HARVEST DATE DETERMINED BY DIFFERENT METHODS OF STARCH INDEX READINGS AND TEXTURE CHANGES DURING APPLE STORAGE

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Summary. The paper presents potential applications of starch index (SI) analysis methods. The results of starch decomposition were used to estimate the optimal harvest date. Two different apple cultivars (Melrose and Jonagold) were used in the study. Harvest dates were determined by the results of starch tests interpreted by scanner (SC), digital camera (CA), and visual assessment (VA). Apples were stored in ULO chambers (1.5% O2, 2.5% CO2) up to 120 days. Fruits were sampled in 30-day intervals, where elasticity and cohesiveness were evaluated. The best storage results were observed for the fruit harvested on SI readings by SC method. Results of storage for the fruits harvested by CA readings were available but slightly worse than in SC method of SI reading.

Keywords: apples, starch index, image analysis, storage of fruits.

INTRODUCTION

Stored fruits are susceptible to different kind of disorders [Tomala 2005, Tomala 2007]. For example, apples are protected only from some of them by preharvest orchard treatments [McGlashon 2005]. It is very difficult to protect stored organims such as fruits and vegetables due to their high biological activity as well as variable conditions of storage. Storage disorders are revealed after several months of storage and in spite of carefully controlled atmosphere conditions they often occur [Lau 1992]. These disorders are caused by incorrectly composed storage atmosphere [Paliath 1995] or fruit's susceptibility to disorders resulting from inappropriate harvest date [Baurt 2007]. It is very important to determine harvest date by an adequate method. Traditional methods that rely on weather observation and computation of vegetation period fail in judgment when the fruits are subjected to CA or ULO storage [Tomala 2004]. Once the fruits are harvested too late they must be stored shortly because of very high respiration rates. Early harvested fruits are susceptible to CO2 injury [Kaminski 2006] and superficial scald even when the conditions of storage are optimal [Morales 2007].

The harvest date of fruits that are subjected to long-term storage must be precisely evaluated [Tomala 1995, 2004]. This is the main factor that assures excellent quality of commodity after storage [Fellman 2003]. There are many precise methods of estimation of the fruit's ripeness but some of them are too expensive or too complex to be performed in common orchards and cold storage.
[Lysiak 1998] The simple and inexpensive starch test which is based on starch decomposition in fruits (apples and pears) during ripening process is the only science-based method that is possible to be performed in common use. The judgment of its results however leads to uncertain decision of harvest because of wide dispersion of scores by control panelists [Peirs 2002, Guz 2006]. It is suggested that other improved methods of SI reading are needed. The result of maturity evaluation should be scored in conjunction with storage results [Tomala 2004]. This practice allows to judge about the precision of method used in the experiment. The results of storage are dependent on the storage conditions. Once the storage conditions meet the standards, the judgment should be quite accurate.

The use of different starch test “reading” methods should be scored with the results of storage also because of lack of identity patterns to be compared with the experimental fruits.

MATERIALS AND METHODS

Two different apple cultivars were used in the experiment: Melrose and Jonagold.

The choice of apple cultivars was made based on their starch content and distribution and starch decomposition in the fruits was observed until its total disappearance (Fig. 1).

![Starch decomposition patterns](image)

A B

**Fig. 1. The starch decomposition patterns: A – Melrose, B – Jonagold**

Fruits of the Melrose cultivar (high starch) and of the Jonagold cultivar (low starch) were harvested at 4-day intervals in late-morning hours. Average-size apples (7-8 cm) were picked at a height of about 1.5 m above ground level. The experiment was begun three weeks prior to the calendar harvest time for the fruits. After performing the standard starch test in a solution of 5g I$_2$ + 20g KI/1000 ml of water and allowing the specimens to dry, slices with the "starch pattern" were cut and then their images were acquired by means of a digital camera (CA). The last stage of specimen image acquisition was scanning of the surface of sheared and coloured slices of the apples (SC).

Also, visual assessment (VA) of the material was performed (5 jurors), consisting in comparison of the specimens with standard tables (Plantares, Kraków 2003) and estimation of the value of the starch index in the scale from 1 to 10. Once the Starch Index was close to the optimum values the harvest began. About 30 kg of apples of each cultivar were harvested and stored up to 180 days. Melrose apples are harvested when SI value is near 3 whereas Jonagold apples are harvested at SI
from 6 to 7. The harvested apples were divided into groups harvested by the indications of three (CA, SC and VA) methods.

The fruits were stored under conditions of controlled atmospheres (ULO). After the chamber was closed and sealed, it was filled with nitrogen from a generator so as to reduce the level of oxygen to 5.6%. ULO conditions, i.e., O₂ concentration was 1.4%, and CO₂ concentration was 2.3%. Those conditions were stabilized by the respiration of fruits and controlled by ULO equipment. Fruits were sampled in 30-days intervals when 5 kg fruits were taken from the storage chamber. From the central part of the apple a slice was cut, about 15 mm thick, so that the planes of cutting were perpendicular to the axis of the fruit. Next, using a cylindrical knife with a diameter of \(d=13\text{mm}\), cylindrical core samples with a height of \(h=10\text{mm}\) were taken. Apple flesh core samples were subjected to compression. Compression tests were conducted always at a constant rate of 50 mm/min. The coefficient of sample deformation was 50%.

During the compression the following parameters were recorded:
- force required to destroy the sample,
- section inclination within the elastic range.

RESULTS

<table>
<thead>
<tr>
<th>Method</th>
<th>Harvest date</th>
<th>CA</th>
<th>SC</th>
<th>VA</th>
<th>CA VA</th>
<th>SC VA</th>
<th>SC CA</th>
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<tbody>
<tr>
<td>1</td>
<td>1.56</td>
<td>1.17</td>
<td>2.87</td>
<td>-1.23</td>
<td>-1.70</td>
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<tr>
<td>2</td>
<td>1.92</td>
<td>2.57</td>
<td>3.84</td>
<td>-1.92</td>
<td>-1.27</td>
<td>0.65</td>
<td></td>
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<tr>
<td>3</td>
<td>3.03</td>
<td>3.61</td>
<td>4.11</td>
<td>1.38</td>
<td>0.61</td>
<td>0.56</td>
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</tr>
<tr>
<td>4</td>
<td>2.72</td>
<td>3.43</td>
<td>4.25</td>
<td>-1.53</td>
<td>-0.82</td>
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<tr>
<td>5</td>
<td>3.80</td>
<td>3.37</td>
<td>4.89</td>
<td>-1.09</td>
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</tr>
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<td>6</td>
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<td>2.92</td>
<td>4.53</td>
<td>-1.40</td>
<td>-1.61</td>
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<tr>
<td>7</td>
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<td>4.69</td>
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<tr>
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<td>3.25</td>
<td>2.76</td>
<td>4.59</td>
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</tr>
<tr>
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<td>1.96</td>
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<td>3.36</td>
<td>-1.60</td>
<td>-2.33</td>
<td>-0.73</td>
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<tr>
<td>10</td>
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<td>4.11</td>
<td>6.40</td>
<td>-1.21</td>
<td>-3.29</td>
<td>-1.06</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>4.57</td>
<td>3.62</td>
<td>5.93</td>
<td>-1.37</td>
<td>-2.32</td>
<td>-0.95</td>
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<tr>
<td>12</td>
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<td>7.18</td>
<td>8.43</td>
<td>-0.38</td>
<td>-1.25</td>
<td>-0.67</td>
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</tr>
<tr>
<td>13</td>
<td>6.24</td>
<td>5.33</td>
<td>7.19</td>
<td>-0.35</td>
<td>-1.85</td>
<td>-1.51</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6.24</td>
<td>5.30</td>
<td>7.61</td>
<td>-0.67</td>
<td>-2.12</td>
<td>-1.44</td>
<td></td>
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<tr>
<td>15</td>
<td>8.98</td>
<td>8.31</td>
<td>9.44</td>
<td>-0.46</td>
<td>-1.15</td>
<td>-0.67</td>
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</tr>
<tr>
<td>Mean value</td>
<td>4.34</td>
<td>3.87</td>
<td>5.11</td>
<td>-1.17</td>
<td>-1.64</td>
<td>-0.48</td>
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</tbody>
</table>

The starch decomposition was variable in Melrose apples. Fruits were harvested just after the first term of starch tests judged by visual assessment. The SI values received by other methods of
judgement were at low level. The differences were 0.35 to 1.9 smaller IS for CA method and 0.9 to 2.0 smaller for SC method in comparison to VA method. Fruits were also harvested by the indication of the other methods. Harvest was performed after 24 (SC method) and 36 (CA method) terms of experiment. The results of elasticity and cohesiveness were shown in Figures 2 and 3.

**Fig. 2. Effect of elasticity changes in Melrose apples harvested by these methods of SI evaluation**

**Fig. 3. Effect of cohesiveness changes in Melrose apples harvested by these methods of SI evaluation**
Apple harvest performed by the indications obtained by SC method resulted best in preserving high elasticity and cohesiveness of apple flesh. Cohesiveness was expressed by the force needed to destroy the flesh sample. Higher elasticity values resulted in preserving more resistance to bruising during transportation and market handling. The bruise susceptibility of fruits is the main problem after long-term storage and shelf life. Its market value is low and has no consumer acceptance.

The results of this experiment show that the term of harvest influences the elasticity with high importance level (α=0.05). Fruits that were harvested too early had the lowest levels of elasticity (Fig. 1.) and cohesiveness (Fig. 3.).

The apples that were harvested by the use of computational methods (SC and CA) have significantly higher elasticity values in comparison to those that were harvested by the use of visual assessment. The cohesiveness of apple flesh was reduced in storage time. This was especially important by the end of storage. The values of this parameter were independent of the method of SI evaluation and term of harvest.

Fruits of Jonagold cultivar were observed in 9 terms of experiment during starch decomposition. This is a low-starch cultivar so decomposition happens quicker than in high-starch cultivars.

### Table 2

<table>
<thead>
<tr>
<th>Method</th>
<th>CA</th>
<th>SC</th>
<th>VA</th>
<th>CA-VA</th>
<th>SC-VA</th>
<th>SC-CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>6.66</td>
<td>6.52</td>
<td>-1.01</td>
<td>0.14</td>
<td>1.15</td>
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<tr>
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<td>7.59</td>
<td>7.29</td>
<td>-1.52</td>
<td>0.30</td>
<td>1.92</td>
</tr>
<tr>
<td>3</td>
<td>6.11</td>
<td>7.81</td>
<td>7.36</td>
<td>-1.25</td>
<td>0.23</td>
<td>1.30</td>
</tr>
<tr>
<td>4</td>
<td>7.15</td>
<td>8.38</td>
<td>8.15</td>
<td>-0.99</td>
<td>0.24</td>
<td>1.23</td>
</tr>
<tr>
<td>5</td>
<td>8.03</td>
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<td>7.79</td>
<td>0.24</td>
<td>0.18</td>
<td>-0.06</td>
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<tr>
<td>6</td>
<td>8.27</td>
<td>8.21</td>
<td>8.72</td>
<td>-0.45</td>
<td>-0.51</td>
<td>-0.06</td>
</tr>
<tr>
<td>7</td>
<td>8.39</td>
<td>8.44</td>
<td>8.88</td>
<td>-0.49</td>
<td>-0.44</td>
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<tr>
<td>8</td>
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<td>-0.41</td>
<td>-0.61</td>
<td>-0.20</td>
</tr>
<tr>
<td>9</td>
<td>9.96</td>
<td>9.22</td>
<td>9.97</td>
<td>-0.42</td>
<td>-0.74</td>
<td>-0.22</td>
</tr>
<tr>
<td>Mean value</td>
<td>7.52</td>
<td>8.10</td>
<td>8.24</td>
<td>-0.71</td>
<td>-0.13</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Fruits being in an initial phase of starch disintegration cannot be harvested because of their low value for long term storage and susceptibility to many disorders and diseases.

The harvest time of the Jonagold apples was performed after the 1st term of SI reading by the use of SC and VA methods (Tab. 2) and after the 3rd term using CA method. In these terms of experiment the SI value was 6 which was assumed as the best stage of ripeness to harvest and storage.

The results of SI values were similar at the use of VA and SC. The difference was only 0.13 of SI unit taking into account all harvest dates. The values deviations were more distinct in the use of CA method where values were lower, of 0.7 (VA) and 0.53 (SC). This resulted in retardation of harvesting the fruits where CA reading method was taken as a harvest indicator. An initial stages of harvests the differences between IS values were the highest (over 1.0 SI).

Harvest delay resulted in low elasticity values of apple flesh just after 30 days of storage (Fig. 4.).
The lowest values were sustained during the whole time of storage. Results of cohesiveness were similar to elasticity curves in Fig. 5. The differences between fruits harvested by SC and VA methods were not statistically important. After long-time storage the cohesiveness of apple flesh was slightly higher after harvest using CA method.
CONCLUSIONS

1. Storage of fruits harvested by SI interpretation of SC method had the best results for two apple cultivars.
2. Harvest respiration of Jonagold apples caused by variations of SI evaluation resulted in reduction of strength and elasticity in apple flesh.
3. Premature harvest of McIntosh fruits resulted in reduction of strength and elasticity values through the whole storage period.
4. The differences of SI interpretation were smaller in Jonagold apples. The span of variation was from 0.13 to 0.71 of SI values.
5. The use of scanner for SI evaluation and determination of harvest date had the best results in storage effects.

REFERENCES

Amosah J.G.N., Hotchkiss J.H., Watkins C.B.: 
Diphenylamine and pre-dicing storage effects on the responses of apple discs to elevated CO2 atmospheres


Billy L., Mahamag E., Royer G., Raenad C., Arvianoet G., et al.: Relationship between texture and pectin composition of two apple cultivars during storage

Fellman J. K., Rudell D. R., Mattson D. S., Mathias J. P. (2003): Relationship of harvest maturity to flavor regeneration after Ca storage of ‘Delicious’ apples
Postharvest Biology and Technology 27, 39–51

McCauley, W. B., Fathi A. C., Legumes E.: Preharvest application of aminoethylcarboxy-methylene (AEC) modifies harvest maturity and cool storage life of ‘Arctic Snow’ nectarines
Postharvest Biology and Technology Volume: 36, Issue: 1, April, 2005, pp. 93-102

Gur T. 2006: Komparatywne analiza obrzezi u owocu misku kukułce podczas dystrybucji jabłek
Inżynieria Rolnicza 7(32), 199-207


Postharvest Biology and Technology 13, 19-26

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TERMION ZBIORU WYZNACZONY RÓŻNymi METODAMI OCENY INDEKSU SKROBIOweGO A ZMIANY TEKSTURY JABŁEK W CZASIE PRZECHOWYWANIA.

Streszczenie. Praca przedstawia możliwość podjęcia decyzji o wykorzystaniu metod analitycznych w interpretacji indeksu skrobioowego. Wyniki oceny tego testu były wykorzystywane do podjęcia decyzji o zbiorze owoców. Dodatkowo podane były owoce oznaczone Melrose oraz Jonagolda. Zbiór owoców wykorzystano w oparciu o wyniki testu skrobioowego, który był interpretowany w oparciu o ocenę wizualną ocenianych (OW) analizą obszaru testu skrobioowego (SK) oraz spisem cyfrowym (AC). Owoce przechowywane w kontencie ULO (1,8% CO2, 2,1% O2) przez 180 dni. Podczas przechowywania w ubiegłych 30 dniach oznaczono zmiany wskazujące na objawianie się skrobienia owoców. W przedstawionych eksperymentach dobre wyniki przechowywania owoców uzyskano posługując się metody AC (w przypadku obszaru owoców) oraz metodą OW (tylko dla Jonagolda). Zbiór owoców według wskazań metody AC dawał nieco gorzej wyniki podczas przechowywania obręd oznaczenia owoców.

Słowa kluczowe: jabłka, indeks skrobioowy, analiza obszaru, przechowywanie owoców