CHANGES IN FRUIT QUALITY DURING RIPENING AND STORAGE IN THE APPLE CULTIVAR 'AUKSIS'

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ABSTRACT

Changes in fruit quality parameters were studied in the apple cultivar 'Auskis', one of the most popular and commercially important apple cultivars in Lithuania, with the aim of determining the optimal harvest time.

Every week during the ripening process, a batch of apples was gathered and put into long term storage. The apples were evaluated for firmness, soluble solids content, starch index, titratable acidity, sugar content and sugar/acid ratio. At the end of the 150 day storage period, the apples were evaluated for firmness, soluble solids content, titratable acidity, sugar content, loss of mass and rot.

Fruit quality parameters both at harvest and after storage were found to correlate with the stage of ripeness at which the apples were picked. The correlations were particularly strong between firmness and acidity, between firmness and sugar/acid ratio, and between firmness and starch index.

Fruit quality parameters and losses during storage were also found to correlate with the stage of ripeness at which the apples were picked. Apples picked at the optimal harvest time lost the least mass during storage. Apples that were picked too late were the least firm after storage.

Fruit quality parameters after storage were statistically compared to fruit quality parameters at harvest. There was a particularly strong positive correlation between post-storage acidity and firmness at harvest, and a particularly strong negative correlation between post-storage sugar/acid ratio and firmness at harvest. Post-storage soluble solids content and post-storage sugar/acid ratio were strongly correlated with soluble solids content at harvest.

Based on these changes in fruit quality parameters during ripening and storage, the optimal harvest time for 'Auskis' is between 114 and 121 days after full bloom.

Key words: *Malus* x *domestica*, fruit firmness, soluble solids content, starch index, titratable acidity, sugar content, storage

INTRODUCTION

'Auksis' is one of the most popular and commercially important apple cultivars in Lithuania, where it makes up about 15% of the national crop. It is a particularly tasty and attractive variety, and is also quite winter hardy. 'Auksis' is picked at the beginning of September, and can be stored until February. Unfortunately, 'Auskis' is prone to fruit drop and to softening during storage. Therefore, it is very important to systematically monitor changes in fruit quality to determine optimal harvest time and storage conditions.

To ensure maximum storability, apples should be picked when mature, but not fully ripe. If apples are picked when they are too ripe, physiological processes are underway which complicate storage, even under optimal conditions (Ingle et al., 2000; Braun et al., 1995). Apples picked at right stage have the organoleptic qualities which enable them to survive more than six months of storage.

Most fruit quality parameters are useful not only for gauging fruit maturity, but for evaluating the eating quality of the apple as well (Hoehn et al., 2003). Fruit firmness is a measure of texture. SSC, acidity and sugar content are associated with taste. Volatile substances contribute to fruit aroma. Many factors affect fruit quality, including genetics, soil properties, and weather conditions.

The aim of this study was to investigate changes in fruit quality parameters during ripening and storage in order to determine the optimum harvest time for apples of the cultivar 'Auksis'.

MATERIAL AND METHODS

In 1997, 2000 and 2001, changes in fruit quality parameters were studied in the apple cultivar 'Auskis' grafted on MM106 rootstock. The experiment was carried out with four replicates of ten trees per plot.

Every week during the ripening process, a batch of apples was gathered and put into long term storage. Batches were picked 100, 107, 114, 121 and 128 days after full bloom (DAFB). Ten apples from each batch were immediately evaluated for firmness, soluble solids content, starch index, titratable acidity, sugar content and sugar/acid ratio. At the end of the 150 day storage period, 100 apples from each batch were evaluated for firmness, soluble solids content, titratable acidity sugar content, loss of mass and rot.

Firmness was measured with a penetrometer (FT-327) with 11 mm diameter probe. Soluble solids content was measured with a refractometer. The starch index was determined using a 0.1N iodine and potassium iodine solution. Titratable acidity was measured by titration, and recorded as equivalents of malic acid. Sugar content was measured by Bertrand's method (Peterburskij, 1963).

Data were statistically elaborated using ANOVA.

RESULTS

From 100 to 128 DAFB, fruit firmness decreased by an average of 20% (Tab. 1). This is confirmed by the strong negative correlation between DAFB and firmness (Tab. 3). During storage, fruit firmness decreased by 41 to 51% of its original value (Tab. 2). Apples which were picked later were less firm both at harvest time and at the end of the storage period, though the difference at the end of the storage period was significant only between the first and the last batches picked. Fruit firmness after storage was not highly correlated with firmness at picking time (Tab. 4).

Table 1. Effect of harvest time on fruit quality during ripening (mean of 1997, 2000 and 2001)

Harvest time in days after full bloom (DAFB)	Firmness [kg]	Soluble solids content [%]	Starch index	Titratable acidity [%]	Sugar content [%]	Sugar/acid ratio
100	10.2	11.2	2.1	0.73	8.64	12.31
107	9.2	11.4	3.0	0.76	9.98	12.36
114	8.6	12.3	4.1	0.62	8.96	16.23
121	8.2	12.4	5.0	0.57	10.05	18.80
128	8.2	12.3	6.5	0.55	10.65	19.54
LSD_{05}	0.35	0.29	0.64	0.082	1.175	2.986

Table 2. Effect of harvest time on fruit quality after the storage (mean of 1997, 2000, 2001)

Harvest time in days after full bloom (DAFB)	Firmness [kg]	Soluble solids content [%]	Titratable acidity [%]	Sugar content [%]	Mass loss [%]	Loss due to rot [%]
100	5.0	12.1	0.37	9.5	4.6	4.8
107	5.0	12.3	0.33	9.9	3.7	5.9
114	5.1	12.8	0.30	9.6	3.5	6.0
121	4.8	12.5	0.30	10.2	3.4	6.9
128	4.7	12.6	0.29	10.05	4.5	10.8
LSD_{05}	0.28	0.19	0.058	0.49	0.48	2.52

Soluble solids content (SSC) abruptly increased between 107 and 114 DAFB, after which it levelled off (Tab. 1). There was no apparent correlation between SSC and DAFB (Tab. 3). Apples picked 114 DAFB had the highest post storage SSC, whereas apples picked 100 DAFB had the lowest post-storage SSC (Tab. 2). There was a positive correlation between SSC after storage and SSC at harvest time (Tab. 4).

Table 3. Correlations among fruit quality parameters at harvest (mean of 1997, 2000 and 2001)

	Firmness	SSC	Starch index	TA	Sugar content	Sugar/acid ratio
DAFB	-0.92**	0.49*	0.98**	-0.81**	0.78**	0.96**
Firmness		-0.79**	-0.91**	0.83**	0.40*	0.85**
SSC			0.77**	0.67**	0.30	0.74**
Starch index				-0.84**	0.55**	0.86**
TA					-0.36	-0.95**
Sugar content						0.48*

*Significant at P≤0.05 **Significant at P≤0.01

Table 4. Correlations among fruit quality parameters at harvest after 150 days of storage (mean of 1997, 2000 and 2001)

At harvest	After storage						
	firmness	SSC	TA	sugar content	sugar/ acid	mass loss	loss due to rot
DAFB	-0.64**	0.56**	-0.68**	0.50*	0.72**	0.61**	0.51**
Firmness	0.54**	-0.50*	0.75**	-0.38	-0.77**	-0.47*	0.44*
SSC	-0.42*	0.72**	-0.68**	0.51**	0.71**	0.49*	0.39
Starch index	-0.65**	0.52**	-0.67**	0.41*	0.70**	0.64**	0.55**
TA	0.44*	-0.42*	0.59**	0.28	0.63**	-0.36	-0.30
Sugar content	-0.51**	0.44*	-0.30	0.59**	0.43*	0.50*	0.37
Sugar/acid ratio	-0.46*	0.56**	-0.67**	0.41*	0.71**	0.44*	0.35

*Significant at P≤0.05 **Significant at P≤0.01

Starch index declined during the maturation period. The starch conversion rate did not differ significantly from year to year of the study. There was a very strong positive correlation between starch index and DAFB, and a negative correlation between starch index and firmness.

During the maturation period, sugar content increased by 23% and titratable acidity decreased by 30% (Tab. 1). As expected, sugar content and acidity were strongly correlated with DAFB (Tab. 3). After storage, acidity decreased by 47 to 67% of its harvest value. Post-storage acidity was negatively correlated with DAFB (Tab. 2). Apples picked 107 and 114 DAFB had the highest relative drop in acidity by the end of the storage period, losing 52 to 57% of the value at harvest. Apples picked 128 DAFB had the lowest relative drop in acidity. The correlations between DAFB and acidity and between DAFB and sugar content were not as strong after storage as they were at harvest time.

During the maturation period, the sugar/acid ration increased from 12.3 to 19.5. There was a very strong correlation between the sugar/acid ratio and DAFB. There were also significant correlations between the sugar/acid ratio and all of the other fruit quality parameters, both at harvest time and after storage.

During the 150 day storage period, the apples lost 3.4 to 4.6% of their mass due to water loss. Apples picked 100 and 128 DAFB lost the most of mass, whereas apples picked 114 and 121 DAFB lost the least. Mass loss was most strongly correlated with starch index at harvest, and less so with the other fruit quality parameters.

The incidence of rot was 4.8 to 10.8%, and was positively correlated with DAFB. Loss due to rot was 4.8% in apples picked 100 DAFB, and 10.8% in apples picked 128 DAFB.

DISCUSSION

Fruit quality varies from year to year, and depends largely on growing conditions during the vegetative season. Nonetheless, the changes in fruit quality parameters that occur during the ripening period follow the same pattern every year. The changes observed in this study were generally those expected and agreed well with previous studies which also used the date of full bloom as a reference point (Braun et al., 1995; Zude-Sasse et al., 2001; Ingle et al., 2000; Eccher Zerbini et al., 1999; Kvikliene, 2004). Fruits that were harvested later were softer and less tart, and had a higher starch index and SSC.

The rate of fruit softening was the same in all years of the study, and depended only on DAFB. Apples which were harvested the earliest were firmest both before and after storage, but lost a greater percentage of their firmness during storage. Apples harvested 100 DAFB had a firmness of 10.2 kg at harvest and 5.0 kg after storage, and lost 51% of their initial firmness. Apples harvested 128 DAFB had a firmness of 8.2 kg at harvest and 4.7 kg after storage, and lost 43% of their initial firmness. Apples harvested 114 and 121 DAFB lost only 41% of their initial firmness. This agrees well with an earlier study on fruit softening in other cultivars (Meresz et al., 1993). However, the softening rate has also been reported to vary from cultivar to cultivar, depending on the presence and expression of genes which regulate the activity of hydrolytic enzymes (Ingle et al., 2000; Konopacka and Plocharski, 2002; Johnston et al., 2001).

SSC varied from year to year and was dependent more on weather conditions than on any other factor. Apples which are harvested later have been reported to have a higher SSC both at harvest and, generally, after storage as well (Ingle et al., 2000). In our study, the apples with the highest post-storage SSC were those harvested 114 DAFB. However, in other cultivars, post-storage SSC was not significantly affected by harvest time (Kvikliene, 2004; Braun et al., 1995).

Changes in sugar content during storage were generally more subtle and it is difficult to distinguish any clear patterns. Post-storage sugar content was most strongly correlated with sugar content at harvest, SSC and DAFB, and less so with the other fruit quality parameters.

Post-storage titratable acidity and sugar/acid ratio, on the other hand, were strongly correlated with all of the fruit quality parameters at harvest time except for sugar content.

Loss of mass and decay during storage can greatly affect marketability. Mass loss during storage depends on fruit maturity at harvest time (Ferguson et al., 1999). Apples picked too early or too late lost more mass than apples picked at the optimum stage of ripeness. Apples which are picked earlier are less prone to rot, but are not as tasty and attractive than apples which are picked later. Apples picked 128 DAFB were over-ripe and too metabolically active, whereas apples picked 114 and 121 DAFB lost the least mass. Fruit picked at the optimal harvest time lose less mass during storage than fruits picked too early or too late (Elgar et. al., 1999; DeLong et al., 1999; Dris and Niskanen 1999).

Based on the changes in fruit quality parameters during ripening and storage, the optimal harvest time for 'Auskis' is between 114 and 121 days after full bloom.

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ZMIANY JAKOŚCI JABŁEK ODMIANY 'AUKSIS' PODCZAS DOJRZEWANIA I PRZECHOWYWANIA

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STRESZCZENIE

Badania jakości owoców przeprowadzono na jabłkach odmiany 'Auksis' zebranych pomiędzy 100-128 dniem po pełni kwitnienia (DAFB). Ich celem było określenie optymalnego terminu zbioru. Partie owoców przeznaczone do długiego przechowywania zbierano co tydzień. W każdym terminie zbioru jabłek oznaczano jędrność, zawartość ekstraktu (SSC), kwasowość miareczkową (TA), indeks skrobiowy (SI), zawartość cukrów i stosunek cukrów do kwasów. Po zakończeniu przechowywania, po 150 dniach, określono jędrność, zawartość ekstraktu, kwasowość miareczkową, zawartość cukrów, ubytki masy i obecność chorób przechowalniczych.

Parametry jakości owoców oznaczane zarówno podczas zbioru, jak i po przechowywaniu były skorelowane ze stadium dojrzałości w jakim znajdowały się owoce w momencie zbioru. Szczególnie silne korelacje występowały pomiędzy jędrnością i kwasowością, jędrnością i stosunkiem cukrów do kwasów oraz jędrnością i indeksem skrobiowym.

Parametry jakości owoców i ubytki podczas przechowywania również korelowały ze stadium dojrzałości w jakim jabłka były zebrane. Owoce zebrane w optymalnym terminie miały najmniejsze ubytki masy po przechowywaniu. Owoce zebrane zbyt późno były po przechowywaniu najmniej jędrne.

Porównano parametry jakości owoców oznaczone na zbiorze i po zakończeniu przechowywania. Jędrność owoców na zbiorze silnie pozytywnie korelowała z TA i negatywnie ze stosunkiem cukrów do kwasów po przechowywaniu. SSC oznaczona

podczas zbiorów korelowała dodatnio z SSC i stosunkiem cukrów do kwasów po przechowywaniu.

Na podstawie zmian parametrów jakości owoców podczas dojrzewania i w trakcie przechowywania, za optymalny termin zbioru jabłek odmiany ‘Auksis’ można uznać czas pomiędzy 114 a 121 dniem po pełni kwitnienia.

Słowa kluczowe: *Malus* x *domestica*, jędrność owoców, zawartość ekstraktu, indeks skrobiowy, kwasowość miareczkowa, zawartość cukrów, przechowywanie