Differences in fruit skin thickness between selected apple (*Malus domestica* Borkh.) cultivars assessed by histological and sensory methods

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ABSTRACT: In total 20 grown cultivars and advanced selections were included in a two-year study of apple skin thickness. The mean skin thickness of single cultivars measured on classical histological sections through the skin varied from 33.3 μm to 73.1 μm. The late ripening cultivars (Resista, Melrose, Angold and Zuzana) had a thicker skin than the earlier ripening ones. Direct measurements of the apple skin showed that its thickness was not uniform but variable to a great extent between single slices even within a very short distance. The magnitude of variability seemed to be also somewhat dependent on the cultivar. The skin thickness was significantly influenced by the year in some cultivars. The greatest difference in this respect was found in Gala Must where the skin was much thicker in 2003 than 2004. A close relationship was found between the varietal means of skin thickness obtained by direct measurement and corresponding mean scores of panellists. The values of Idared and Topaz were notably remote from the regression line. This disagreement was probably related to different skin structures of both cultivars.

Keywords: apple; skin; thickness; histology; sensory evaluation; cultivars; relationship

The fruit skin in apples consists of the cuticle, epidermis and several layers of hypodermis (Tukey, Young 1942; Cipruš, Danilov 1973; Babos et al. 1984). Both skin and its waxy coat are of significant importance during transportation and storage. Its mechanical resistance is directly related to apple fruit damage. The sensory properties of the skin and flesh are unique for each individual apple variety (Pierzynowska-Korniak et al. 2002).

The skin thickness is not uniform on apples. It differs considerably between cultivars and between different years within the same cultivar. The skin is thicker at the stem end of fruits than at the stylar end, whereas the thickness is intermediate at the point of maximum fruit diameter (Knuth, Stösser 1987; Homutová 2005). The cuticle is also thicker on the shaded than on the sun-exposed side of apple (Babos et al. 1984). Fruits of late-ripening cultivars have the thicker cuticle and hypodermis than earlier-ripening fruits. The fruits grown in highlands differ greatly from fruits of the same cultivars grown on plains. They have thinner cuticle, more numerous stomata and lenticels, and longer epidermal cells and thick hypodermis (Kumachova 2003).

The skin characteristics influence fruit bruising to a large extent. Early harvesting reduces the susceptibility of fruits to bruising (Garcia et al. 1995). The skin thickness influences Ca penetration into apple fruits (Glenn et al. 1985) and also the penetration of fungal pathogens into fruits (Mourichon, Bompeix 1979).

The apple skin structure and its thickness clearly affect the storage ability of fruits (Cipruš, Danilov 1973; Ruffa et al. 1992). The thickness of the epidermis and the surface wax are the main skin characteristics that are related to weight losses in cold-stored apples (Bebic 1972).

The thicker skin diminishes total losses of apples during storage and helps to retain a perfect appearance of the fruits before selling but may also be a disadvantage for consumers who eat apples without peeling. Therefore the skin of middle thickness is

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probably the best compromise between both points of view (Blažek, Paprštein 2003).

The intent of this study was to quantify differences in the skin thickness between selected apple cultivars and advanced selections that were used for a study of apple resistance against fungal storage diseases. For this purpose two methods were applied, namely the direct measurement under a microscope and the sensory evaluation by panellists. The results obtained by both approaches should be mutually compared.

MATERIAL AND METHODS

In 2003 six apple cultivars were chosen for this study that differed in fruit skin thickness. In 2004 the number was enlarged to 20 genotypes including several advanced selections with very tender skin. All fruit samples were harvested at an optimum time of ripening in experimental orchards at Holovousy from trees grafted on M 9 rootstock. The location is characterised by an average annual temperature of 8.1°C, average rainfall about 650 mm and altitude about 300 m above sea level.

Shortly after harvest samples of 10 fruits of each cultivar without obvious blemishes were used to prepare permanent preparations. Small discs of the skin were removed with a razor blade from two opposite sides of each fruit at the equator position and stabilised by the method of paraffin block (Votrubová 1987). Then radial transects 16 µm thick were cut from these blocks with a sledge microtome. After removing the paraffin coating and staining with alcian blue and nuclear red the slices were sealed into closing media. From each apple series of 10 slices were used for measurements at 100× enlargement with a Nikon microscope attached to a digital camera DS – 5 M – L1. In such a way 100 measurements per cultivar were done. As a skin the exocarp was measured composed of the cuticle, one layer of epidermis and 2 or 3 layers of adjacent cells of hypodermis. Statistical evaluation in SAS programme was applied for the construction of intervals of significant differences in the skin thickness for each cultivar.

Samples of a few fruits from each genotype were also used to determine the skin thickness by sensory evaluation. This evaluation was done by 10 volunteer taste panellists from the staff of the Research and Breeding Institute of Pomology who had been involved in this method of apple quality evaluation for a long time. Each person scored the skin thickness of each genotype anonymously upon a piece of apple section in two panel sessions using a 1–9 rating scale. The sequence of samples in the first session was random but in the second session the sequence went in the opposite direction. The mean score of each genotype was calculated from 20 replications.

RESULTS

The values of skin thickness in cultivars that were assessed both in 2003 and 2004 were in total nearly the same close to 60 µm (Table 1). The ranges of maximum and minimum values of direct measurements were also very similar in both years. In general the relative thickness was the highest in Melrose cultivar, while the skin of Gala Must was the thinnest. The range of cultivar means in 2003 was greater for sensory evaluation but in 2004 direct measurements were a bit better. The mean values of single cultivar measurements in 2003 and 2004 were in good agreement in the case of Golden Delicious, Topaz and Zuzana but significantly different in Angold and Melrose and very different in Gala Must. The skin of Angold and Melrose was about 9 µm thicker in 2004 than in 2003 whereas that of Gala Must was about 13.3 µm thicker in 2003. These differences, however,

Table 1. Skin thickness of selected cultivars measured in 2003 and 2004

Cultivar	2003				2004			
	Thickness (µm)			Sensory evaluation	Thickness (µm)			Sensory evaluation
	total mean	maximum	minimum		total mean	maximum	minimum	
Angold	60.1	88.4	34.3	6.0	69.6	99.2	50.4	6.2
Gala Must	58.0	86.1	31.3	4.3	44.7	59.2	31.5	4.5
Golden Delicious	60.9	84.4	44.1	5.4	59.0	75.4	42.0	4.8
Topaz	58.0	79.2	36.8	3.9	60.9	80.0	43.0	4.2
Zuzana	63.7	97.3	47.3	6.7	64.4	84.0	44.9	6.7
Melrose	64.7	89.6	43.7	6.4	73.1	115.4	47.5	7.2
Total	60.1	97.3	31.3	5.3	59.7	115.4	31.5	5.3

Table 2. Comparison of skin thickness measured histologically and determined by sensory evaluation in 20 genotypes in 2004

Cultivar	Thickness (μm)				Sensory evaluation (1–9)
	total mean*	maximum	minimum	*CV* (%)	
Angold	69.6 c	99.2	50.4	14.6	6.2
Gala Must	44.7 i	59.2	31.5	13.9	4.5
Gloster	50.0 h	70.7	26.6	17.3	4.1
Golden Delicious	59.0 e	75.4	42.0	11.8	4.8
HL 1805	57.7 e, f	89.3	31.5	20.6	5.0
HL 1816	55.0 f, g	79.7	31.5	13.8	4.2
HL 1821	45.2 i	70.8	25.0	22.2	4.1
HL 1834	59.6 e	83.0	45.9	14.6	5.3
HL 1840	33.3 k	49.9	18.2	18.1	2.7
HL 1981	40.5 j	63.0	29.1	18.1	3.6
HL 1987	45.2 i	65.7	27.9	18.7	4.5
HL 447	61.0 d, e	76.7	41.5	14.4	5.5
Idared	46.1 i	60.9	33.4	13.0	6.0
King Jonagold	53.6 g	78.7	29.3	16.6	4.8
Melrose	73.1 b	115.4	47.5	19.6	7.2
Resista	78.3 a	139.5	44.7	24.5	7.0
Rubinola	53.1 g, h	77.3	31.7	15.8	4.4
Rubinstep	53.8 g	71.8	37.3	13.4	4.6
Topaz	60.9 d, e	80.0	43.0	13.8	4.2
Zuzana	64.4 d	84.0	44.9	13.6	6.7
Total	55.2	139.5	18.2	16.4	5.0

*Mean separation at 5% level of significance

were not confirmed by the panellists' sensory evaluation of the trait.

In the set of 20 genotypes assessed in 2004 by direct measurements the mean skin thickness amounted to 55.2 μm (Table 2). The thinnest skin of the mean value 33.3 μm was found in the genotype HL 1840, which was easily distinguished by a very delicate skin (Fig. 1). Cv. Resista with the thickest skin equal to 73.1 μm on average was proved to be the opposite (Fig. 2). Besides Resista also Melrose, Angold and Zuzana were ranked among apple cultivars possessing thick skin. This finding was also fully supported by the sensory evaluation. In addition to HL 1840, also HL 1981, Gala Must, HL 1821 and HL 1987 belonged to the opposite group of apples with thin skin. The rest of the cultivars and genotypes had intermediate values of skin thickness between both groups.

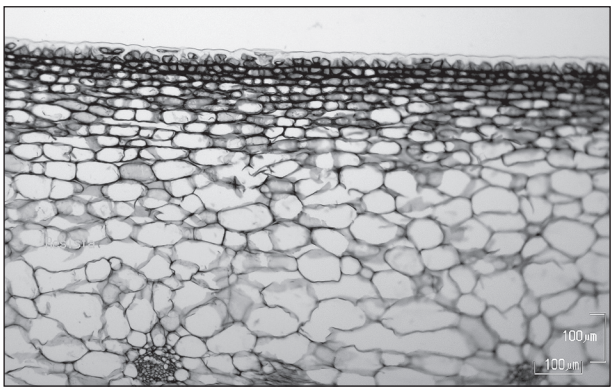

Fig. 1. Resista cv. characterised by the thickest skin

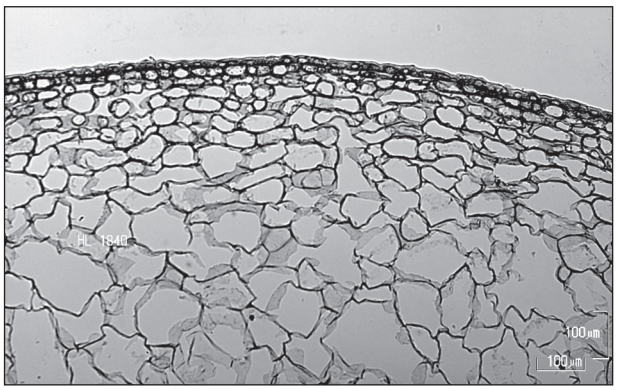

Fig. 2. HL 1840 characterised by the thinnest skin

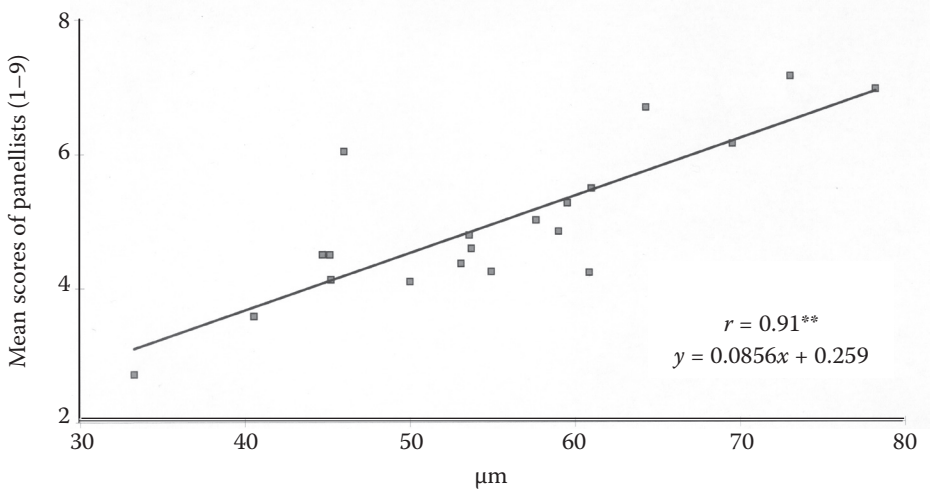

Fig. 3. Relationship between skin thickness measured histologically and that determined by panellists' sensory evaluation (2004)

The measuring of all cultivars further revealed that the skin thickness was not mostly uniform but frequently fluctuated between single slices considerably. The magnitude of such fluctuation often depended on cultivar, however, sometimes it was typical of certain sections of the measured skin within the same apple. Varietal differences in the fluctuation were expressed by coefficients of variability (Table 2). The utmost swing of the skin thickness was noted in Resista (*CV* = 24.5%) followed by HL 1821 and HL 1805. On the contrary, the skin of Idared cv. was the most uniform in this respect having the *CV* value equal to 13% only.

A close relationship was found between varietal means of skin thickness obtained by direct measurement and corresponding mean scores of panellists (Fig. 3). A sufficient tightness of the regression was expressed by the highly significant value of correlation coefficient $r = 0.91^{**}$. Only 2 cultivars were notably remote from the regression line, namely Idared and Topaz. In the former cultivar the skin directly measured was evaluated as rather thin but panellists assigned to it much higher scores that could be considered for the thick one. The opposite situation was observed in Topaz. Here the mean value of direct skin measuring was quite high whereas the mean score of panellists was very low.

DISCUSSION

The present study proved considerable varietal differences in the skin thickness of apples, which in general tallies with earlier findings (Cipruš, Danilov 1973; Babos et al. 1984). The late ripening cultivars mostly had thicker skin than the earlier ripening ones. Therefore if early summer cultivars (known to have extremely tender skin) had been included in the study, the range of skin thickness would have been even larger (Kumachova 2003). The finding of thick skin in cv. Melrose from this study is supported by the report of a Polish researcher (Pierzynowska-Korniak et al. 2002).

The direct measurements of the apple skin in this study showed that its thickness was not uniform but variable to a great extent between single slices even at a very short distance. The magnitude of variability seemed to be also somewhat dependent on the cultivar. This fact has not been clearly described in literature up to now. For impartial characterisation of skin thickness in each single cultivar it is necessary to carry out a large number of measurements for the reason of variability.

The skin thickness was also significantly influenced by the year. The greatest difference in this respect was found in Gala Must, where the skin was much thicker in 2003 than 2004. In 2003 it was extremely hot summer (July, August) with a lot of sunshine at Holovousy, which caused much apple sunburn especially on Gala Must, which is characterised by an earlier time of ripening and red fruit. Therefore the reaction of Gala Must to these conditions might be different from the other cultivars. The factors influencing the skin thickness in single years may however be quite numerous such as programme of pesticide applications as mentioned by Babos et al. (1984).

The good agreement between direct measurements and panellists' evaluation regarding the skin thickness is also an important result of this study. A discrepancy between both methods showed

itself only in 2 cultivars – Idared and Topaz. This disagreement could be connected with a difference in the skin structure of these cultivars. The skin of Idared seems to be more tenacious, whereas in Topaz the skin is more tender and easier to be chewed. This difference might distort the scoring of panellists. The sensory evaluation of skin thickness in any case requires some experience of panellists. If the characteristic is assessed by inexperienced tasters, the results are less reliable (Blažek, Paprštein 2003).

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Rozdíly v tloušťce slupky plodu u vybraných odrůd (*Malus domestica* Borkh.) měřené histologicky a bonitované organolepticky

ABSTRAKT: Celkem 20 pěstovaných kultivarů a novošlechtění bylo zahrnuto do dvouletého studia tloušťky slupky plodů jabloní. Průměrná tloušťka slupky jednotlivých odrůd měřená na klasických histologických řezech kolísala od 33,3 μm do 73,1 μm. Pozdní zimní odrůdy (Resista, Melrose, Angold a Zuzana) měly většinou tuto slupku tlustší než odrůdy raně zimní. Přímá měření na těchto řezech ukázala, že tloušťka slupky není uniformní, ale poměrně značně kolísá mezi jednotlivými řezy, a to často i ve velmi malé vzdálenosti. Zdá se, že také velikost tohoto kolísání závisí na odrůdě. U některých odrůd byly zjištěny významné rozdíly v tloušťce slupky vyvolané ročníkem. Největší rozdíl byl v tomto směru zjištěn u odrůdy Gala Must, která měla mnohem tlustší slupku v r. 2003 než v r. 2004. Dále byl zjištěn těsný regresní vztah mezi průměrnými hodnotami tloušťky slupky měřenými na řezech a průměrnými bonitačními známkami posuzovatelů při organoleptickém hodnocení tohoto znaku. Od sestrojené regresní přímky

se výrazně odlišovaly pouze dvě odrůdy – Idared a Topaz. Tento nesoulad je vysvětlován pravděpodobnými rozdíly ve struktuře slupky mezi těmito dvěma kultivary, které ovlivňovaly rozhodování posuzovatelů.

Klíčová slova: jablko; slupka; tloušťka; histologie; organoleptické hodnocení; odrůdy; závislost

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