weight loss (0.7%) and disease incidence (22%) after storage at 10°C (Table 2). Visual quality ratings were highest for fruit stored in MP bags, followed by PF packages. Soluble solids contents ranged from 18 to 19%, with slight differences among package treatments, whereas titratable acidity was greatest for longans packed in boxes or CL (Table 2).

The three most promising packages (MP, CL, PF) were included in the Jan. 2009 longan study. Fruit packaged in MP bags or CL containers had higher visual quality and lower disease incidences than those in PF bags after storage at 10°C (Fig. 4). Among fruit exhibiting disease symptoms, the most frequently isolated fungi were \textit{Phomopsis} sp. (93 to 97%) and \textit{Pestalotiopsis} sp. (17 to 40%). Shelf-life was longest for fruit in MP bags (19 d). Weight loss (0.6%) was lowest and aril firmness was highest (3.8 N) for fruit stored in PF bags (data not shown). Gas concentrations inside MP or CL packages remained at ambient atmosphere, whereas the steady state levels inside PF packages were 16.7% CO₂ and 7.6% O₂, slightly higher than the previous experiment (15% CO₂ and 7% O₂). The modified atmospheres inside the PF packages impacted longan sensory quality (Fig. 4). Fruit from the PF treatment had significantly lower appearance, texture and taste scores when compared to longans placed in MP bags or CL. Others have reported an increase in ethanol concentrations for longans stored in MAP using sealed polyethylene bags or under controlled atmospheres with low O₂ (4%) (Tian et al., 2002). Our study showed that postharvest and sensory quality of longan was maintained, overall disease incidence minimized, and shelf-life extended when MP packages or CL containers were used in conjunction with storage at 10°C.

**CONCLUSIONS**

Pericarp browning and fungal diseases are the main postharvest problems for longans and rambutans. \textit{Phomopsis} and \textit{Pestalotiopsis} species were the primary postharvest pathogens isolated from longan fruit, and \textit{Lasmenia} sp. was the most commonly isolated pathogen from rambutans. However, similar pathogens were found on both rambutan and longan trees, indicating that orchards cultivating both crops simultaneously could have susceptible hosts for these pathogens year-round. Although Serenade® showed 100% fungal inhibition in the laboratory, preharvest field applications were ineffective at controlling postharvest diseases. This may be a result of the difficulty in maintaining fungicide coverage in a high-rainfall tropical climate.

Modified atmosphere packaging with Peakfresh® film, combined with optimal temperatures (10°C), reduced rambutan browning and diseases and extended shelf-life when compared to current industry packages. However, aril flavor was adversely affected when fruit weight was increased inside packages and the rambutans were stored under simulated shipping temperatures. Decreasing the ratio between fruit weight and package surface area to achieve more ideal gas concentrations inside the PF bags might provide improved visual quality and reduced disease incidence, without compromising sensory quality.

Longan postharvest quality and sensory ratings were superior for fruit packaged in MP bags or CL containers, when compared to MAP with PF or LS films. This suggests that maintaining high relative humidity may be more important to extending longan shelf-life than modifying CO₂ or O₂ concentrations. Although current industry practice is to use similar packaging materials for both rambutans and longans, it appears that the optimal package will differ for these fruit. Adoption of a new or improved packaging system for rambutans and longans should be of significant benefit to the industry, because it does not
require a change in field practices in order to reduce postharvest quality problems that have constrained export and marketing.

Literature Cited

Tables

Table 1. Quality of rambutans (‘Jit Lee’) harvested Dec. 2007 and stored 10 days at 10°C in different types of packages.

<table>
<thead>
<tr>
<th>Package</th>
<th>Weight loss (%)</th>
<th>Visual rating²</th>
<th>Disease (%)</th>
<th>Soluble solids (%)</th>
<th>Titratable acids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peakfresh</td>
<td>0.36 a</td>
<td>3.46 a</td>
<td>13.8 a</td>
<td>18.2 a</td>
<td>0.39 a</td>
</tr>
<tr>
<td>Lifespan</td>
<td>3.08 b</td>
<td>3.32 a</td>
<td>9.2 a</td>
<td>17.3 b</td>
<td>0.37 a</td>
</tr>
<tr>
<td>Microperf.</td>
<td>2.84 b</td>
<td>2.93 ab</td>
<td>37.9 b</td>
<td>17.6 ab</td>
<td>0.44 a</td>
</tr>
<tr>
<td>Clamshell</td>
<td>3.13 b</td>
<td>2.84 c</td>
<td>48.2 b</td>
<td>16.6 c</td>
<td>0.39 a</td>
</tr>
<tr>
<td>Box</td>
<td>6.21 c</td>
<td>2.71 c</td>
<td>15.9 a</td>
<td>17.6 ab</td>
<td>0.40 a</td>
</tr>
</tbody>
</table>

²Visual ratings were on a scale from 1 to 5, with a score of 5 = excellent, no darkening; 4 = good, some spinterns darkened, pericarp not darkened; 3 = average, most spinterns dark, slight pericarp blemishes; 2 = below average, all spinterns dark, pericarp with <50% discoloration; and 1 = poor, all spinterns dark, pericarp with >50% discoloration.

³Means in columns followed by the same letter are not significantly different (P>0.05).
Table 2. Quality of longans (‘Biew Kiew’) harvested Oct. 2008 and stored at 10°C in different types of packages.

<table>
<thead>
<tr>
<th>Package</th>
<th>Shelf-life (d)</th>
<th>Weight loss (%)</th>
<th>Visual rating(^z)</th>
<th>Disease (%)</th>
<th>Soluble solids (%)</th>
<th>Titratable acids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peakfresh</td>
<td>19</td>
<td>0.68 a(^y)</td>
<td>3.16 b</td>
<td>22 a</td>
<td>18.2 ab</td>
<td>0.044 b</td>
</tr>
<tr>
<td>Lifespan</td>
<td>12</td>
<td>2.66 b</td>
<td>2.70 bc</td>
<td>42 bc</td>
<td>18.7 ab</td>
<td>0.030 c</td>
</tr>
<tr>
<td>Microperf.</td>
<td>23</td>
<td>3.50 c</td>
<td>3.46 a</td>
<td>34 ab</td>
<td>18.3 ab</td>
<td>0.056 a</td>
</tr>
<tr>
<td>Clamshell</td>
<td>23</td>
<td>4.06 d</td>
<td>2.92 bc</td>
<td>52 bc</td>
<td>17.9 b</td>
<td>0.060 a</td>
</tr>
<tr>
<td>Box</td>
<td>9</td>
<td>5.82 e</td>
<td>2.64 c</td>
<td>60 c</td>
<td>19.0 a</td>
<td>0.038 b</td>
</tr>
</tbody>
</table>

\(^z\)Visual ratings were on a scale from 1 to 5, with a score of 5= excellent (no discoloration); 4 = good (slight discoloration); 3 = average (<25% discoloration); 2 = below average (25 to 50% discoloration); and 1 = poor (>50% discoloration).

\(^y\)Means in columns followed by the same letter are not significantly different (\(P>0.05\)).

Figures

Fig. 1. Weight loss (A), aril firmness (B), visual quality (C) and disease incidence (D) of rambutans harvested in Feb. 2009 and stored in clamshells (Clam), Lifespan (LS), microperforated (MP) or Peakfresh (PF) packages at constant 10°C for 10 d (control) or under a fluctuating temperature regime (simulated) of 2 d at 20°C, followed by 5 d at 10°C, and 2 d at 20°C. *Significantly different (\(P>0.05\)).
Fig. 2. Sensory quality of rambutans harvested in Feb. 2009 and stored in clamshells (Clam), Lifespan (LS), microperforated (MP) or Peakfresh (PF) packages under a simulated shipping treatment of 2 d at 20°C, followed by 5 d at 10°C, and 2 d at 20°C. Ratings were on a scale from 1 (least favorable) to 9 (most favorable). Means with the same letter are not significantly different ($P>0.05$).

Fig. 3. Visual quality and disease incidence of longans harvested in Jan. 2009 and stored in microperforated (MP) bags, clamshells (Clam), or Peakfresh (PF) packages at 10°C. External quality ratings were on a scale from 1 to 5, with a score of 5 = excellent (no discoloration); 4 = good (slight discoloration); 3 = average (<25% discoloration); 2 = below average (25 to 50% discoloration); and 1 = poor (>50% discoloration). Bars represent standard errors.
Fig. 4. Sensory quality of longans harvested in Jan. 2009 and stored in microperforated (MP) bags, clamshells (Clam), or Peakfresh (PF) packages at 10°C. Ratings were on a scale from 1 (least favorable) to 9 (most favorable). Means with the same letter are not significantly different ($P>0.05$).