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Influence of maturity stage on fruit quality during storage of 'Shampion' apples

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Influence of fruit maturity on apple cv. 'Shampion' storage ability and rot development was investigated at the Lithuanian Institute of Horticulture in 2004–2005. Fruits for storage were harvested 5 times at weekly intervals before, during and after predictable optimum harvest date. Quality changes, presence of storage disorders, mass losses were measured during harvest period and at the end of storage. During investigation period fruit quality parameters changed according to harvest date and were specific for each trial year. Later harvested fruits were softer and had higher content of soluble solids. Fruit storage ability was closely connected to fruit maturity too. Apples were of the best quality at the end of storage, when maturity index at picking date was 0.22–0.17. During storage 'Shampion' apple rot was caused by *Monilinia* sp., *Gloeosporium* spp. and *Penicillium* spp. On the average apple fruits were mostly infected by fungus of Gloeosporium genus.

Key words: *Malus × domestica*, maturity index, rots, storage, weight loss.

Introduction. Different picking date of apple fruits during the harvest season may have a significant impact on fruit quality (Vielma et al., 2008; Rizzolo et al., 2006; Kvikliene, 2001; Franelli, Casera, 1996; Streif, 1996). To ensure the highest fruit quality at the end of long storage, apples must be harvested mature but not fully ripe. If harvested too early fruits are smaller, have reduced flavour and colour, and are more susceptible to scald, bitter rot and internal breakdown. Mass reduction by water loss is greater in earlier picked apples because waxy surface is not completely formed at this moment (Zerbini et al., 1999; Juan et al., 1999). Early picked fruits are smaller and their surface in a storage unit is larger. Because water transpiration depends on fruit surface area too, small fruits loss their weight faster. Another reason of more intensive evaporation is structure of fruit cuticle, which is not fully developed when fruits are harvested too early. At the same time the cuticle is the first barrier that pathogens have to challenge (Ihabi et al., 1998). Later picked apples often are over-mature and all physiological processes, which complicate storage, even under optimal conditions, are underway (Ingle et al., 2000; Braun et al., 1995). Apples harvested too late are vulnerable to mechanical injures, sensitive to low temperature breakdown, water core and more rot (Hribar et al., 1996). At optimal harvest time picked apples have the organoleptic qualities (Casals et al., 2006), which enable them

to survive more than six months of storage.

The objective of this study was to investigate the effect of harvest time on fruit quality and storage ability of cv. 'Shampion' apples.

Object, methods and conditions. Investigations were carried out with apple cv. 'Shampion' on M.9 rootstock in 2004 and 2005. The measurements of fruit quality changes were performed 2–3 weeks before and after the predictable optimum harvest date. Apples for long storage were harvested 5 times at weekly intervals. The experiment was carried out with 4 replications and 20 trees per plot.

On each picking date 10 fruits from each replication were taken for laboratory measurements: fruit firmness (kg cm^{-2}, measured with penetrometer FT-327 with 11 mm diameter probe), soluble solids content (%, with refractometer), starch conversion (with 0.1 N iodine and potassium iodine solution, according to the scale 1–10). Maturity index was calculated as F/RS, where F – firmness, R – soluble solids concentration, S – starch conversion.

On each picking date 100 fruits from each replication were taken in order to measure storability (firmness, soluble solids concentration, weight loss, storage disorders and rots). Fruits were stored for 180 days.

The incidence (%) of fruit rot was established according to the formula: $A = B / C \cdot 100$ %; A – incidence of fruit rot; B – the number of samples, in which the rot has been detected, C – total number of investigated samples.

Variance analysis of the main quality characters was done using 'ANOVA' statistical program.

Results. During ripening period fruit firmness decreased by 13–15 % (Table 1). In both trial years significant differences were recorded starting from the 3rd harvest. During the last week of investigation fruit softening was not significant.

Table 1. Effect of harvest time on fruit quality during ripening
1 lentelė. Skynimo laiko įtaka obuolių kokybei skynimo metu

Harvest Skynimai	Firmness Kietumas (kg cm^{-2})			Soluble solids content Tirpios sausosios medžiagos (%)			Maturity index Sunokimo indeksas		
	2004	2005	average vidutiniškai	2004	2005	average vidutiniškai	2004	2005	average vidutiniškai
1	7.9	8.0	8.0	10.6	10.8	10.7	0.33	0.54	0.44
2	7.8	7.9	7.9	10.7	11.2	11.0	0.22	0.36	0.29
3	7.3	7.4	7.4	11.1	11.9	11.5	0.14	0.17	0.16
4	6.8	6.9	6.9	10.9	11.2	11.1	0.09	0.11	0.10
5	6.9	6.8	6.9	10.6	11.7	11.2	0.08	0.09	0.09
LSD_{05} / R_{05}	0.24	0.37	0.29	0.25	0.20	0.27	0.014	0.023	0.021

The dynamic of soluble solids content (SSC) was similar each year. The highest amount of SSC was observed in the third week of measurements, after which it levelled off.

Maturity index decreased linearly to harvest date. In 2005 at 1st harvest the value of maturity index was much higher. In spite of that, fruit maturation process was much faster and no significant differences were found at last harvest among year.

At the end of storage fruit firmness gradually decreased according to harvest time and in most cases differences between dates were significant (Table 2). During storage, fruit firmness decreased on the average from 47 to 54 % of its original value.

During the 180 days of storage period SSC on the average increased by 6–15 % from its original value at harvest. In 2004 the highest SSC was found at 1st harvest after which it levelled off, whereas in 2005 value of SSC linearly depended on harvest time, and the highest amount was observed in fruits of the two last harvests.

Table 2. Effect of harvest time on fruit quality at the end of storage
2 lentelė. Skynimo laiko įtaka obuolių kokybei laikymo pabaigoje

Harvest Skynimai	Firmness Kietumas (kg cm^{-2})			Soluble solids content Tirpios sausosios medžiagos (%)		
	2004	2005	average vidutiniškai	2004	2005	average vidutiniškai
1	4.3	3.5	3.9	12.2	12.3	12.3
2	3.9	3.2	3.6	12.1	12.4	12.3
3	3.7	3.3	3.5	12.0	12.4	12.2
4	4.2	3.0	3.6	11.9	12.5	12.2
5	4.0	3.2	3.6	12.0	12.5	12.3
LSD_{05} / R_{05}	0.24	0.17	0.21	0.20	0.25	0.24

Weight losses during storage depended on harvest time and were dissimilar every year (Fig. 1). In 2004 weight loss was lowest in early picked apples. From 3rd harvest its value significantly increased. In 2005 the obviously lowest weight loss was established at 3rd harvest. Apples picked at this stage lost by 16–20 % less their mass in comparison with earlier or later picked fruits.

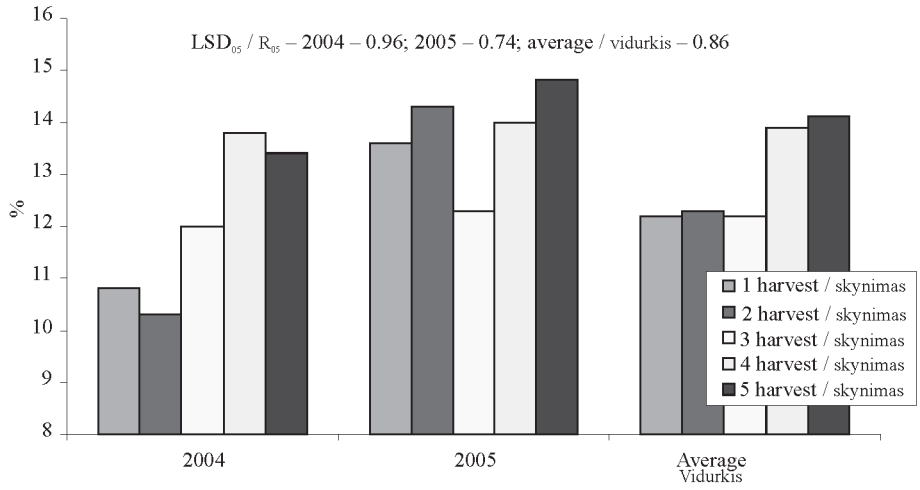

Fig. 1. Effect of harvest time on fruit weight losses during storage
1 pav. Skynimo laiko įtaka natūraliems masės nuostoliams laikymo metu

On the average up till 19.8 % of apple rotted during 180 days of storage period (Fig. 2). The extent of losses linearly depended on harvest time. At each picking the significant increase of rotten apples was recorded and the maximum of damaged fruits was estimated of apples picked at the latest. At this stage picked apples rotted by 5 times more in comparison with apples picked at the earliest harvest.

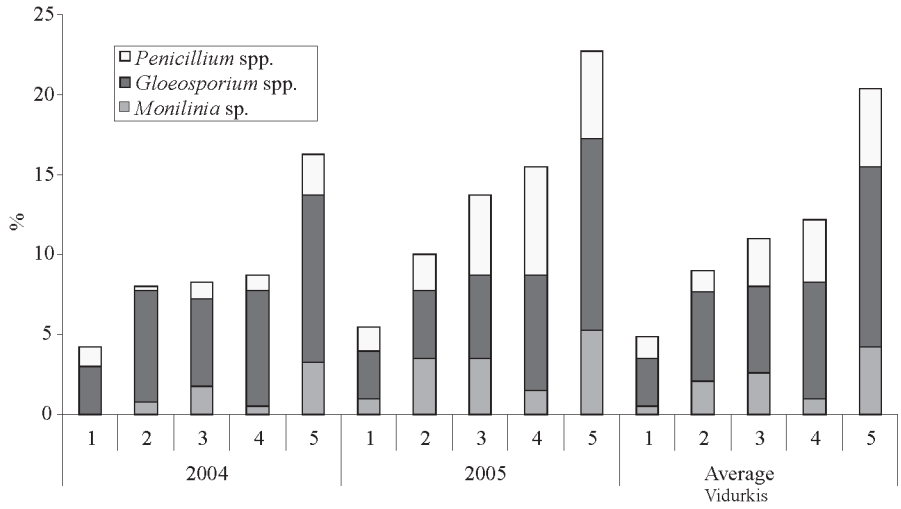

Fig. 2. Effect of harvest time on fruit rots incidence during storage
2 pav. Skynimo laiko įtaka obuolių puvimui laikymo metu

During the storage 'Shampion' apple rot was caused by *Monilinia* sp., *Gloeosporium* spp. and *Penicillium* spp. On the average 58 % of apple rots were caused by *Gloeosporium* spp., 21 % by *Penicillium* spp. and 20 % by *Monilinia* sp. More rot injuries of Gloeosporium rot as dominating rot was detected on latterly picked apples. Significantly smaller amount of rotten apples was recorded in apples picked at optimum maturity.

Discussion. During investigation period fruit quality parameters changed according to harvest date and dynamic of their changes were similar for each trial year. Later harvested fruits were softer and more mature. Fruit storage ability was closely connected to fruit maturity too.

The softening rate of apple fruit 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, Plocharski, 2002; Johnston et al., 2002). In our trials, measurements of firmness showed that cv. 'Shampion' belong to the group of medium firm fruits. Softening rate during ripening and storage was low. Fruits of cv. 'Shampion' tended to lose their firmness slower than 'Auksis', 'Lobo' and 'Lodel' (Kviklienė, 2001; Kviklienė et al., 2006), however, faster than fruits of cv. 'Ligol' (Kviklienė et al., 2008).

The concentration of soluble solids is a good indicator of sugar content and presumably of sweetness. Usually later picked apples show higher SSC value not only at harvest time, but at the end of storage too (Yong Soo et al., 1998). In our study SSC reached maximum at third harvest after which it levelled off. However, post-storage SSC was not significantly affected by harvest time. Similar tendencies were obtained in different trials (Kviklienė et al., 2006; Wargo, Watkins, 2004; Echeverria et al., 2002; Braun et al., 1995).

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). Fruit picked at the optimal harvest time lose less mass during storage than fruits picked too early or too late (Elgar et al., 1999; Dris and Niskanen, 1999). In our trials lower general fruit losses were obtained at 2nd and 3rd harvest time. Too early and too late picked fruits had bigger losses.

Incidence of rots and decay in our trial directly depended on harvest time. The higher incidence of rots in later picked apples can be explained by more intensive all the physiological processes in overmature fruits. Similar results were recorded with other apple cultivars (Dris & Niskanen, 1999; Elgar et al., 1999; Ingle et al., 2000; Kviklienė, 2004). In both trial years apple fruits were mostly infected by fungus of *Gloeosporium* genus.

Conclusions. 1. Harvest time has a significant effect on fruit internal quality at harvest time and during storage. Apples were of the best quality at the end of storage, when maturity index at picking date was 0.22–0.17.

2. Incidence of decay and rots depended linearly on fruit maturity: more late harvest – more fruit loss.

4. During storage 'Shampion' apple rot was caused by *Monilinia* sp., *Gloeosporium* spp. and *Penicillium* spp. On the average apple fruits were mostly infected by fungus of Gloeosporium genus.

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Skynimo laiko įtaka ‘Šampion’ obuolių kokybei vaisiams nokstant ir juos laikant

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Santrauka

2004 ir 2005 m. Lietuvos sodininkystės ir daržininkystės institute tirta veislės ‘Šampion’ obuolių, nuskintų skirtingo sunokimo, įtaka jų išsilaikymui. Vaisiai skinti penkis kartus per savaitę. Kiekvieno skynimo metu apskaičiuotas sunokimo indeksas. Obuolius laikant matuotas jų minkštimo kietumas, tirpių sausųjų medžiagų kiekis ir apskaičiuoti masės nuostoliai. Nustatyta, kad vaisių kokybė skynimo ir laikymo metu priklausė nuo sunokimo laipsnio. Vėliau nuskinti vaisiai buvo minkštesni ir skynimo metu, ir laikymo pabaigoje. Metų įtaka vaisių kokybės rodikliams buvo nežymi. Laikymo pabaigoje geriausia kokybe pasižymėjo vaisiai nuskinti, kai sunokimo indeksas skynimo metu buvo 0,22–0,17. Sandėliavimo metu ‘Šampion’ veislės obuoliai buvo pažeisti *Monilinia* sp., *Gloeosporium* spp. ir *Penicillium* spp. genčių grybų. Abejais tyrimų metais dominavo Gloeosporium spp. genties grybų sukeliami obuolių puviniai.

Reikšminiai žodžiai: laikymas, *Malus* × *domestica*, masės nuostoliai, puviniai, sunokimo indeksas.