WATERMELON COLOR AS AFFECTED BY MATURITY
AND STORAGE

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Experimental Procedure

Measuring the average color or pigment of watermelon flesh was difficult because the area was large and the color was not uniform throughout the melon. A % inch cross-section slice was cut from the sample melons about midway between the two ends. The edible portion was cut from the rind, deseeded, and blended for 1/4 minutes to a uniform slurry. Duplicate 4 gram samples of the slurry were extracted with an ethyl alcohol-benzene mixture (5:3) by shaking in an Erlenmeyer flask for 10 minutes. The solution was filtered, made up to 100 ml, and the percent transmittance was measured with a Spectronic 20 Colorimeter at 475 millimicrons using the alcohol-benzene mixture as the reference solvent.

Reflectance measurements were made on a cross-section of the melon adjacent to the slice which was removed for pigment analysis. Eight to ten seedless areas, % inch in diameter, on the cut surface of each melon were measured with a Photovolt Reflection Meter, Model 610, equipped with tristimulus filters. The three readings at each location were made immediately after cutting the melon to avoid changes in color. The reflection meter was standardized with a light red ceramic tile which was calibrated by a G.E. recording spectrophotometer as follows: green 36.9, amber 50.2, and blue 32.3.

Sampling

This study was conducted during the 1959 and 1960 seasons. Three lots of Charleston Gray watermelons were obtained from commercial growers during 1959. In lot 1, the pigment content of melons stored 2 weeks at 72°-92°F was compared with that at harvest. Melons from lots 2 and 3 were stored at 50°
and 72°-92° and examined after 2 or 4 weeks. Pigment analyses were made on six melons from each storage temperature and examination period. In 1960, two lots of Charleston Gray melons were stored at 50° and 78°-88°, and one lot of Congo melons was stored at 50° and 36°. Pigment and reflectance measurements were made on six melons per treatment after 1 and 2 week storage periods.

It was important that the melons in each lot be harvested at a similar stage of maturity. When the melons were selected in the field an attempt was made to take only those with pale red or good red flesh and to exclude all immature and over-mature melons. A number of melons in each field were cut before selecting those for the storage tests. In one lot (No. 3, 1960) the same melons were sampled at harvest and after 1 and 2 weeks in storage to make certain that differences in color after storage were not due to differences at harvest. One half of each melon was stored at 50°

Table 1. Relation of Internal Color Ratings to Reflectance and Transmittance Values for Watermelons.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Green filter</td>
<td>Amber filter</td>
<td>Blue filter</td>
</tr>
<tr>
<td>1</td>
<td>Pink</td>
<td>23.4</td>
<td>33.0</td>
<td>16.1</td>
</tr>
<tr>
<td>2</td>
<td>Pink</td>
<td>23.1</td>
<td>32.9</td>
<td>16.8</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>18.4</td>
<td>28.0</td>
<td>11.2</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>17.0</td>
<td>27.5</td>
<td>9.5</td>
</tr>
<tr>
<td>5</td>
<td>Red</td>
<td>16.6</td>
<td>26.8</td>
<td>10.2</td>
</tr>
<tr>
<td>6</td>
<td>Dark Red</td>
<td>13.8</td>
<td>24.2</td>
<td>7.3</td>
</tr>
<tr>
<td>7</td>
<td>Dark Red</td>
<td>12.5</td>
<td>21.6</td>
<td>6.2</td>
</tr>
<tr>
<td>8</td>
<td>Dark Red</td>
<td>11.5</td>
<td>20.0</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Table 2. Effect of Temperature and Duration of Storage on the Pigment Content of Watermelons.

<table>
<thead>
<tr>
<th>Storage Temp. °F</th>
<th>Lot No.</th>
<th>Season</th>
<th>Harvest</th>
<th>1 week</th>
<th>2 weeks</th>
<th>4 weeks</th>
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<tr>
<td>72-92</td>
<td>1</td>
<td>1959</td>
<td>30.1</td>
<td>22.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72-92</td>
<td>2</td>
<td>1959</td>
<td>27.0</td>
<td>25.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>1959</td>
<td>27.0</td>
<td>34.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72-92</td>
<td>3</td>
<td>1959</td>
<td>27.6</td>
<td>23.6</td>
<td>26.1</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>1959</td>
<td>27.6</td>
<td></td>
<td></td>
<td>37.9</td>
</tr>
<tr>
<td>78-88</td>
<td>1</td>
<td>1960</td>
<td>32.5</td>
<td>28.0</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>1960</td>
<td>32.5</td>
<td>35.8</td>
<td>38.4</td>
<td></td>
</tr>
<tr>
<td>78-88</td>
<td>2</td>
<td>1960</td>
<td>32.2</td>
<td>22.5</td>
<td>22.7</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>1960</td>
<td>32.2</td>
<td>33.0</td>
<td>37.3</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>1960</td>
<td>33.1</td>
<td>38.5</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>3</td>
<td>1960</td>
<td>33.1</td>
<td>38.6</td>
<td>42.2</td>
<td></td>
</tr>
</tbody>
</table>
and the other half at 36°. Although no decay symptoms developed at 50° or 36°, the 78°-88° treatment was not included because spoilage occurs rapidly at the higher temperatures. In another experiment to measure the effects of maturation, watermelons of widely varying maturities were harvested. The reflectance and pigment content were measured in melons varying in flesh color from pink to dark red.

Table 3. Changes in Pigment Content of Six Watermelons after Storage at 50° and 36°F for 1 and 2 weeks.

<table>
<thead>
<tr>
<th>Melon No.</th>
<th>Harvest</th>
<th>Storage @ 50°F</th>
<th>Storage @ 36°F</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>1 week</td>
<td>2 weeks</td>
</tr>
<tr>
<td>1</td>
<td>31.5</td>
<td>37.5</td>
<td>43.5</td>
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<tr>
<td>2</td>
<td>31.0</td>
<td>34.2</td>
<td>38.5</td>
</tr>
<tr>
<td>3</td>
<td>27.0</td>
<td>33.0</td>
<td>37.0</td>
</tr>
<tr>
<td>4</td>
<td>35.0</td>
<td>41.5</td>
<td>44.5</td>
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<tr>
<td>5</td>
<td>44.0</td>
<td>48.0</td>
<td>48.5</td>
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<tr>
<td>6</td>
<td>30.0</td>
<td>37.0</td>
<td>43.5</td>
</tr>
<tr>
<td>Mean</td>
<td>33.1</td>
<td>38.5</td>
<td>42.6</td>
</tr>
</tbody>
</table>

Table 4. Effect of Temperature and Duration of Storage on the Internal Color of Watermelons as Measured with the Photovolt Reflection Meter.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Variety</th>
<th>Reflectance Value</th>
<th>At Harvest</th>
<th>Storage Temperature and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Green Filter</td>
<td></td>
<td>Temp. 78-88°F: 1 Week : 2 Weeks</td>
</tr>
<tr>
<td>1</td>
<td>Charleston Gray</td>
<td>17.5</td>
<td>14.1</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amber Filter</td>
<td>23.2</td>
<td>22.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blue Filter</td>
<td>7.8</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C.I.E. x</td>
<td>.441</td>
<td>.461</td>
</tr>
<tr>
<td>2</td>
<td>Charleston Gray</td>
<td>17.2</td>
<td>13.2</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amber Filter</td>
<td>23.1</td>
<td>23.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blue Filter</td>
<td>8.4</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C.I.E. x</td>
<td>.439</td>
<td>.475</td>
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<td>3</td>
<td>Congo</td>
<td>Green Filter</td>
<td>17.3</td>
<td>23.3</td>
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<tr>
<td></td>
<td></td>
<td>Amber Filter</td>
<td>26.9</td>
<td>33.7</td>
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<td></td>
<td></td>
<td>Blue Filter</td>
<td>10.1</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C.I.E. x</td>
<td>.444</td>
<td>.419</td>
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</tbody>
</table>
RESULTS

Measurements of the pigment content of eight melons having a wide range of maturity (Table 1) yielded transmittance values ranging from 52 for an immature melon to 16 for a fully mature melon. Excellent precision was obtained between duplicate samples of blended melon used for pigment extraction.

Reflectance measurements (Table 1) for the melons of varying maturities were generally higher for the pink, immature melons and lower for the dark red, mature melons. However, the range in reflectance values was not as great, nor the correlation with visual color as good, as it was for the transmittance values from the same melons. Since the values obtained with the tristimulus filters cannot be interpreted in terms of visual colors, they were converted to C.I.E. values according to the formulas of Hunter (2). The green filter values are equal to Y values and indicate lightness or luminance. The amber and blue filter values were converted to chromaticity coordinates x and y.

The Y values decreased as the maturity ratings progressed from pink to dark red. The y values showed no changes which correlated with watermelon colors. The x values were inversely related to the Y values and the transmittance values. When the x and y points in Table 1 were located on a chromaticity diagram the .480 point was redder than the .409 point.

During the 1959 and 1960 seasons, the 5 lots (Table 2) of melons stored for two week periods at high fluctuating summer temperatures showed a considerable decrease in transmittance compared with the levels at harvest. The internal color also became redder in 2 lots stored for 1 week and 1 lot stored for 4 weeks at high temperatures. The transmittance values in Table 2 are all averages obtained from the analyses of 6 melons in each treatment.

In each of the 5 lots stored at 50° there was an increase in transmittance, and the melons were not as red visually as they were at harvest. In the Congo melons where the same melons were sampled before and after storage (Table 3), there was an average increase in transmittance of 17 percent during 1 week at both 50° and 36°. The increase in transmittance continued during the second week and was 28 and 29 percent above the harvest level at the end of the two week period.

Reflectance measurements were made only on the 3 lots of melons studied in 1960. The values obtained with the three filters of the reflection meter (Table 4) show a general decrease during storage at 78°-88° and an increase at 50°. There was a decrease of about 20 percent in green filter values (luminance) at the higher temperatures and an increase of about 15 percent at 50°.

When the amber and blue filter values were converted to x and y values, little difference in y values was noted among the treatments. However, the x values for the melons stored at high temperatures were always higher than the initial samples, and the x values for the melons stored at 50° and 36° were always lower than the initial samples. The similarity of the x values obtained at 50° and 36° indicated little difference in response of the melons to the temperature difference of 14 degrees.

DISCUSSION AND SUMMARY

Changes in redness in watermelons during maturation and storage were measured by pigment extraction and light reflectance. Differences in total extracted pigments were measured as percent transmittance with the Spectronic 20 colorimeter. Changes in redness were associated with the x values of the C.I.E. color scale computed from the tristimulus readings of the Photovolt Reflection Meter.

Watermelons increased in pigment content and redness during storage for two weeks at 72°-92°F. Ezell and Wilcox (1) attributed the decrease in carotenoid pigments in sweet potatoes stored at 50° to chilling injury. The decrease in pigment content and redness of watermelons during storage at 50° and 36° may also result from chilling injury since watermelons develop other symptoms of chilling injury at these temperatures. The absence of a good red color in some watermelons harvested early in the spring could also be due to field temperatures too low for normal color development.

LITERATURE CITED

Freshly prepared citrus juices are normally cloudy. Preservation of this cloud is of concern to the producers of frozen concentrates and chilled juices. It has long been recognized that activity of the enzyme pectinesterase (PE) is generally associated with cloud instability in orange juice and a correlation has been observed (4). Complete or partial inactivation or inhibition of the PE is therefore desirable.

Current methods for inactivating the enzyme involve the use of heat, which may affect the fresh flavor of juice products. Control of enzyme activity by means other than heat might be advantageous. Bell and Etchells (1) found an inhibitor of the enzyme polygalacturonase and cellulase in a water extract of grape leaves. Etchells, Bell, and Williams (3) used the extract to control softening of cucumber pickles during fermentation. Their work suggested the search for an inhibitor of PE from similar sources.

**Experimental Methods**

**Raw Materials.** Leaves of domestic muscadine grapes (Vitis rotundifolia, Michx.) were obtained from the vineyard of Dr. Charles Demko, Altoona, Florida. Varieties included Topsail, Stuckey, Tar Heel, and Thomas x Munsoniana. Leaves were also obtained from wild grape (Vitis munsoniana, Simpson) widely distributed in central Florida.

The leaves were transported to the laboratory promptly after picking and rinsed in tap water. They were then dipped in dilute hydrochloric acid solution and rinsed again with tap water to remove spray residue. A final rinse with distilled water was followed by drying in a current of air. Part of the leaves were used to prepare an extract and part were frozen for future use.

**Preparation of extract:** The stems were removed and 40 g. of leaf tissue were comminuted with 400 g. distilled water for 3 minutes in a high speed blender. The mixture was strained through four layers of cheesecloth, then centrifuged in 50 ml. tubes for 10 minutes at 1400 r.p.m. with a tip radius of 8 inches. Sediment was discarded. The supernatant extract was used in this study and hereafter referred to as GLE.

Partial purification of the wild grape leaf extract was effected by concentrating 5 volumes to 1 under vacuum, and extracting repeatedly with ethyl ether. The active principle was returned to water solution, for comparison with the crude extract, by evaporation of the ether in the presence of distilled water.

**Pectinesterase activity.** PE activity was determined by the method published by MacDonnell, Jansen, and Lineweaver (7) and further described by Bissett, Veldhuis, and Rushing (2), except that a more concentrated solution of pectin (2%) was used to facilitate manipulation of concentrations. In this method the reaction mixture is adjusted to pH 7.5 and diluted to 40 ml., after which the rate of reaction is measured. Dilution is normally made with distilled water. For the study of its inhibitory effect, GLE was added in place of part of the water. It was therefore not necessary to individually dilute each control sample without inhibitor to compare activities. Activities were expressed as pectinesterase units per milliliter of single strength or reconstituted orange juice multiplied by 10,000 (PEu/mlx10^4).

**Cloud retention by visual observation.** Portions of reconstituted orange juices were placed in 1 x 8 inch test tubes fitted with