EFFECT OF FRUIT PORTION, STAGE OF RIPENESS AND GROWTH HABIT ON CHEMICAL COMPOSITION OF FRESH TOMATOES

ABSTRACT

Tomato fruits were analyzed for total and reduced ascorbic acid, pH, titratable acidity (% citric acid) and % soluble solids. Locular material from table ripe fruits were higher in total ascorbic acid and titratable acidity and lower in pH compared to pericarp tissue. In two pairs of cultivars, each pair having determinate and indeterminate growth habits in essentially the same genetic background, fruits from the indeterminate had more ascorbic acid and soluble solids than did those from the determinate. When table ripe and mature green fruits (eight cultivars) were harvested on the same day, table ripe fruits were higher in reduced ascorbic acid and titratable acidity and were lower in pH. No differences in total ascorbic acid were noted between the two stages of ripeness.

INTRODUCTION

INVESTIGATIONS dealing with chemical compositional quality attributes in tomato fruits generally include measurements for % soluble solids, titratable acidity (% citric acid), pH, reduced ascorbic acid content and sugar content. Although a substantial amount of work has been directed towards investigating the influence of inherent and/or environmental factors such as cultivar (Tripp et al., 1937; Maclinn and Pellers, 1938; Currence, 1940; Crane and Zilva, 1949; Matthews et al., 1973), stage of ripeness (LoCoco, 1945, Malewski and Markakis, 1971; Yamaguchi et al., 1960), fruit size (Hallsworth and Lewis, 1944; Brown and Moser, 1941; Brown and Bolen, 1946; McCollum, 1944, Maclinn et al., 1936, Tripp et al., 1937), growing location (Hammer et al., 1942, 1945; Somers et al., 1950), field illumination (McCollum, 1944, 1946; Somers et al., 1950; Brown, 1955), date of harvest (Hammer et al., 1942; Yamaguchi et al., 1960), and postharvest holding conditions (Hammer et al., 1945; Craft and Heinze, 1954) on the reduced ascorbic acid content in tomato fruits, generalizations are difficult to make due to the presence of highly conflicting results. Due to the importance of pH for tomato processing, numerous studies have been conducted that have indicated factors such as cultivar (Lower and Thompson, 1966; Vittum et al., 1962), harvest date (Lambeth et al., 1964; Massey et al., 1962) and stage of ripeness (Iwahori and Lyons, 1970), have a marked influence on pH values in tomato fruits. Field illumination and postharvest holding temperature, however, have negligible effects on pH (Craft and Heinze, 1954; McCollum, 1946). The soluble solids content in tomato fruit has been shown to be correlated with flavor (Simandle et al., 1966); in fact a difference of 0.2% in soluble solids can be important commercially (Lower and Thompson, 1967). Significant differences in % soluble solids have been attributed to growth habit (Emery and Munger, 1970), cultivar and harvest date (Simandle et al., 1966) but negligible effects of stage of ripeness have been noted (Massey et al., 1962). Since titratable acidity has also been shown to influence flavor, various studies have been conducted that have shown that storage conditions (Lampe and Watada, 1971), cultivars (Massey et al., 1962), fruit size (Lower and Thompson, 1967), stage of ripeness (Iwahori and Lyons, 1970) all influence this quality attribute.

The purpose of this study was to determine the influences of stage of ripeness, growth habit and fruit portion on selected chemical quality attributes from various cultivars. Special attention was given to the total ascorbic acid content since no information was available as to the influence of inherent factors such as growth habit, cultivar or stage of ripeness on this component. Furthermore, the validity of the assumption (Mapson, 1958) that 95% of the total ascorbic acid content in tomato fruit is in the reduced state was investigated.

EXPERIMENTAL

Material

Fruits from selected cultivars (Tables 1, 2 and 3) were harvested during the summers of 1973 and 1974 from East Ithaca, Freeville and Varna, New York. Table ripe fruits were analyzed in all experiments, except for the stage of ripeness experiments where mature green and table ripe fruits harvested on the same day were used. Immediately after harvest, entire fruits or fruit tissue portions were frozen in liquid nitrogen and held at -20°C until analyzed. For each experiment, the frozen tomato fruits were crushed into a fine powder, mixed thoroughly and subsamples of the powder from bulk samples of 10–20 fruits were used to make chemical analyses for all treatment–cultivar combinations.

Compositional analyses for fruit tissue portion experiments were made on locular (placental tissue and seeds) and pericarp tissue as well as entire fruits from four cultivars (Table 5).

Data presented herein are taken from representative experiments since trends for given treatments and cultivars harvested at various times were similar for all experiments conducted.

Chemical analyses

Total ascorbic acid. Duplicate frozen subsamples of tomato fruit powder (25g) were homogenized at 1°C in a Waring Blender in 100 ml of 1% oxalic acid for 2 min at high speed. The method of Roe and Oesterling (1944) was used for the remainder of the extraction and subsequent identification of the total ascorbic acid content. Triplicate readings for total ascorbic acid and duplicate readings for reduced ascorbic acid (below) were made for each subsample on a Bausch and Lomb Spectronic 20 spectrophotometer.

Reduced ascorbic acid. Duplicate 25g frozen powder subsamples were blended at 1°C in a Waring Blender at high speed in 100 ml of 3% metaphosphoric acid. The indophenol xylene–extraction method of Nelson and Somers (1945) was then followed for the rest of the extraction and subsequent identification of reduced ascorbic acid. The commonly used method of Loeffler and Ponting (1947) was considered undesirable because substantial variation was noted by using this method.

pH. The pH determinations were made on 25-g aliquots of homogenized subsamples with a Corning pH meter.

Titratable acidity. Titratable acidity was expressed as % citric acid equivalent and was measured by titrating 25-g aliquots with 0.1N NaOH to an end point of 8.1.

Soluble solids. A drop of homogenized sample was placed on the prism of a Bausch and Lomb desk refractometer and the % soluble solids content was read directly.

RESULTS & DISCUSSION

Composition of mature green and table ripe fruits

Ascorbic acid. Reduced ascorbic acid content in tomato fruits has characteristically been used as an indicator of the vitamin C content of these fruits (Hassan and McCollum,
1954). It has been assumed that due to the acidic nature of the fruit, the majority of the ascorbic acid is in the reduced form and is not dehydroascorbic acid (DHA) or 2,3-diketogulonic acid (DKA) (Mapson, 1958). To establish if this assumption was correct, mature green and table ripe fruits were harvested on the same day and were subsequently analyzed for total and reduced ascorbic acid.

For all cultivars tested, the reduced ascorbic acid content in mature green fruits was lower than that in table ripe fruits; the reduced ascorbic acid level of mature green fruits ranged from 27–68% of the value for table ripe fruits for the various cultivars tested (Table 1). These findings are consistent with the works of several other workers (LoCoco, 1945; Malewski and Markakis, 1971).

Values for total ascorbic acid from mature green and table ripe fruits did not follow the above trend. In fact, seven of the eight cultivars showed little or no difference between the two stages of ripeness (Table 1). These observations suggest that the levels of DHA and/or DKA were high in the mature green fruits and that they steadily decreased during ripening either by reduction to ascorbic acid or by oxidation to other intermediates. Our results show negligible DHA and/or DKA in the ripe fruits, thus suggesting the possibility that the destruction of ascorbic acid is retarded by metabolites which inhibit ascorbic acid oxidation. This speculation is intriguing and parallels observations by Hooper and Ayres (1950) who found such substances in black currants.

Table 1-Effect of ripening on the chemical quality attributes of tomato fruits

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fireball</th>
<th>Indeterminate fireball</th>
<th>Gardener</th>
<th>Determinate gardener</th>
<th>Heinz 1350</th>
<th>Cornell 72 - 35</th>
<th>Willamette</th>
<th>Cornell 72 - 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of ripeness</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
<td>Total ascorbic acid (mg/100g FW)</td>
</tr>
<tr>
<td>Mature green</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Table ripe</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Titratable acidity and pH. For all cultivars studied, mature green fruits were lower in titratable acidity than table ripe fruits with the greatest differences between stages of ripeness noted in the following cultivars: Fireball, Gardener, Determinate Gardener, Heinz 1350, Cornell 72-35 and Cornell 72-98 (Table 1). The reason that these results do not parallel the observations of others (Iwahori and Lyons, 1970; Hall, 1966) could be due to the fact that we harvested the fruits on the same day, used different cultivars and imposed no postharvest holding conditions.

For six of eight cultivars tested, the pH values were slightly more acid in table ripe than mature green fruits. These results were consistent with those of Kaski et al. (1944) but in contrast, with those of others (Iwahori and Lyons, 1970). The possibility that reduced ascorbic acid is oxidized preferentially in mature green relative to table ripe fruits as a result of differences in pH is thus not very likely.

Soluble solids. As reported by others using different cultivars and ripening conditions, (Hall, 1966), no appreciable differences in soluble solids were noted in mature green or table ripe fruits from seven of eight cultivars tested.
Fruit composition as influenced by growth habit

Comparison of chemical quality attributes in fruits taken from plants with either determinate or indeterminate growth habits were made by using two pairs of cultivars with essentially the same genetic background. Indeterminate Fireball had been backcrossed eight times to the standard determinate Fireball while determinate Gardener had been backcrossed eight times to Gardener which is indeterminate. This procedure gives on the average well over 99% similarity in genotype except for the growth habit genes. On determinate plants, clusters of fruit are separated by one or, occasionally, two leaves while on indeterminate plants clusters are mostly three leaves apart.

Ascorbic acid. Several investigators (Somers et al., 1950) have shown that shaded fruits are lower in reduced ascorbic acid than unshaded ones. Since more shading of fruits from leaves did occur on fruits grown on indeterminate vines, we had hypothesized that lower reduced ascorbic acid levels would be noted in these fruits relative to ones grown on determinate vines. The opposite trend, however, was observed. Fruits from indeterminate Fireball plants contained more total and reduced ascorbic acid than fruits from determinate vines. For the cultivar Gardener, fruits analyzed from indeterminate plants were either equal to or greater than fruits from determinate plants (Table 2).

% Soluble solids. As noted previously (Emery and Munger, 1970), indeterminate plants were consistently higher in % soluble solids than were determinate ones for both cultivars (Table 2). Greater photosynthetic capabilities in the indeterminate plants, due to their increased leaf number, could feasibly allow for greater photosynthetic movement to the fruit and a higher % soluble solids level in these fruits. McCollum and Skok (1960) demonstrated that photosynthates were translocated from leaves to fruits and that exogenously applied glucose to the leaf was translocated to fruits. Therefore, increased amounts of ascorbic acid precursors such as glucose in fruits from indeterminate vines could be linked with enhanced ascorbic acid synthesis and this is currently under investigation.

Fruit portion

Titratable acidity and pH. No consistent trends or differences in pH or titratable acidity could be attributed to growth habit (Table 2).

Total ascorbic acid. Relative to pericarp tissue, the locular tissue contained significantly more total ascorbic acid for all cultivars studied (Table 3). The total ascorbic acid levels in locular material were 37, 37, 20 and 37% higher than pericarp tissue for cultivars Supersonic, Glamour, Springset and Jet Star respectively (Table 3). These data suggest that plants that are bred to bear fruits with a higher proportion of locular material to pericarp tissue should have a correspondingly higher total ascorbic acid content on a per fruit basis. These data are in agreement with the work of Maclennan and Fellers (1938) who showed that reduced ascorbic acid was concentrated in the gelatinous material about the seed but in contrast with the results of McCollum (1944) who reported that, depending on the amount of sunlight, wall tissue was equal to or greater than placental tissue in reduced ascorbic acid.

Titratable acidity and pH. As reported by McCollum (1956), the titratable acidity was substantially higher in locular tissue relative to pericarp tissue (Table 3). For cultivars Supersonic, Glamour, Springset and Jet Star respectively, the titratable acidity was 50%, 43%, 48% and 48% higher in the locular material compared to that of the pericarp tissue. For three of the four cultivars studied, the pH values were more acidic in the locular material.

Soluble solids. Cultivar differences were noted in the soluble solids content of the two portions (Table 3). For example, pericarp tissue of Springset had a soluble solids level of 4.75 whereas Glamour had a 6.50 soluble solids level. Furthermore, differences in soluble solids between tissue portions were dependent on the cultivar. For instance, the % soluble solids content in pericarp tissue was equal to the locular material for the cultivars Supersonic and Glamour, but much less than the locular material for Springset and Jet Star.

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Table 2—Influence of growth habit on the chemical quality attributes of tomato fruits

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Determinate</th>
<th>Indeterminate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fireball</td>
<td>19.0</td>
<td>22.5 ± 0.5</td>
</tr>
<tr>
<td>Gardener</td>
<td>12.5 ± 0.5</td>
<td>14.5</td>
</tr>
<tr>
<td>Reduced ascorbic acid (mg/100g FW)a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fireball</td>
<td>18.7</td>
<td>21.5 ± 0.5</td>
</tr>
<tr>
<td>Gardener</td>
<td>12.6</td>
<td>14.5</td>
</tr>
<tr>
<td>pH</td>
<td>4.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Fireball</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Gardener</td>
<td>4.2</td>
<td>4.4</td>
</tr>
<tr>
<td>% Soluble solids</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>Fireball</td>
<td>5.0</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table 3—Chemical quality attributes of tomato fruit tissue portions

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pericarp</th>
<th>Locular material</th>
<th>Entire fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supersonic</td>
<td>13.5</td>
<td>21.3</td>
<td>15.2 ± 0.5</td>
</tr>
<tr>
<td>Glamour</td>
<td>11.3</td>
<td>18.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Springset</td>
<td>15.2</td>
<td>19.0</td>
<td>15.2 ± 0.5</td>
</tr>
<tr>
<td>Jet Star</td>
<td>11.3</td>
<td>18.0</td>
<td>11.3</td>
</tr>
<tr>
<td>pH</td>
<td>Supersonic</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Glamour</td>
<td>4.5</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Springset</td>
<td>4.4</td>
<td>4.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Jet Star</td>
<td>4.5</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>Titratable acidity (% citric acid)</td>
<td>Supersonic</td>
<td>0.41</td>
<td>0.82</td>
</tr>
<tr>
<td>Glamour</td>
<td>0.40</td>
<td>0.70</td>
<td>0.46</td>
</tr>
<tr>
<td>Springset</td>
<td>0.43</td>
<td>0.82</td>
<td>0.46</td>
</tr>
<tr>
<td>Jet Star</td>
<td>0.38</td>
<td>0.73</td>
<td>0.47</td>
</tr>
<tr>
<td>% Soluble solids</td>
<td>Supersonic</td>
<td>6.25</td>
<td>6.25</td>
</tr>
<tr>
<td>Glamour</td>
<td>6.50</td>
<td>6.50</td>
<td>7.00</td>
</tr>
<tr>
<td>Springset</td>
<td>4.75</td>
<td>6.26</td>
<td>5.25</td>
</tr>
<tr>
<td>Jet Star</td>
<td>6.00</td>
<td>7.00</td>
<td>6.00</td>
</tr>
</tbody>
</table>

Mean value of three determinations; standard deviations greater than zero are shown.

Mean value of four determinations; standard deviations greater than zero are shown.
Twelve cultivars were studied and differences in composition between cultivars were noted (Tables 1 and 3). It should be kept in mind, however, that in these investigations the influence of harvest date on composition could not be separated out due to the fact that some cultivars were early while others were middle and late season producers of tomato fruits. Thus, whether differences in chemical quality attributes among cultivars were exclusively a function of genetic or environmental factors could not be sorted out in this study.

Ascorbic acid. Total ascorbic acid levels ranged from a low of 12 mg/100g FW for Supersonic to highs in the neighborhood of 20 mg/100g FW for Fireball, Heinz 1350, New Yorker, Williamette and Cornell 72-98. Reduced ascorbic acid levels in the cultivars tested followed the same trend; however, as noted previously, this generalization could be made only for table ripe fruits (Table 1).

pH and Titratable acidity. The pH values for the various cultivars studied ranged from 4.35 for Supersonic to 4.7 for Jet Star. Interestingly, six of the twelve cultivars tested had pH values of 4.5 or greater which could possibly be a concern to the processing industry. Marked differences in titratable acidity were also noted. The range for the cultivars analyzed were 0.31 for Jet Star to 0.56 for Gardener (Tables 1 and 3).

Soluble solids. Soluble solids varied greatly with cultivar, with Glamour, indeterminate Fireball and Gardener having values of 7.0, 6.5 and 6.5, respectively, and Springset and determinate Gardner having values of 4.75 and 5.0, respectively.

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