POST-HARVEST QUALITY OF FRESH-MARKETED TOMATOES AS A FUNCTION OF HARVEST PERIODS

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ABSTRACT: Losses on tomato business chain start at harvest, a two-months period. At the beginning of the harvest, fruits concentrate at the basal part of the plant, then in the middle, and finally at the top, and undergo changes in diameter and maturity indexes as harvest progresses. The aim of this work was to evaluate the impact of handling at three different periods: (I) 15 days, (II) 30 days, and (III) 45 days after the beginning of harvest. Tomatoes were ordinarily grown and harvested in bamboo baskets, and transferred to plastics boxes. Fruits were classified according to ripening stage and diameter, and evaluated for mechanical damage and external defects caused by harvesting procedures. The time required for the harvest operation was measured; damage to fruits (%) and weight loss (%), caused either in the field and/or during the harvesting process, were taken into consideration and related to the final quality of fruit after storage for 21 days. The same methodology was used all through the production and harvest cycle. The highest % fruit damage occurred during period II, a longer harvest time than the other two periods. Fruits not submitted to handling showed lower weight loss than handled fruits. Fruits harvested in period II and stored for 21 days showed higher losses due to mechanical injury.

Key words: Lycopersicon esculentum, losses, post-harvest, mechanical injury

QUALIDADE DO TOMATE DE MESA EM FUNÇÃO DA ÉPOCA DE COLHEITA

RESUMO: As perdas na cadeia produtiva do tomate de mesa iniciam-se no campo durante a colheita, a qual ocorre por cerca de dois meses. No início da colheita frutos concentram-se na parte basal da planta, posteriormente na região mediana e finalizam na parte superior. Frutos durante o período de colheita apresentam alterações quanto ao diâmetro e estádio de maturidade. O objetivo deste trabalho foi avaliar o efeito do manuseio durante a colheita na qualidade do tomate de mesa, cultivar ‘Fanny’ após 15, 30 e 45 dias, depois de iniciada a colheita. Tomates foram colhidos no sistema tradicional, utilizando-se de uma cesta de bambu e transferidos para caixas plásticas. Foi realizada uma classificação para o estádio de maturação e diâmetro e avaliação para danos físicos e defeitos externos nos frutos colhidos. O tempo necessário para colheita foi mensurado. Para avaliação da qualidade dos frutos foram considerados: perda de peso (%), incidência de danos físicos (%) originados no processo de colheita e originados em campo. Estes resultados foram relacionados à qualidade final dos frutos após armazenagem por 21 dias. A mesma metodologia foi utilizada nas três diferentes épocas. Os maiores valores em danos físicos (%) obtidos na etapa de colheita foram na segunda época, juntamente com um maior tempo para realização desta colheita. Nas três épocas, frutos não submetidos ao manuseio apresentaram menor perda de peso. Após armazenamento por 21 dias, frutos obtidos na segunda época demonstram maiores perdas devido a danos físicos do que as demais épocas.

Palavras-chave: Lycopersicon esculentum, perdas, pós-colheita, danos físicos

INTRODUCTION

Post-harvest losses in horticultural fruit crops are mainly related to handling, from harvest to retail. Losses are caused by mechanical injuries, inadequate storage, unsuitable handling and transport, and on-display time in the retail market (CEAGESP, 2002). These losses may result in up to US$ 0.012 cost increase per kilogram (FNP Consultoria & Comércio, 2001). Changes in tomatoes quality can be of mechanical, physiological, or pathological nature (Mohsenin, 1986).

Mechanical injuries may cause metabolic and physiological changes in tomatoes, leading to the appearance of either typical external (Fluck & Halsey, 1973; Halsey, 1955) or internal signs (Moretti et al., 1998; Sargent et al., 1992), and alterations in respiratory me-
Harvesting boxes contained an average 170 fruits each. In period I, 502 plants were required to fill the three boxes; in period II, 315 plants; and 130 plants were needed in period III, reflecting variations in concentra-
tion of fruits per plant during the crop cycle. A digital
caliper rule was used to measure transversal fruit diam-
eter. To evaluate maturity stage and physical damage and
defects at harvest time, the Normas e Padrões de Classifi-
cação para Tomate de Mesa (Classification Rules and
Standards for Table Tomato) (CEAGESP, 2000) were
used as a reference. In relation to defects, fruits were clas-
sified according to the following rating scale: (1) with-
out physical damage; (2) light external surface physical
damage; (3) serious external physical damage, caused by
insects, fruit borer, or bamboo boxes stakes; (4) deformed
fruit; (5) stained fruit, showing viral disease. The time
required to harvest was measured using chronometers,
comprising the harvest of the three plastic boxes.

To measure the effect of harvest periods on fruit
quality during storage samples of 40 fruits at the salad
stage (CEAGESP, 2000) were taken from each box (rep-
licates), and the same number of fruits were taken directly
from the plant at the same maturity stage. These fruits
were transported to the laboratory, individually wrapped
in foam inside cardboard packages, and stored at 20°C
and 60% relative humidity for 21 days. Weight loss (%),
external physical damages (%), and final quality after
storage were assessed. Weight loss was determined by the
percent relation between initial and final weight, using
fruits from both origins (field and harvest), every three
days, from the harvest day to the end of the 21-day stor-
age period.

The external areas corresponding to physical
damage were delimited using a black permanent marker,
fruits being marked two days after harvest. Based on the
Normas e Padrões de Classificação (Classification Rules
and Standards) (CEAGESP, 2000), physical damages
were identified and divided in two categories: those
derived during crop cycle and those resulting from the har-
vest process. Physical damages caused in the field are
those derived from abrasion against bamboo stakes and
tyning tape, insects attacks, and physiological and nutri-
tional disorders. Physical damages resulting from the har-
vesting process were identified as those derived from
compression of the fruits against the harvesting basket
and/or plastic box, impact of the fruit when falling into
the plastic box and/or harvesting basket, fingernail mark-
ings or fingerprints, and compression of the fruits pe-
duncle against each other.

After delimiting the areas corresponding to physi-
cal damages, the markings were transferred onto tissue
paper, individualized by fruit. A planimeter (Keuffel &
Esser Co.) was used to measure the areas. The measured
areas were compared with the total surface of the fruit,

MATERIAL AND METHODS

Tomato fruits, ‘Fanny’ cultivar harvested in
Estiva Gerbi, State of São Paulo, Brazil (46°53’ W and
22°19’ S), mean annual temperature 19.6°C and annual
precipitation of 1,565 mm, after growing on a Typic
Hapludox, traditional planting system over bamboo
stakes, under furrow irrigation, spaced 1.00 m between
rows and 0.50 m between plants. Fruits were harvested
by an experienced harvester to bamboo baskets (40 cm
length; 25 cm height; and 20 cm width) and later trans-
ferred to plastic boxes (55 cm length; 30 cm height; and
35 cm width) which were placed on the main planting car-
rrier. The harvest of three plastic boxes was defined as a
standard for the evaluations.

The fruits were classified in the field at three dif-
erent harvesting periods: initial (I), middle (II), and fi-
nal (III) (15, 30, and 45 days, respectively), in relation
to fruit diameter, maturity stage, and physical damages
and defects observed. Evaluations were made along the
three harvesting periods at the same place, but with dif-
ferent numbers of plants.
considering the fruit as a sphere (Mohsenin, 1986), and using the following formula: external area of the fruit = 4 × 3.1415 × R² (R = radius), with the result expressed as a percentage. To measure final quality after storage for 21 days, fruits were evaluated based on the following scale: (0) fruit suitable for consumption; (1) discarded because of surface physical damage; (2) discarded because of serious external physical damage; (3) discarded because of physical damage and associated rotten areas; (4) discarded because of rottenness; (5) discarded because of excessive water loss.

The comparisons between different harvest periods for data on weight loss and physical damages in the plant and in the field were made based on Student's t test (α = 0.05) The proportions-difference statistical test (Bussab & Morettin, 2002) was used to compare quality evaluation after storage, by comparing harvest periods and fruits submitted or not to the harvest stage.

RESULTS AND DISCUSSION

In the maturity stage characterization of fruits at harvest, a higher concentration (62.39%) of fruits at stage 2 (salad) was observed in the second harvesting period, differently from the other periods, with values of 48.80% (period I) and 26.28% (period III) (Figure 1). However, a high concentration of fruits (above 25%) at the green stage occurred in all harvesting periods. However, fruits harvested at the green stage could be unripe, compromising the quality of the final product (Caliman et al., 2003). In the last harvesting period (III), a considerable concentration of fruits at stage 3 (colored, 30.10%) and 4 (red, 10.67%) was recorded. Tomatoes at more advanced maturity stages are more sensitive to physical damages than at the green stage (Halsey, 1955). These maturity stage differences could be related to temperature variations in the field, since the optimal temperature range to promote synthesis of the pigment lycopene, responsible for the intense-red color of fruits is 24°C-28°C (Melo, 1993). However, during the rainy period (spring-summer), with high temperature and humidity, more serious phytosanitary problems may occur, resulting in lower productivity and low fruit quality (Sediyama et al., 2003). The highest mean temperatures in the field occurred in period III, and could have influenced maturity stage. In periods I and II, the mean temperatures registered were 28.2°C (maximum) and 14.6°C (minimum). In period III, the average maximum temperature was 33°C, with a mean minimum temperature 19.5°C.

In period III there was a higher concentration (35.43%) of fruits with smaller diameter (50-60 mm), and a smaller proportion (13.52%) of fruits with greater diameters (70-80 mm), when compared with the other periods (Figure 2). Fruits with smaller diameters are more frequent in the last harvesting period, possibly because of the loss in plant vigor, a common phenomenon at the end of the tomato crop cycle.

In period I, 54.92% of the fruits did not show any type of physical damage, followed by 24.30% in period III and 21.30% in period II (Figure 3). However, a greater concentration of light physical damages (52.86%) occurred in period II, differently from period I (31.29%) and period III (27.43%). This greater increase in physical damages was later detected in the laboratory. There was a higher percentage (14.70%) of serious damages in pe-
Post-harvest quality of tomatoes

Table 1 - Evaluation for physical damage caused in the field and during harvest on cultivar “Fanny” tomato fruits, during three periods: 15 (Stage I), 30 (Stage II), and 45 days (Stage III) after the beginning of harvest.

<table>
<thead>
<tr>
<th>Harvest periods</th>
<th>Percentage of Physical Damage - Field</th>
<th>C. V.</th>
<th>Percentage of Physical Damage - Harvest</th>
<th>C. V. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.12\textsuperscript{a}</td>
<td>266.58\textsuperscript{b}</td>
<td>1.32\textsuperscript{*}</td>
<td>100.18\textsuperscript{**}</td>
</tr>
<tr>
<td>II</td>
<td>1.18</td>
<td>133.21</td>
<td>1.59</td>
<td>94.54</td>
</tr>
<tr>
<td>III</td>
<td>1.46</td>
<td>119.03</td>
<td>1.16</td>
<td>119.25</td>
</tr>
</tbody>
</table>

Comparisons\textsuperscript{c}

<table>
<thead>
<tr>
<th></th>
<th>I × II</th>
<th>I × III</th>
<th>III × I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Means from plots
\textsuperscript{b} Coefficient of variation in plots
\textsuperscript{c} Comparisons made based on Student’s t test (P < 0.05)

Table 2 - Time required to harvest three plastic boxes per cultivar “Fanny” tomato crop, at three harvest stages: 15 (Period I), 30 (Period II), and 45 days (Period III) after the beginning of harvest.

<table>
<thead>
<tr>
<th>Period</th>
<th>Time to harvest</th>
<th>Number of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>23\textsuperscript{*}</td>
<td>502</td>
</tr>
<tr>
<td>II</td>
<td>36\textsuperscript{*}</td>
<td>315</td>
</tr>
<tr>
<td>III</td>
<td>18\textsuperscript{*}</td>
<td>130</td>
</tr>
</tbody>
</table>

Table 3 - Weight loss between tomatoes submitted to the harvesting process and tomatoes removed from the plant after storage for 15 days at room temperature in three periods: 15 (I), 30 (II), and 45 days (III) after the beginning of harvest.

<table>
<thead>
<tr>
<th>Harvest periods</th>
<th>Plant</th>
<th>C. V.</th>
<th>Harvest</th>
<th>C. V.</th>
<th>Significance\textsuperscript{c}</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3.27\textsuperscript{*}</td>
<td>30.04\textsuperscript{b}</td>
<td>3.73</td>
<td>35.78</td>
<td>*</td>
</tr>
<tr>
<td>II</td>
<td>4.15</td>
<td>12.19</td>
<td>4.56</td>
<td>14.30</td>
<td>*</td>
</tr>
<tr>
<td>III</td>
<td>3.53</td>
<td>19.29</td>
<td>4.00</td>
<td>24.08</td>
<td>*</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Treatment means.
\textsuperscript{b}Coefficient of variation in plots.
\textsuperscript{c}Comparisons made based on Student’s t test (P < 0.05).

Non-handled fruits showed smaller weight loss than the ones that were handled (Table 3). Although significant, this weight loss difference was small, in some cases smaller than 0.5%. Excessive handling caused fruit stress, which could be related to an increase in the metabolic activity of fruits, thus explaining their greater weight loss (Galvis Vanegas, 1987). Weight loss measurements were done only at the harvest stage, and values increased until the product reached the consumer. Weight loss is cumulative along post-harvest, and may be as high as 7% in the traditional system, measured from the harvest stage until retail (Ferreira et al., 2003).

In the evaluation for final quality after storage for 21 days, considerable percentages of fruits suitable for
consumption were observed in fruits removed directly from the plant (Table 4), with values of 75, 70, and 50% for periods I, II, and III, respectively. This high percentage of fruits suitable for consumption could also have been related to the fact that the product was not handled, in addition to the use of cultivar “Fanny”, known for its extended shelf life. Period III showed the highest percentage of fruits discarded for serious physical damage (42.5%), differently from the other periods; this value could also be related to a greater exposure of plants to cultivation.

This situation is totally different in harvested fruits after storage for 21 days at a temperature of 20°C. The field stands out as a potential source of physical damages and, as the crop develops, the incidence of physical damages becomes increasingly higher. The main sources of physical damages are related to inadequate tying and staking, becoming worse during cultivation as sprays, prunings, shoot trimmings, etc. are performed. Greater care during management practices and the application of appropriate technology may reduce losses. To decrease the incidence of physical damages and consequent losses they cause, simple measures could be adopted, such as the use of wheelbarrows for transportation. Providing training for employees is a necessity. The use of protecting gloves and greater care in handling may greatly influence the reduction in post-harvest losses.

**CONCLUSION**

The field stands out as a potential source of physical damages and, as the crop develops, the incidence of physical damages becomes increasingly higher. The main sources of physical damages are related to inadequate tying and staking, becoming worse during cultivation as sprays, prunings, shoot trimmings, etc. are performed. Greater care during management practices and the application of appropriate technology may reduce losses. To decrease the incidence of physical damages and consequent losses they cause, simple measures could be adopted, such as the use of wheelbarrows for transportation. Providing training for employees is a necessity. The use of protecting gloves and greater care in handling may greatly influence the reduction in post-harvest losses.

### Table 4 - Evaluation for the quality of fruits harvested directly in the field after storage for 21 days at a temperature of 20°C.

<table>
<thead>
<tr>
<th>Harvest periods</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>75</td>
<td>7.5</td>
<td>2.5</td>
<td>10</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>70</td>
<td>0</td>
<td>17.5</td>
<td>5</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>III</td>
<td>50</td>
<td>0</td>
<td>42.5</td>
<td>7.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Comparisons:

- I × II: n.s.
- I × III: *n.s.
- II × III: n.s.

*Scale from 0-5, considering (0) fruit suitable for consumption; (1) discarded because of surface physical damage; (2) discarded because of physical damage and associated rottenness; (3) discarded because of rottenness; (5) discarded because of excessive water loss.

### Table 5 - Evaluation for quality of fruits after storage for 21 days at a temperature of 20°C, based on a scale from 0-5, considering (0) fruit suitable for consumption; (1) discarded because of surface physical damage; (2) discarded because of serious external physical damage; (3) discarded because of physical damage and associated rottenness; (4) discarded because of rottenness; (5) discarded because of water loss (dry).

<table>
<thead>
<tr>
<th>Harvest periods</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>57.50*</td>
<td>13.33</td>
<td>6.67</td>
<td>12.50</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>40.83</td>
<td>2.52</td>
<td>38.33</td>
<td>9.17</td>
<td>7.5</td>
<td>1.67</td>
</tr>
<tr>
<td>III</td>
<td>42.02</td>
<td>2.52</td>
<td>30.26</td>
<td>1.68</td>
<td>16.80</td>
<td>6.72</td>
</tr>
</tbody>
</table>

Comparisons:

- I × II: 0.0088*
- I × III: 0.0152
- II × III: n.s.

*Probability values (z) lower than 0.05 indicate that the difference between proportions is significant (Bussab & Morettin, 2002).
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