Changes in Sugars, Starch and Amylase Activity during Ripening of Sugar Apples at Different Storage Temperatures

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The total soluble solids of the sugar apple increased and then decreased a little during ripening at different storage temperatures, glucose, fructose and sucrose were increased gradually during the fruits ripening, with the fruits stored at 26 and 21°C being higher in the sugar contents than those stored at 16°C. The decrease of starch in the fruits stored at 26 and 21°C was quicker than those stored at 16°C. The fruits stored at 21°C led to the higher activity in amylase than the others.

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Immature sugar apples are astringent, acidic and have a high starch content, but as the starch decreases with maturity, the fruits become sweet in taste (KE et al., 1983 ; YU et al., 1992 ; TSAY and WU, 1990 ; FREDDY, 1990). Starch hydrolysis in the ripening sugar apple fruit has been reported (KE et al., 1983), which leads to a higher sucrose content (ROBERT et al., 1983). Scant information is available on the changes in sugar and starch contents and amylase activity during ripening. The present study relates to changes occurring in sugars, starch and amylase activity during the ripening of sugar apples “cv Tsulin” at different storage temperatures.

MATERIALS AND METHODS

Sugar apple fruits (Annona squamosa L. cv Tsulin) were harvested at physiological maturity (mature hard green fruit ; at 50% of ripeness which could become soft with 4 days ; WU and TSAY, 1998) from the orchard in Taitung, and 300 ± 10 g of weight. They were brought to the laboratory of the University by road within 4 hr. after harvest. Storage temperatures were 16, 21 and 26°C and 85-90% relative humidity. There were three replications and each consisted of 3-4 fruits.

Total soluble solids (°Brix), starch (AOAC, 1984), glucose, fructose and sucrose (MEDLICOTT and THOMPSON, 1985), protein in the pulp by that of BRADFORD (1976) and amylase (MOWLAH and ITOO, 1982) were analyzed daily or every two days depending on storage conditions. Data were analyzed using a Statistical Analysis (SAS Institute Inc., 1989) program package. After an analysis of variance (ANOVA), the significant difference was defined at p<0.05.

RESULTS AND DISCUSSION

Soluble solids and carbohydrates

Tables 1 to 5 show the concentrations of soluble solids, glucose, fructose, sucrose and starch during ripening at different storage temperatures. The
total soluble solids of the fruits stored at 26 or 21°C increased drastically to 21° Brix on the 4th and 7th day respectively, those fruits stored at 16°C increased gradually and reached to 10.5° Brix after being stored for 12 days (Table 1). The soluble solid contents of the fruit depend upon the stage of maturity and degree of ripening (DRAKE and FELLMAN, 1987). From the results shown in Table 1, it is shown that the sugar apples stored at 16°C can’t ripen completely, while the browning reaction is occurring in the pericarp and the surface of the fruits is spoiled on the 12th day.

The reducing sugars content increased with the fruit ripening, and the glucose being higher than the fructose during the whole ripening period (Table 2 and 3). The glucose contents were 7.0% and 5.9% of the fruits stored at 26 and 21°C on the 5th and 8th day respectively, while those fruits stored at 16°C were 3.56% after being stored for 12 days. The fruits stored at 16°C contained the lower fructose (2.76%) on the 12th days) than those fruits stored at 26 and 21°C (4.87 and 4.53% on the 5th and 8th days respectively). The same results were gotten on the sucrose contents, the sucrose contents were 5.7, 5.9 and 3.7% of the fruits stored at 26, 21 and 16°C on the 5th, 8th and 12th day, respectively.

The starch contents of the fruits were gradually decreased as the storage proceeded, with the change in starch generally quicker in fruits stored...
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The fruits which were stored at 26°C and 21°C contained 1.2 and 1.0% of starch on the 6th and 8th days respectively, but the fruits which were stored at 16°C contained 3.3% of the starch on the 12th days, which shows that the starch contents of the fruits is also affected by the storage temperatures.

**Amylase activity**

In unripe fruits the amylase activity was low and increased as the fruit ripened, reaching a peak (1.87, 2.42 and 1.45μmole maltose per mg protein in 3 min) after 4th, 5th and 6th days of the fruits stored at 26, 21 and 16°C, respectively (Table 6). Enzyme activity decreased as the fruits over-ripened. The breakdown of starch by amylase during the fruits started ripening, led to a greater sucrose content and consequent sweetness (LAKSHMINARAYANA, et al. 1970; TANDON and KALRA, 1983). The increase of sucrose coincided with the appearance of starch, which suggests that sucrose syntheses and its progressive accumulation were directly related to the hydrolyzed by-products of starch such as glucose. TARRA et al. (1983) demonstrated the transformation of starch to sucrose via glucose-1-phosphate-UDP-glucose in bananas. It will be of interest to study whether a similar pattern exists in sugar apples.

<table>
<thead>
<tr>
<th>Storage Temp(°C)</th>
<th>Days after harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>1.57p</td>
</tr>
<tr>
<td>21</td>
<td>1.70op</td>
</tr>
<tr>
<td>26</td>
<td>1.83no</td>
</tr>
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</table>

a-p : Means in the table by the same superscript letter are not significantly different (p>0.05) separated by the Duncan Method.

<table>
<thead>
<tr>
<th>Storage Temp(°C)</th>
<th>Days after harvesting</th>
</tr>
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<tbody>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>18.4a</td>
</tr>
<tr>
<td>21</td>
<td>18.4a</td>
</tr>
<tr>
<td>26</td>
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</table>

a-t : Means in the table by the same superscript letter are not significantly different (p>0.05) separated by the Duncan Method.

<table>
<thead>
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<th>Days after harvesting</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10</td>
</tr>
<tr>
<td>16</td>
<td>0.51n</td>
</tr>
<tr>
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<tr>
<td>26</td>
<td>0.63kl</td>
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</tbody>
</table>

a-m : Means in the table by the same superscript letter are not significantly different (p>0.05) separated by the Duncan Method.

t : The unit of amylase activity was calculated in μ moles of maltose formed per mg protein in 3 min at 37°C.
CONCLUSIONS

From the foregoing data on the three different storage temperatures of the sugar apple, the fruits stored at 16°C got less in total soluble solid and sugar contents than those stored at 26 and 16°C. The peak of amylase activity was different while the fruit was stored at different temperatures. The fruits stored at 21 and 26°C achieved get nearly the same quality level.

REFERENCES


パンレイン果実の各種貯蔵温度における糖分、澱粉およびアミラーゼ活性の変化

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パンレイン果実を26℃、21℃及び16℃で貯蔵したとき、それぞれ追熱が進行したが、その可溶性固形物量の変化を測定すると、一時的な増加が見られ、一定の高い量を保ってから減少する傾向であった。果実の追熟が進むにつれ、ブドウ糖、果糖およびショ糖などの糖分が増加した。26℃および21℃で貯蔵した果実は、澱粉が完全に糖化していたために、全糖含量は16℃に比べて高かった。さらにアミラーゼの活性を測定したが、21℃で貯蔵した果実のアミラーゼ活性は最も高かった。

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