Quality changes in sapote mamey fruit during ripening and storage

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Abstract

Physical and chemical changes in sapote mamey (Pouteria sapota (Jacq.) H.E. Moore and Stearn) fruit during ripening and storage at various temperatures were evaluated. Ripening was associated with flesh softening, an increase in soluble solids content (SSC), and a change in flesh color from yellow or pale pink to a dark pink or red. No changes in fruit skin color or in flesh acidity were observed as ripening progressed. Ripe fruit had 30% or higher SSC, orange or red flesh (hue angle = 52; chroma = 45; L = 60), acidity of 6–8 mM H⁺, and flesh firmness (compression force) ≤ 50 N. Flesh turned brown (L* value declined) in overripe fruit. Fruit held at 27, 25, or 20°C ripened in 3.5, 5 or 7 days after harvest, respectively. Fruit kept at 10°C showed minor changes in color and firmness and a slow rate of SSC increase. Fruit stored at 10 or 15°C and then ripened at 20°C had portions of the flesh with a much higher firmness and poorer development of red color compared to other parts of the fruit. This uneven ripening was probably a result of chilling injury. The number of fruit with injury was higher at 10°C than at 15°C, and increased with storage time. The rates of fruit weight loss relative to the initial fruit weight were 0.58, 0.98 and 1.83% d⁻¹ at 10, 20 and 27°C, respectively. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Chilling injury; Postharvest; Quality; Ripening; Fruit transpiration; Pouteria sapota

1. Introduction

Sapote mamey is a tropical fruit tree native to Mexico and Central America (Popenoe, 1948; Martínez, 1959). Sapote mamey trees have been cultivated in tropical America for several centuries, although there is little horticultural information about this crop (CONAFRUT, 1974; Almeyda and Martin, 1976; Balerdi et al., 1996). In Mexico, the fruit is seldom refrigerated and receives no postharvest treatments.

The sapote mamey fruit exhibits large postharvest losses because of its high respiration rate (Kader, 1992) and susceptibility to internal fruit...
Table 1
Abbreviated analysis of variance for the main effects and interactions of storage temperature (S) and time (t) of sapote mamey fruit

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Acidity (mM H⁺)</th>
<th>SSC (%)</th>
<th>Firmness (N)</th>
<th>L*</th>
<th>Hue angle</th>
<th>Chroma</th>
<th>Weight loss (% d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage (S)</td>
<td>NS*</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Time (t)</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>S×t</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>NS</td>
</tr>
</tbody>
</table>

*NS, not significant.
* Significant at 0.05.
** Significant at 0.01.

Fig. 1. Respiration rates, reported as evolved CO₂, during ripening of sapote mamey fruit as affected by prior storage at 15°C. Circles, fruit stored continuously at 25°C; squares, fruit stored 7 days at 15°C and then ripened at 25°C; triangles, fruit stored 14 days at 15°C and then ripened at 25°C. Each point represents the mean (± S.E.) of five fruit.
2. Materials and methods

2.1. Fruit sampling and storage

Fruit grown in Coatlán del Río, Morelos, Mexico were harvested according to the grower experience, i.e. fruit approaches maturity when pink rather than green tissue is seen upon light scratching of its skin. Within 2 h of harvest fruit (mean weight 550 g) were carefully packed in cardboard boxes or wooden crates and taken to the laboratory.

In the first year (1997) of this 2-year study, fruit were stored in controlled-temperature rooms at 10°C (75% RH; vapor pressure difference, VPD, 0.92 kPa), 20°C (65% RH; VPD 1.52 kPa) or at ambient temperature (mean 27 ± 2°C; 84% RH; VPD 2.99 kPa). Ambient temperature was used to simulate storage by farmers and retail temperature conditions. The storage regimes were: (a) 10°C for 24 days; (b) 10°C for 7 days and then 20°C for 10 days; (c) 10°C for 14 days and then 20°C for 10 days; (d) 20°C for 16 days; and (e) 27°C for 12 days. In all storage regimes, fruit were stored past their ripe stage. Storage was interrupted when fruit were overripe and deteriorated.

In the second experiment (1998), fruit were stored in a controlled-temperature room at 15°C (75% RH) or at ambient temperature (mean 25 ± 2°C). After 7 or 14 days of storage at 15°C, fruit were ripened at 25°C for 6 days.

2.2. Experimental design

Fruit were arranged in a completely randomized design with three storage temperatures (10, 20 and 27°C) in 1997 and two temperatures (15 and 25°C) in 1998. The experimental units were the fruit. The number of fruit replicates were 16, 5
and 10 for physical and chemical, respiration and transpiration determinations, respectively. Statistical analysis was performed with the GLM procedure of SAS (SAS Institute, 1988) and treatment differences were separated using L.S.D. at $P = 0.05$. Treatment effects and interactions are shown in Table 1.

2.3. Respiration

Fruit respiration (CO$_2$ evolved) was measured colorimetrically (Claypool and Keefer, 1942) on fruit at 25°C. Individual fruit were enclosed in 4-L containers connected to a respirometer and were continuously ventilated with saturated air. The airflow was maintained constant ($6 \text{ L h}^{-1}$) with a capillary manometer. The gas passing over the fruit was allowed to equilibrate for 5 min with a dilute solution of sodium bicarbonate containing bromthymol blue as indicator. CO$_2$ concentration was calculated from the transmittance ($617 \text{ nm}$) of the solution. The rate of respiration was determined once daily for 6 days.

2.4. Physical and chemical determinations

Flesh color, firmness, titratable acidity and soluble solids content (SSC) were evaluated on 16 fruit per treatment sampled at 3-day intervals over the storage and ripening periods.

2.4.1. Color

Flesh color was determined using a colorimeter (Color Mate Color Analyzer, Milton Roy, Rochester, NY) calibrated to a white standard reflective plate ($X = 82.59$, $Y = 86.94$ and $Z = 89.30$). Color measurements were recorded using the CIE L*$a*b*$ color space. From these values, hue angle was calculated as, $H = \tan^{-1}(b^* / a^*)$, and chroma as, $C = (a^{*2} + b^{*2})^{1/2}$ (Francis, 1980). Color values for each fruit were computed as means of two measurements taken from opposite sides at the equatorial region of the fruit. Portions of the fruit skin 2–3 cm in diameter were removed and the naked portion of the flesh was placed over the small aperture of the colorimeter to determine the flesh color.

2.4.2. Firmness

Flesh firmness was measured immediately after color determination in the same portions of the fruit as for the color measurements. Firmness was measured as resistance to a 3-mm quasi-static compression of the flesh with a digital force gauge (Chantillon, DFIS 100), fitted with a 13-mm diameter stainless steel flat disc.

2.4.3. SSC and acidity

SSC was measured with a refractometer on fruit juice extracted directly from the ripe fruit flesh. In unripe fruit, SSC was measured from an

<table>
<thead>
<tr>
<th>Days at 25°C</th>
<th>Acidity (mM H$^+$)</th>
<th>SSC (%)</th>
<th>Firmness (N)</th>
<th>$L^*$</th>
<th>Hue angle$^c$</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6.9 ± 0.3</td>
<td>10.2 ± 0.1</td>
<td>114.6 ± 1.54</td>
<td>68.2 ± 0.4</td>
<td>53.3 ± 0.5</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>8.2 ± 0.3</td>
<td>24.4 ± 1.7</td>
<td>79.6 ± 10.6</td>
<td>64.9 ± 1.1</td>
<td>53.6 ± 0.4</td>
<td>5.2 ± 0.1</td>
</tr>
<tr>
<td>6</td>
<td>7.9 ± 0.1</td>
<td>32.4 ± 0.2</td>
<td>16.7 ± 1.5</td>
<td>54.1 ± 0.1</td>
<td>49.4 ± 0.9</td>
<td>10.8 ± 0.1</td>
</tr>
<tr>
<td>7-Day storage</td>
<td>5.9 ± 0.1</td>
<td>25.5 ± 0.7</td>
<td>70.0 ± 4.8</td>
<td>65.1 ± 1.2</td>
<td>54.0 ± 0.8</td>
<td>6.5 ± 0.2</td>
</tr>
<tr>
<td>3</td>
<td>6.2 ± 0.2</td>
<td>32.4 ± 0.3</td>
<td>11.4 ± 0.4</td>
<td>54.7 ± 0.9</td>
<td>47.8 ± 0.4</td>
<td>11.4 ± 0.3</td>
</tr>
<tr>
<td>14-Day storage</td>
<td>7.1 ± 0.3</td>
<td>28.2 ± 0.6</td>
<td>118.6 ± 1.5</td>
<td>65.2 ± 0.5</td>
<td>52.3 ± 0.2</td>
<td>9.7 ± 0.2</td>
</tr>
<tr>
<td>3</td>
<td>6.0 ± 0.2</td>
<td>32.3 ± 0.3</td>
<td>18.5 ± 0.4</td>
<td>55.6 ± 0.6</td>
<td>50.2 ± 0.5</td>
<td>13.7 ± 0.2</td>
</tr>
</tbody>
</table>

$^a$ Values shown are means ± S.E.

$^b$ $L$, lightness to darkness; 100 = pure white, 0 = pure black.

$^c$ Hue angle; 90 = pure yellow, 0 = pure red.
### 3. Results and discussion

#### 3.1. Respiration and ripening

Sapote mamey fruit kept at 25°C had a climacteric peak four days after harvest (Fig. 1). Fruit stored at 15°C exhibited the climacteric peak 1 day after they were transferred to 25°C. The rates of CO$_2$ production varied from 20 to 50 mg kg$^{-1}$ h$^{-1}$ at the preclimacteric stage and from 110 to 500 mg kg$^{-1}$ h$^{-1}$ at the climacteric peak. These values are similar to those previously reported (Casas Alencaster, 1977; Kader, 1992).

Similarly to avocados (Lewis, 1978) mature sapote mamey fruit that are attached to the tree will not ripen for several weeks. Ripening proceeds after fruit are detached from the tree. Fruit harvested at the commercial stage and kept at 27, 25, or 20°C ripened in about 4, 5 or 6 days after harvest, respectively. Overripe fruit kept at $\leq 20°C$ emitted off-odors and were attacked by a fungus, previously identified as *Pestalotia* sp. (Bautista and Diaz-Perez, 1997). The mycelium of the fungus grew only in the fruit flesh (data not shown).

#### 3.2. Color

Flesh color changed from yellow or pale pink (hue angle = 55) in mature fruit to an orange or red color (hue angle = 47) in ripe fruit (Fig. 2, Table 2). The purity of flesh color (chroma) changed little during ripening, although there was a tendency for chroma values to be higher in ripe fruit and to decline as the fruit became overripe (Fig. 2). As fruit ripened, the $L^*$ values declined from about 70 to 60 and this reduction was due to gradual flesh browning, until the flesh in overripe fruit was brown ($L^* = 50$). Browning of the flesh is possibly associated with the high concentration of phenolics in ripe fruit (0.3% total phenolics) (Casas Alencaster, 1977).

The typical red or orange color of the flesh in sapote mamey fruit is due to the presence of carotenoids (130 mg kg$^{-1}$) (Casas Alencaster, 1977), of which β-carotene is the most dominant (94% of total carotenoid content) (Morales-Vázquez, 1983). There were few changes in hue.
angle, chroma or \(L^*\) value during storage at 10 or 15°C (Fig. 2, Table 2), due possibly to limited carotenoid synthesis at lower temperature (Gross, 1979). Flesh color changed more rapidly when fruit stored at low temperature were subsequently exposed to 20 or 25°C. However, the flesh of fruit stored at 10°C and then ripened at 20°C tended to have lower \(L^*\) values (flesh was less dark) and higher hue angle values (flesh was less red) compared to the flesh of fruit kept continuously at 20°C (Fig. 2). In contrast, the flesh of fruit ripened at 25°C, after storage at 15°C, had similar color values compared to the flesh in fruit held continuously at 25°C (Table 2).

### 3.3. Firmness

Ripening was associated with a reduction in fruit firmness from about 120 N in mature fruit to 50 N in ripe fruit and nearly 0 N in overripe fruit (Fig. 3). The number of days required by a mature fruit to ripen (soften) was a function of temperature. Fruit kept at 27 or 20°C softened 3–4 days or 6 days after harvest, respectively (Fig. 3). Fruit had little change in firmness during storage but softened once transferred to 20 or 25°C (Fig. 3, Table 2). However, at 15 or 10°C the fruit ripened irregularly and showed uneven softening and the flesh adhered to the seed. A typical ripe fruit with uneven softening had portions of the flesh with a firmness of 20–50 N and adjacent portions of the flesh with a firmness of \(\geq 100\) N (data not shown). This uneven softening was more severe in fruit stored at 10°C for 14 days than fruit stored for 7 days. This ripening disorder was probably a result of chilling injury (Paull, 1990; Kader, 1992). Similar to sapote mamey, sapodillas also fail to ripen and lose flavor after exposure to chilling-injury conditions (Paull, 1990).

### 3.4. SSC

Immediately after harvest, SSC in mature fruit was about 12% and increased to about 30–35% in ripe fruit (Fig. 3). This increase in SSC was faster at higher storage temperatures. There was a trend for a higher SSC in ripe fruit kept at 27°C compared to those at 20°C, regardless of prior storage at 10°C. The increase in SSC during the ripening of sapote mamey is due in part to a conversion of starch into sugars as starch is reduced from 14 to 5% and there is increase in total sugar from 6 to 16% in ripe fruit (Casas Alencaster, 1977). The sugar content of sapote mamey is similar to that in sapodilla of 6% in unripe fruit and 16% in ripe fruit (Lakshminarayana, 1980).

### 3.5. Titratable acidity

Acidity ranged from 6 to 8 mM H⁺ in mature fruit and changed little during ripening (Table 2). These values are similar to those for ripe sapodilla fruit (Roy and Joshi, 1997).

### 3.6. Fruit water loss

Fruit skin showed few visual changes as a result of fruit water loss. Fruit kept for 6 days at 25°C lost 10.8% (1.8% d⁻¹) of their initial weight (Table 2), although their appearance and taste were acceptable as judged by informal taste panels (data not shown). Fruit WLR was 0.58, 0.98, and 1.83% d⁻¹ at 10, 20 and 27°C, respectively. These differences in WLR were due to the differences in VPD around the fruit at the various storage temperatures (Burton, 1982). Fruit WLR was linearly related with VPD (WLR = 0.599VPD + 0.046; \(r^2 = 0.999, P \geq 0.02\)).

The RH (i.e. VPD) conditions used in this study were lower than those typically used for most commodities (Burton, 1982). Thus, it is possible that higher RH conditions might be required to reduce water loss in sapote mamey fruit. In a separate study we found that sapote mamey fruit packed in perforated polyethylene bags and kept at 25°C showed a lower rate of water loss and a higher firmness and SSC after an 8-day ripening period, compared to fruit left uncovered (Díaz-Pérez et al., unpublished data).

The rate of fruit ripening of sapote mamey was related to storage temperature (Table 1). However, as the temperature was increased, there was also an increase in VPD. Thus, we can not separate the effect of temperature on fruit ripening from those of VPD. It is then possible that the
rapid ripening of fruit at higher temperatures was in part associated with the high rates of fruit water loss. Further studies are necessary to evaluate the storage of sapote mamey at higher relative humidities or the use of modified atmosphere packaging and its effect on fruit quality and softening. Other fruit, such as plantains and bananas, are usually packed with polyethylene films to reduce fruit transpiration, because high rates of transpiration have been associated with rapid rates of fruit ripening (George and Marriott, 1985).

In summary, ripening of sapote mamey fruit was associated with softening of the flesh, an increase in soluble solids content, and a change in flesh color from yellow or pale pink to a dark pink or red color. At ambient temperature (25°C), fruit ripened in 5 days and had high rates of respiration (CO$_2$ production > 100 mg kg$^{-1}$ h$^{-1}$) and water loss (1.8% d$^{-1}$). Fruit stored at 10°C and then ripened at 20°C ripened irregularly probably because they were chill-injured.

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References


