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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 studies. 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 180 days. Fruits were sampled in 30-days intervals where elasticity and cohesiveness were evaluated. The best storage results were observed for the fruits harvested of SI readings by SC method. Results of storage for the fruits harvested by CA readings were credible but slightly worse than in SC method of SI reading.

Key words: 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 [McGlasson 2005]. It is very difficult to protect stored organisms 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 1998]. These disorders are caused by incorrectly composed storage atmosphere [Paliyath 1998] or fruit's susceptibility to disorders resulting from inappropriate harvest date [Baert 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 CO_2 injury [Amissah 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

[Łysiak 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 the 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).

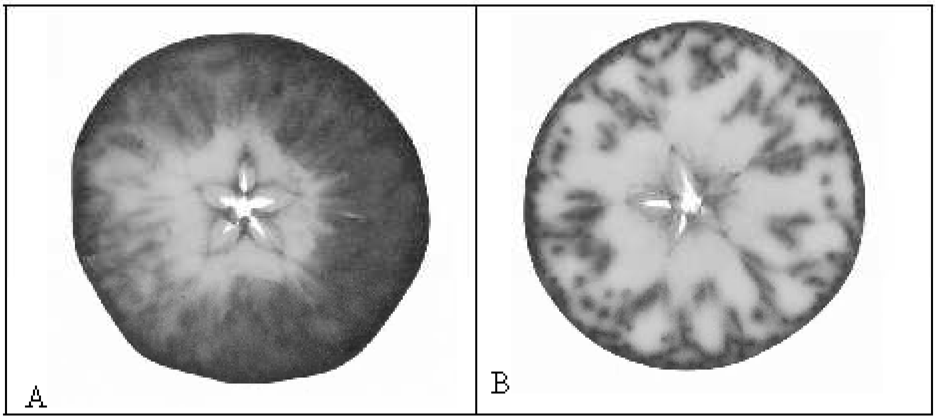

Fig. 1. The starch decomposition patterns: A – Melrose, B – Jonagold

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 J_2 + 20g KJ/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 (Plantpress, 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 atmosphere (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. O_2 concentration was 1,4%, and CO_2 concentration was 2,3%. Those conditions were stabilised 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 ϕ=13mm, cylindrical core samples with a height of h=10 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 1. Starch contents expressed by starch index (SI) in Melrose apples by different methods of judgement.

Method	MELEROSE					
Harvest date	**CA**	**SC**	**VA**	**CA-VA**	**SC-VA**	**SC-CA**
1	1,64	1,17	2,87	-1,23	-1,70	-0,47
2	1,92	2,57	3,84	-1,92	-1,27	0,65
3	3,03	3,61	4,41	-1,38	-0,81	0,58
4	2,72	3,43	4,25	-1,53	-0,82	0,71
5	3,80	3,57	4,89	-1,09	-1,32	-0,23
6	3,13	2,92	4,53	-1,40	-1,61	-0,21
7	3,24	2,69	4,69	-1,45	-2,00	-0,55
8	3,35	2,76	4,59	-1,23	-1,82	-0,59
9	1,96	1,23	3,56	-1,60	-2,33	-0,73
10	5,19	4,11	6,40	-1,21	-2,29	-1,08
11	4,57	3,62	5,93	-1,37	-2,32	-0,95
12	7,85	7,18	8,43	-0,58	-1,25	-0,67
13	6,84	5,33	7,19	-0,35	-1,85	-1,51
14	6,94	5,50	7,61	-0,67	-2,12	-1,44
15	8,98	8,31	9,44	-0,46	-1,13	-0,67
Mean value	4,34	3,87	5,51	**-1,17**	**-1,64**	**-0,48**

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 2 [nd] (SC method) and 3 [rd] (CA method) terms of experiment. The results of elasticity and cohesiveness were shown in Figures 2 and 3.

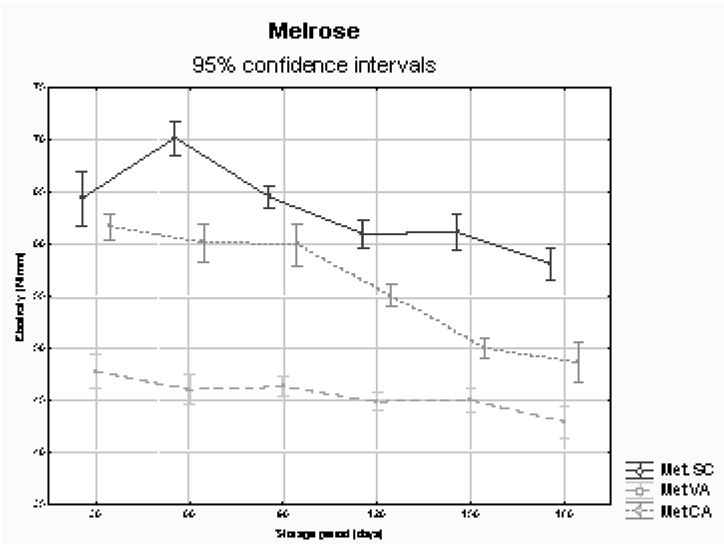

Fig. 2. Effect of elasticity changes in Melrose apples harvested by three methods of SI evaluation

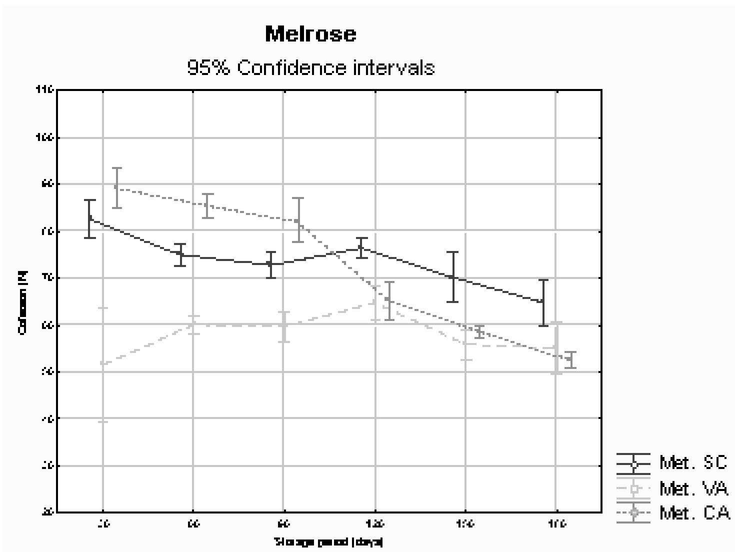

Fig. 3. Effect of cohesiveness changes in Melrose apples harvested by three methods of SI evaluation

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. 2.) 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. Starch contents expressed by starch index (SI) in Jonagold apples by different methods of judgement

Jonagold						
Method / Harvest date	CA	SC	VA	CA-VA	SC-VA	SC-CA
1	5,51	6,66	6,52	-1,01	0,14	1,15
2	5,67	7,59	7,29	-1,62	0,30	1,92
3	6,11	7,61	7,36	-1,25	0,25	1,50
4	7,15	8,38	8,15	-0,99	0,24	1,23
5	8,03	7,97	7,79	0,24	0,18	-0,06
6	8,27	8,21	8,72	-0,45	-0,51	-0,06
7	8,39	8,44	8,88	-0,49	-0,44	0,06
8	9,03	8,83	9,44	-0,41	-0,61	-0,20
9	9,56	9,23	9,97	-0,42	-0,74	-0,32
Mean value	7,52	8,10	8,24	-0,71	-0,13	0,58

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 1 st term of SI reading by the use of SC and VA methods (Tab. 2.) and after the 3 rd term using CA method. In those 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 0,58 (SC). This resulted in retardation of harvesting the fruits where CA reading method was taken as a harvest indicator. At 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.).

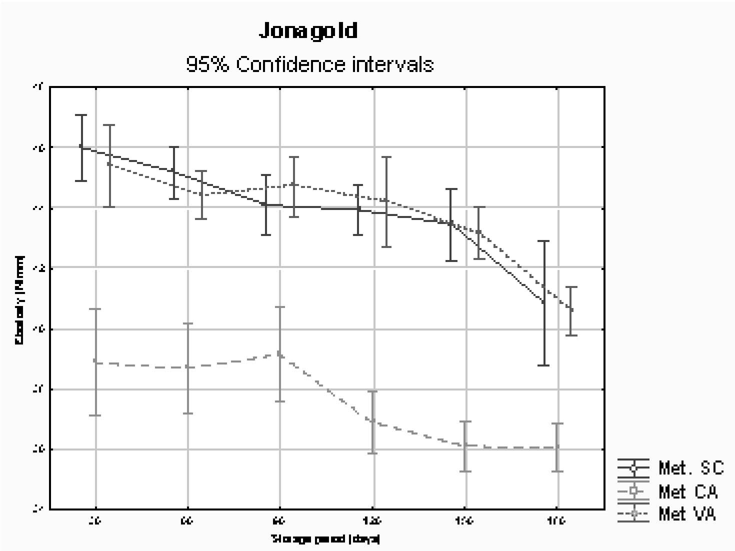

Fig. 4. Effect of elasticity changes in Jonagold apples harvested by three methods of SI evaluation

The lowest values were sustained during the whole time of storage. Results of cohesiveness were familiar 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.

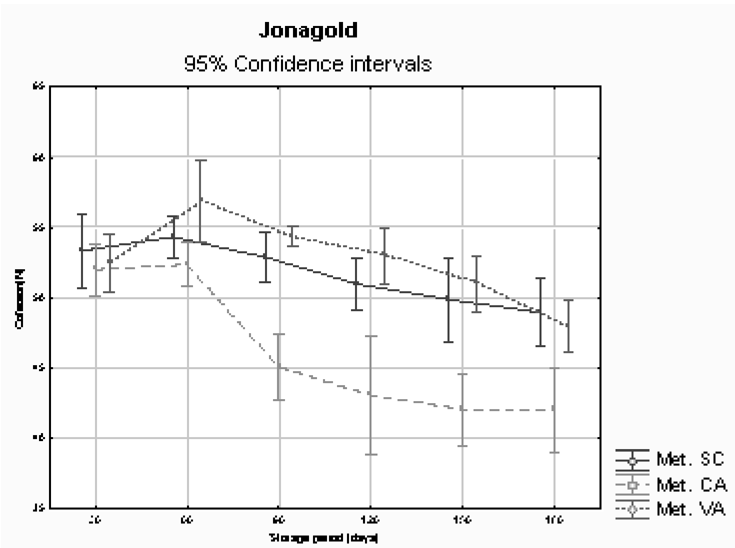

Fig. 5. Effect of cohesiveness changes in Jonagold apples harvested by three methods of SI evaluation

CONCLUSIONS

1. Storage of fruits harvested by SI interpretation of SC method had the best results for two apple cultivars.
2. Harvest retardation of Jonagold apples caused by variations of SI evaluation resulted in reduction of strength and elasticity in apple flesh.
3. Premature harvest of Melrose 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.

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TERMIN ZBIORU WYZNACZONY RÓŻNYMI METODAMI OCENY INDEKSU SKROBIOWEGO A ZMIANY TEKSTURY JABŁEK W CZASIE PRZECHOWYWANIA.

Streszczenie. Praca przedstawia możliwość praktycznego wykorzystania metod analitycznych w interpretacji indeksu skrobiowego. Wyniki oceny tego testu były wykorzystane do podjęcia decyzji o zbiorze owoców. Badaniom poddane były owoce odmiany Melrose oraz Jonagold. Zbiór owoców wykonywano w oparciu o wyniki testu skrobiowego, który był interpretowany w oparciu o ocenę wzrokową 5 oceniających (OW), analizę obrazu testu skrobiowego skanerem (SK) oraz aparatem cyfrowym (AC). Owoce przechowywane w komorze ULO (1,5% O2, 2,4% CO2) przez 180 dni. Podczas przechowywania, w odstępach 30-dniowych oceniano własności mechaniczne miąższu (elastyczność oraz spoistość). W przedstawionym eksperymencie dobre wyniki przechowywania owoców uzyskano posługując się metodą SK (w przypadku obu odmian owoców) oraz metodą OW (tylko dla Jonagolda). Zbiór owoców według wskazań metody AC dawał nieco gorsze wyniki podczas przechowywania obu odmian owoców.

Słowa kluczowe: jabłka, indeks skrobiowy, analiza obrazu, przechowywanie owoców