Harvest Maturity and Acceptability of Flora-Dade Tomatoes

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Abstract. Composition and sensory acceptability of fresh market tomatoes (Lycopersicon esculentum Mill 'Flora-
Dade') were investigated to determine the influence of harvest maturity on quality after fruit had ripened to a table-
ripe stage. Tomatoes were harvested from commercial plots at 'immature green', 'mature green', 'breaker', 'light
pink', and 'light red'. The differentiation between tomatoes harvested 'mature green' and 'immature green' was
aided by application of 40 μl/liter of ethylene in a ripening room at 20°C. Tomatoes harvested at 'breaker' were more
acceptable when ripe than all other maturities at harvest. Tomatoes harvested at 'immature green', 'mature green',
'light pink', and 'light red' were of similar sensory acceptability. The tomatoes harvested at 'light pink' and 'light red'
when ripe were similar or lower in total soluble solids and generally lower in locular content compared to other
harvest maturities. There was a high correlation between sensory scores for color and measured external and internal
color.

It is generally held that the highest quality tomatoes for the fresh market are obtained by allowing the fruit to ripen on the
plant (4, 9, 11, 18, 21). Commercially, it is impractical to harvest table-ripe tomatoes, as the fruit are easily damaged and
do not have the shelf life required for transport and distribution through the market chain. Consequently, tomatoes are harvested
green and at early color stages. There is a tendency to harvest a greater proportion of green fruit with the adoption by growers
of a ground cropping system and fewer harvests to reduce production costs (8). Tomatoes harvested green include a propor-
tion that are immature, because it is difficult to estimate maturity without cutting the fruit for an internal inspection (13). In
general, it is agreed that tomatoes harvested immature are of poor quality when ripe, lack flavor, and should not be sold (21).

It is commercial practice to treat green tomatoes with ethylene in a ripening room to advance the onset of ripening. A saturating
dose of ethylene reduces the delay in ripening by about one-half (14). In this investigation, fruit were harvested green and
at 3 color stages, then stored at 20°C in the presence of a continuous supply of ethylene. Fruit harvested green, those that
reached the breaker stage (early color) at either 3 or 5 days after harvest, were selected for comparison with fruit harvested at
the breaker and subsequent color stages. Fruit taking 5 days to reach breaker were expected to have poor quality, because such
fruit would have attained only 80% of development at harvest. The objective was to measure any deficiencies in quality attrib-
tutes of fruit harvested immature and develop practical recommendations for eliminating immature fruit of 'Flora-Dade',
the main cultivar grown in Eastern Australia.

Materials and Methods

Fruit sampling. Tomatoes were obtained from 3 commercial
growing sites in 1983: Maroota, New South Wales (Latitude
33°53') in April, Bundaberg, Queensland (Latitude 24°52') in
June, and Bowen, Queensland (Latitude 20°01') in September.
Two harvests were made at each site. Tomatoes from Maroota
were received at the CSIRO Food Research Laboratory, Syd-
ney, within 4 hr after harvest. Samples from Bundaberg and
Bowen were cooled to 11°C after harvest and sent to the Sydney
Laboratory by refrigerated road truck and air freight, respect-
ively. Fruit were received from Bundaberg 60 hr after harvest;
from Bowen, 30 hr after harvest. The Bundaberg tomatoes ad-
vanced half a color stage during transit, which was equivalent
to holding the fruit one half day at 20°. No adjustment was
made to the experimental schedule to account for this difference.

Tomatoes were color graded at harvest to give samples of at
least 60 fruit for each of the color stages: breaker [Br, first color
at the blossom end, USDA color stage 2 (20)]; turning to light
pink (LP, about 30% of the fruit surface shows pink or red
color, USDA color stage 3 to 4); and light red (LR, about 75%
of the fruit surface shows pinkish-red or red color, USDA color
stage 5). About 400 green fruit were obtained.

Determine immaturity at harvest. The samples of tomatoes
were placed in fiberboard cartons, loosely over-wrapped with
polyethylene film to minimize water loss and stored in a room
at 20°C. Ethylene was admitted continuously to the room to
maintain a concentration of 40 μl/liter. The green fruit were
sorted 3 days after harvest, and tomatoes that had reached breaker
were classified as mature green (MG) at harvest. Fruit at the
breaker stage 5 days after harvest represented the immature green
(IMG) fruit in further evaluations. The assessment of sensory
quality and of the composition of the different harvest maturities
were performed when the fruit were judged table ripe. This stage
was reached 7 days after the breaker stage at 20°. The LP and
LR fruit were stored at 20° for 4 and 2 days, respectively.

Sensory evaluation. The tomatoes were evaluated by 30 ex-
perienced panelists from the laboratory. Fifteen tomatoes that
had been harvested at the same maturity and matched in size
(about 150 g) and color were selected, and one-half of a fruit
was presented to each panelist at each tasting session. Fruit of
one harvest maturity only was presented for evaluation at each
session. In the 'single presentation' design, panelists are com-
mitted to judging tomato quality against past experience alone
(15).

Five separate sessions were needed to assess fruit of the 5
harvest maturities from a given growing site. Testing was rep-
licated for each growing site, necessitating a total of 30 sessions:
3 sites × 5 sessions × 2 replications. Panelists rated color,
tomato flavor, sweetness, acidity/sourness, texture, and general
acceptability by placing a mark on a line 150 mm long (0 mm = extremely poor, 75 mm = satisfactory and 150 mm = extremely good).

Composition analysis. For each maturity, a sample of 15 tomatoes was used for all the measurements of composition. Firmness was measured with a compression tester (19). Compression (mm) was recorded at 5 sec following application of a load of 500 g. Color was evaluated using a Hunter Lab color meter. The measurements were expressed as the ratio of a/b. External color was measured both at the fruit equator and at the blossom end, and internal color was measured at the center of a median cross-section of the fruit. Internal color was measured only for fruit from Bundaberg and Bowen. The percentage of locular tissue was determined by weighing each tomato, and removing and weighing the locular tissue. A bulk sample then was prepared by blending the recombined pericarp and locular tissue for 15 fruit. A subsample was centrifuged. Aliquots of the supernatant were used to assay pH, titratable acidity (ml 0.1 N NaOH to raise pH of 10 ml of juice to 8.1), and total soluble solids, using a Zeiss refractometer.

Statistical analysis. A 4-way analysis of variance was performed for all sensory and compositional data. Coefficients of correlation were calculated for the 15 sensory and compositional variables.

Results

The combined sensory scores for general acceptability, texture, sourness, sweetness, flavor, and color of tomatoes harvested at different maturities and tasted at table-ripe, for all sites and both harvests are shown in Fig. 1A. Differences in the responses for fruit from different sites are described, but for brevity, the data have not been shown. The combined score for general acceptability was highest for fruit harvested at Br. Tomatoes from Maroota harvested at Br were scored significantly more acceptable than fruit harvested at all other maturities. There was no significant difference in the scores for general acceptability of tomatoes harvested IMG, MG, LP, and LR from Maroota. Bundaberg tomatoes harvested at Br were scored significantly higher than fruit harvested LP. Tomatoes from Bundaberg harvested IMG were scored significantly more acceptable compared to tomatoes harvested LP and LR and the tomatoes harvested MG were more acceptable compared to tomatoes harvested LP. The highest scores for general acceptability were given to Bowen tomatoes, and there were no significant differences between the general acceptability of these tomatoes harvested at different maturities.

Flavor. The combined scores for flavor were highest for tomatoes harvested at MG and Br. Maroota tomatoes harvested at Br were scored significantly higher for flavor compared to fruit harvested at LP and LR, but not differently to fruit harvested IMG and MG. Similar results were obtained for the tomatoes from Bundaberg. Also, the Bundaberg tomatoes harvested at MG were scored significantly higher for flavor compared to tomatoes harvested at LP and LR, and tomatoes harvested IMG were scored significantly higher for flavor than tomatoes harvested at LR. There were no differences between harvest maturities for Bowen tomatoes.

The combined scores for sweetness were highest for tomatoes harvested at Br. Tomatoes from Maroota were scored significantly higher for sweetness harvested at Br compared to all other maturities. There were no differences for Bundaberg tomatoes. Bowen tomatoes harvested LR were scored significantly higher for sweetness compared to fruit harvested at IMG, Br, and LP but were not different to MG.

Only tomatoes from Maroota differed significantly in the scores for sourness. Tomatoes harvested at LR were less sour than fruit harvested at IMG, MG, and Br but were similar to those harvested at LP.

Texture. The combined texture scores were highest for tomatoes harvested at Br. Tomatoes harvested at Br from Maroota were given a score significantly higher than those given to all other harvest maturities. Also, tomatoes harvested LR were given a significantly higher score for texture compared to tomatoes harvested at IMG and LP. The tomatoes from Bundaberg harvested at IMG were given a score significantly higher for texture than all other maturities. Tomatoes from Bowen harvested at different maturities were scored the same for texture.

Firmness. Tomatoes from Maroota harvested at IMG, LP, and LR were significantly firmer than tomatoes harvested at Br (Fig. 1B). Tomatoes from Bundaberg harvested at MG and LP were significantly firmer than tomatoes harvested at IMG and Br. Tomatoes from Bowen harvested at IMG and MG were significantly firmer than those harvested at Br, whereas tomatoes harvested at LP and LR were significantly softer than tomatoes harvested at all other maturities.

Locule tissue. The percentage of locular tissue in tomatoes from all sites was significantly higher for tomatoes harvested at IMG and Br compared with tomatoes harvested at LR (Fig. 1C). There was a trend at all sites for the occurrence of decreasing locular tissue with increasing harvest maturity, although tomatoes from Bundaberg and Bowen harvested at MG had significantly less locular tissue compared to tomatoes harvested at Br.

Soluble solids. The percentage of total soluble solids was significantly higher for tomatoes harvested at IMG, compared to all other harvest maturities for fruit from Maroota and Bundaberg, and higher than tomatoes harvested at MG, Br, and LP for tomatoes from Bowen (Fig. 1D). The total soluble solids contents of tomatoes from the 3 sites were significantly different, with Bowen > Maroota > Bundaberg.

pH. Tomatoes from Bundaberg harvested at IMG had a significantly higher pH compared to all other maturities, and tomatoes harvested Br and LR had the lowest pH (Fig. 1E). No other differences were shown.

Acidity. Only tomatoes from Bowen differed significantly in titratable acidity (Fig. 1F). Tomatoes harvested at IMG and MG had significantly lower titratable acidity compared to all other maturities. The trend was similar for tomatoes from Maroota and Bundaberg. Tomatoes from the 3 sites were significantly different in titratable acidity, with Maroota > Bundaberg > Bowen.

Color. The external a/b was significantly larger for tomatoes harvested at MG and Br compared to tomatoes harvested LP and LR for tomatoes from all harvest sites (Fig. 1G). Tomatoes had significantly different a/b values, with Bowen > Maroota > Bundaberg. Visually, large a/b values correspond with best red color. IMG fruit tended to be more pink while LP and LR fruit were more orange.

In contrast, internal a/b values were generally larger for tomatoes harvested at the colored stages (Fig. 1H). Tomatoes from Bowen had significantly larger values for internal a/b, compared to tomatoes from Bundaberg. No measurements were made on Maroota fruit. The measurements of external and internal color determined using the Hunter Lab color meter were
Fig. 1. Effect of harvest maturity on A. Mean scores for sensory evaluation of table-ripe tomatoes harvested at different maturities. LSD \((P < 0.05)\) for general acceptability and color were 5.75 and 5.51, respectively. No other significant differences were shown. The scale on the x axis indicates intervals of one day. IMG and MG fruit took 5 and 3 days, respectively, to reach breaker in the continuous presence of ethylene. ‘Flora-Dade’ fruit take 2 and 4 days to advance from Br to LP and LR, respectively; B. Firmness of tomatoes at a table-ripen stage harvested at different maturities. LSD \((P < 0.05)\); Bowen 0.286, Bundaberg 0.100, Maroota 0.130; C. Locular tissue (percentage) measured in tomatoes at a table-ripe stage harvested at different maturities. LSD \((P < 0.05)\); Bowen 1.48, Bundaberg 1.91; D. Total soluble solids (percentage) of tomatoes at a table-ripe stage harvested at different maturities. LSD \((P < 0.05)\); Bowen 0.126, Bundaberg 0.186, Maroota 0.136; E. The pH of tomatoes at a table-ripe stage, harvested at different maturities. LSD \((P < 0.05)\); Bowen n.d., Bundaberg 0.024, Maroota n.d.; F. Titratable acidity of tomatoes at a table-ripe stage harvested at different maturities. LSD \((P < 0.05)\); Bowen 0.419, Bundaberg n.d., Maroota n.d.; G. External color of tomatoes at a table-ripe stage harvested at different maturities, measured as a/b. LSD \((P < 0.05)\); Bowen 0.090, Bundaberg 0.071, Maroota 0.049; H. Internal color of tomatoes at a table-ripe stage harvested at different maturities, measured as a/b. LSD \((P < 0.05)\); Bowen 0.081, Bundaberg 0.027.
positively correlated with the taste panel evaluation of color and general acceptability (Table 1).

Discussion

The maturity at which 'Flora-Dade' tomatoes were harvested influenced the sensory properties of the fruit at a table-ripe stage. There was a preference by the sensory panel for tomatoes harvested at Br, and tomatoes harvested at later color stages were not preferred to those harvested at the green stages. These trends do not agree with previous reports on other cultivars (4, 10, 12, 13, 21), which showed that sensory acceptability increases with harvest maturity. In retrospect, it is possible that the time required for fruit harvested at later stages to ripen fully was underestimated. It is known, however, that there is considerable variation in the sensory characteristics of tomato cultivars at the table-ripe stage after harvest at different maturities (18). In this study, it should also be noted that experienced panelists awarded comparatively low scores for flavor and texture to fruit of all harvest maturities.

Although the firmness of tomatoes harvested at IMG, MG, LP, and LR was similar for tomatoes from Maroota and Bundaberg, a decrease in firmness with increasing harvest maturity was shown for Bowen tomatoes. The retention of firmness is important in marketing fresh market tomatoes (10, 17) and is desired by the Australian consumer (2). The increased percentage of locular tissue in tomatoes harvested at early maturities also was observed by Bisogni et al. (4). This difference was expected to affect the quality of tomatoes harvested at different maturities, as locular tissue has been found to contain higher titratable acidity than pericarp tissue (6). In this study, however, the proportion of locular tissue was not correlated with the concentration of titratable acidity, total soluble solids, or the sensory evaluation (data not shown).

The high level of total soluble solids in the tomatoes harvested at IMG, compared to tomatoes harvested at the colored stages, is contrary to the findings of other researchers (1, 3, 10). Jones (9), however, found variability in a study of 10 different cultivars harvested at mature green and table-ripe stages.

The lowest pH was found in tomatoes harvested at Br and then LR. The pH and titratable acidity were not significantly correlated. The tomatoes harvested at the colored stages were higher in titratable acidity, whereas other workers have found titratable acidity to decrease with advanced maturity at harvest (4, 9, 10). Variability of this characteristic has been reported (16).

Sensory panelists preferred the color of tomatoes harvested at Br, and these fruit had larger external a/b compared to all other harvest maturities. Buescher et al. (5) measured the external a/b for a number of tomato cultivars at a table-ripe stage that had been harvested at several color stages and found no differences. The external a/b values were larger for tomatoes harvested at the earlier harvest maturities, which agrees with the findings of Hobson et al. (7). These workers suggested that this is because of reduced production of β-carotene when fruit is removed from the plant, but these results differ from some other reports (1, 5).

The internal color measurements also were highly correlated with sensory scores for color, but were not correlated to external color measurements (Table 1). The only tomatoes to have large values for both internal and external color were those harvested at Br. The sensory panel preferred the color of tomatoes harvested at Br.

The values of a/b were generally larger for external measurements than for internal measurements. This difference agrees with the observation of a higher concentration of β-carotene in the locular tissue compared to the pericarp, which has a higher lycopene content (6).

The external color and total soluble solids differed significantly between harvest sites. These characteristics are influenced by light intensity and duration (6) experienced at different locations.

Conclusions

The best quality fruit was harvested at Br. Tomatoes harvested at Br had the highest scores for the sensory attributes of color, flavor, sweetness, texture, and general acceptability with a high proportion of locular tissue, and balanced color, sugar, and acid. The harvest of 'Flora-Dade' tomatoes at Br is suitable for marketing operations, when it is impractical to harvest later color stages. Tomatoes harvested green were generally firmer than fruit harvested at Br. Even though IMG fruit were not significantly lower in quality than tomatoes harvested at MG, there was a trend toward lower sensory acceptability. The longer time required for IMG fruit to reach the table-ripe stage, and the likelihood of additional sorting for color under commercial conditions, could result in poor quality fruit for this harvest maturity. In order that IMG fruit may be culled after harvest, it is recommended that fruit be ripened in a room supplied with a trickle application of ethylene, and those not breaking after 5 days be discarded.

Literature Cited

8. Huett, D., J. Sumeghy, E. Mulholland, B. McGlasson, and V.
Abstract. In an initial experiment, ‘Tribute’ (day-neutral) and ‘Allstar’ (June bearing) strawberry [Fragaria × ananassa (Duch.)] plants were grouped into fruiting, partially deblossomed, and deblossomed treatments. Net photosynthesis (Pn), dark respiration (Rd), and stomatal conductance for CO₂ (gs) were measured at 14-day intervals during the 1st fruiting cycle of both cultivars and at 7-day intervals during the 2nd fruiting cycle of ‘Tribute’. Pn of recently expanded leaves of fruiting plants was greater than that of deblossomed plants only during the 2nd week of the first fruiting cycle and the 2nd and 3rd weeks of the 2nd fruiting cycle. There were no differences in Rd or gs among treatments. At the end of the fruiting cycles, leaves, crowns, and roots of deblossomed plants of both cultivars had greater dry weights than those of fruiting plants. At the end of the first fruiting cycle, roots of deblossomed ‘Tribute’ had a higher percentage of total nonstructural carbohydrates (TNSC) than roots of fruiting plants. In Expt. 2, ‘Tribute’ plants were grouped into fruiting and deblossomed treatments. At 7-day intervals throughout the fruiting cycle, Pn, specific leaf weight (SLW), and chlorophyll content were determined for a leaf that was fully expanded at bloom (old leaf) and for the most recently expanded leaf (young leaf) of each plant. Pn of the young leaf was greater for fruiting plants than deblossomed plants only during weeks 5 and 6 of the fruiting cycle, and no treatment effect was observed for old leaf Pn. During fruit maturation, SLW was higher for deblossomed plants than fruiting plants for both leaf ages. Deblossomed plants had a higher leaf chlorophyll content than fruiting plants during the 1st, 2nd, and 4th weeks of the fruiting cycle.

Fruiting has increased Pn of apple (8), sweet pepper (20), pea (6), soybean (17), eggplant (10), and strawberry (4, 7, 10, 26). Hoffman and Lenz (10) found that fruiting strawberry plants had slightly higher Pn rates than defruited plants, beginning one day after fruit removal. Pn rates (leaf area basis) of the day-neutral strawberry cultivars ‘Hecker’ (4) and ‘Brighton’ (7) were higher for fruiting plants than for deblossomed plants. On a whole plant basis, however, Pn of fruiting ‘Hecker’ plants was not different than deblossomed plants due to a greater leaf area of the deblossomed plants (4). Explanations for reduced Pn of deblossomed plants have included: a) interference with light reception caused by an accumulation of starch in the chloroplasts of deblossomed plants, and b) lower gs, caused by an accumulation of assimilates in the leaves of deblossomed plants (19). Fruiting had no effect on Rd of citrus (12) and strawberry plants (4).

Day-neutral strawberry plants fruit in about 6 week cycles.