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Sensory typology of apples used to evaluate scab-resistant cultivars as compared to known commercial apples

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Abstract

Jankowski P., Tomala K., Szpadzik E., Baryłko-Pikielna N,. Wasiak-Zys G. (2016): **Sensory typology of apples used to evaluate scab-resistant cultivars as compared to known commercial apples**. Hort. Sci. (Prague), 43: 51–58.

The aim of this work was to verify a comparative procedure for evaluating apple cultivars based on typology and comparing the sensory features of the examined cultivars during cold storage and simulated shelf-life. The procedure was applied experimentally to compare scab-resistant apples to known commercial cultivars. The procedure consisted of four sensory profiling analyses of internal apple characteristics: after two and four months of cold storage and after an additional ten days of shelf-life following each cold storage period. Eleven sensory attributes were evaluated at each timing, resulting in four general types of apple cultivars indicated and the cultivar storability over long cold storage time and shelf-life rated. The study was performed on 8 scab-resistant and 14 commercial apple cultivars evaluated over two consecutive years. The examined cultivars were then segmented into six groups of different sensory characteristics, which allowed for indicating those scab-resistant cultivars which might replace the conventional ones of equivalent sensory features.

Keywords: cold storage; shelf-life; profiling analysis; typology; consumer acceptability

In order to have recognizable presence and potential success in the marketplace, any new apple cultivar must have similar or superior quality when compared with well-known cultivars. Different apple cultivars are produced to match preferences of different segments of consumers, characterized with specific sensory preferences. Consumer segments vary in different countries (Harker et al. 2003; Sansavini et al. 2004; Bonany et al. 2013), thus, it may not be possible to assess consumer ac-

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ceptability of a given apple cultivar, even one grown worldwide, in a fully objective way. Moreover, apples, in comparison with berries or stone fruits, are characterized by a potentially long storage period at low temperature which allows for their prolonged sale. The good "storability" of particular new cultivars, understood as preserving high sensory quality over the storage and shelf-life time, becomes one of the key factors of their market success.

The objective of this work was to postulate and verify a comparative procedure for sensory evaluation of the apple cultivars based on cultivar sensory typology and comparing the sensory features of the examined cultivars during cold storage and simulated shelf-life. This study focused on comparing scab-resistant apple cultivars evaluation to commercially grown ones, demonstrating the use of the procedure for comparing a large number of cultivars with typical "market leaders".

Verification of the proposed procedure was based on the experimental material and sensory data, collected within the European project HiDRAS (High-quality Disease Resistant Apples for a Sustainable Agriculture) at the Warsaw University of Life Sciences.

MATERIAL AND METHODS

The experimental procedure. The procedure consisted of a sequence of four sensory evaluations and utilized the Quantitative Descriptive Analysis (QDA) method as an analytical tool (Stone, Sidel 1985). First evaluation (time T1) was performed after a typical short-term cold storage before the retail sale (e.g. two months at 1°C). The second evaluation (time T2, after an additional 10 days at room temperature) considered the effect of the simulated shelf-life condition on apple quality. The following third term (time T3, after four months at 1°C) tested the cultivar usefulness for prolonged long-term cold storage. The final, fourth term (time T4, after an additional 10 days at room temperature since T3) profiled the fruit after simulated shelf-life following prolonged cold storage. A comparison of the QDA data at various times from T1 to T4 provided information on apple storability. QDA assessments in consecutive years were carried out to deliver potentially important information on the year-to-year stability of cultivar sensory characteristics.

Apples. The apples used in the experiment were obtained from the collection of Pomology Department of the Warsaw University of Life Sciences (WULS) at Warsaw-Wilanów in the years 2004 and 2005. The investigation included 22 cultivars. Fourteen commercial cultivars were the scab non-resistant market leaders Boskoop, Gala, Golden Delicious, Gloster, Idared, Elstar and Šampion, Decosta, Elise, Holiday, Ligol, Melrose, Mutsu and Rubin. The first seven commercial cultivars are characterised by the largest production in the EU (Prognosfruit 2013). Eight scab-resistant varieties were the six cvs Novomac, Rajka, Rubinola, Sawa, Selena, Topaz and the two genotypes U5656 (5656) and U641 (Wars). Fruits were picked from trees which were six years old in 2004. Trees were grown on the dwarf M9 rootstock. Tree canopies were trained in the spindle system. In the orchard block the fruitlet thinning was done by hand (only the fruitlets from the terminal flowers were left) as well as the summer tree pruning. The cultivars ranged from autumn to winter varieties and were harvested at their optimum time (starch index 6–8) in September and at the beginning of October. Fruits of each cultivar were selected from the entire crown of two neighbouring trees according to their typical size and appearance. Between 100 and 120 apples with similar degree of colouring were taken for assessment.

Methods. QDA sensory profiling was applied according to ISO 13299:2003 procedure for the detailed sensory characterization of apples. Eleven internal apple sensory attributes were first selected by panellists, and then discussed to ensure the panellists' agreement. Each selected attribute was defined and finally the whole set of attributes was checked during preliminary tasting sessions. The intensity of attributes was measured on the unstructured line scale anchored by "none" and "intensive", ex post converted into a 10-unit scale. Definitions of attributes used in the article are listed in Table 1.

Sensory panel and tasting conditions. The panel consisted of 20 trained panel members, experienced in profiling analysis, fulfilling the requirements of ISO 8586-2:1994. In order to evaluate all 22 apple samples at the same time, the panel was divided into two groups of 9 and 11 panellists, respectively, working in parallel. Each group assessed samples of 12 different cultivars, 10 of which varied and two were the same reference cultivars (Gala and Idared). In two years both groups of panellists consisted of the same individuals. The comparison of reference

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Table 1. Internal apple sensory attributes selected for descriptive analysis (QDA)

	Attribute	Definition	Anchoring points
Aroma/odour	acidic	sharp, sour odour, characteristic for unripe fruit	none-very intensive
	ripe apple	sweet aroma of fresh, fully ripe apple	none-very intensive
	other fruit	sweet aroma of other fresh ripe fruit	none-very intensive
	cut grass	characteristic "green" odour of a just cut lawn	none-very intensive
Texture	firmness	hardness of apple flesh perceived by the first bite	spongy, soft-firm
	juiciness	amount and easiness of juice release when chewing	dry, mealy-very juicy
Taste/flavour	sweetness	basic taste quality evoked by sugars	none-very intensive
	sourness	basic taste quality evoked by organic acids	none-very intensive
	astringent, tart	perception of drying on the tongue (especially perceived along the edges of tongue)	none-very intensive
	flavour of ripe apple	sweet and fruity flavour of fresh, fully ripe apple	inarticulate, watery-complete, aromatic

cvs Gala and Idared apples scoring given by both groups (in each year separately) served as the check. The agreement between the results of both panels was positively checked using the Principle Component Analysis plots. The evaluation was performed in two identically equipped sensory laboratory rooms, according to the requirements of ISO 8589:1988, provided in the data collection system Analsens NT (Caret Systemy Cyfrowe i Oprogramowanie Sp. z o.o., Gdańsk, Poland). At each step of the procedure (times T1–T4) the evaluation took two days. Each group of panellists evaluated two sets of samples, each consisting of the samples of 7 different cultivars (always including cvs Gala and Idared). First set was assessed each day in the morning session and the second set in the afternoon session.

Sample preparation and presentation and tasting procedure. Samples were presented to panellists separately in coded covered plastic containers, in individual random order. To avoid the oxidation and off-flavour development, panellists were instructed to cut a fresh surface of the fruit using plastic knife, cover the container for fifteen seconds, then evaluate odour (aroma) attributes. To avoid the effect of sample unevenness, each panellist received an apple sample consisting of two opposite segments of an apple (differently exposed to the sunlight) and was instructed to test both and give attribute assessment based on their average. Still mineral water (20°C) was used as taste neutralizer between samples.

Statistical analysis of the data. All analyses were performed using the Matlab ver. 6.5.0 (The MathWorks, Inc., Natick, USA) and XLSTAT ver. 7.5.2 (Addinsoft, Paris, France).

The Agglomerative Hierarchical Clustering (AHC) method with the Euclidean (non-standardized) distance and Ward linkage was applied to cluster all 22 apple cultivars according to their sensory profiles. Segmentation was performed for the combined results of two years of the experiment; the same apple cultivars evaluated in 2004 and 2005 were treated as different samples in order to simultaneously verify changes in their year-to-year sensory characteristics. The choice of the number of clusters was examined in the silhouette plots obtained in Matlab.

One-way analysis of variance was applied separately for each sensory attribute to check the differences of mean attribute values in the established apple clusters. After performing the ANOVA analyses homogenous groups of clusters were established using the HSD multiple comparison procedure at the $P < 0.05$ significance level.

RESULTS AND DISCUSSION

QDA sensory typology of apple cultivars

Four clusters of cultivars were distinguished at each time of sensory evaluation T1 to T4. The general characteristics of apple cultivars examined during the experiment differed at the four times of investigation. Moreover, the composition of clusters varied between the evaluation times. It can nonetheless indicate the main invariant features of the clusters based on the results of multiple comparison procedure presented in Table 2. For each attribute, the clusters were roughly divided into

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three groups: consisting of low, medium and high mean value of the attribute. The results are presented in Table 2.

Cultivar segmentation occurred according to two directions. The first one related to the apple texture attributes – of firmness and juiciness. The second direction related to the flavour attributes – of sourness/sweetness and aroma. The relation of the sweet to sour taste seems to play the main role in cultivar distinction: apples with high sweet and sour tastes with well-balanced sweet to sour proportion – cluster 1; high sweet taste with medium or low sour taste – clusters 3 and 4, respectively; very high, unbalanced sour and acidic taste – cluster 2.

In the study (2015), sensory characteristics of each of the four clusters was related to one of the apple types, described in the following way: Type 1 (2015) – aromatic, firm and juicy apples of well-balanced high sweet/sour taste; Type 2 (2015) – firm and juicy and highly sour and acidic apples; Type 3 (2015) – sweet apples with high acidic odour and no other distinctive characteristics; and Type 4 (2015) – sweet, little sour and astringent taste but little juicy and soft apples.

The above typology can be compared with the intuitive segregation of apple cultivars provided by Sansavini et al. (2004) (the numbering of types changed relatively to the original):

Type 1 (2004) – "high quality apples – juicy, firm, crisp, sweet, high acid content; new cultivars like cvs Braeburn and Pink Lady" may correspond to the Type 1 (2015) of apples – aromatic, firm and juicy apples of well-balanced high sweet/sour taste. Their best representatives among the cultivars examined in this study are cvs Ligol, Mutsu, Elise, Topaz and Melrose. None of these cultivars was considered in the study by Sansavini et al. (2004).

Type 2 (2004) – "European refreshing apples – juicy, tart (like cvs Elsta, Boskoop, Gloster)" – may correspond to the Type 2 (2015) – firm and juicy and highly sour and acidic apples, represented by cvs Boskoop, Gloster and Idared.

Type 3 (2004) – this type was not indicated in the 2015 study.

Type 4 (2004) – "American/European dessert apples – fine-textured and juicy flesh, sweet-and-tart-aromatic content, well balanced taste (like cvs Golden Delicious, Gala, Red Delicious, and Jonagold)". Based on its composition, this type may correspond to Type 4 (2015), represented at T1 (before storage affected the original characteristics of apples) by cvs Golden Delicious, Gala, Decosta and Šampion. Still, the sensory description obtained in our work – sweet, a bit sour and astringent taste but soft and a bit juicy apples – hardly corresponds to the description by Sansavini et al. (2004). The only common sensory attribute in both descriptions is sweet.

Type 5 (2004) – "Asian dessert apples – sweet, low tart, highly firm, juicy, flavourful (like cv. Fuji)". The only Asian cultivar considered in the 2015 study was Mutsu, which belonged to the Type 1 (2015).

The resulting apple typology can be related to the consumer preferences indicated in various studies. This task is difficult because, as indicated by many articles (Popper 1998; Bonany et al. 2014), consumers may be segmented into two major groups: the first preferring more acidic, hard and juicy products and the second choosing sweet, aromatic and fruity products with little concern about their firmness and juiciness. Further segmentation of consumers is much more subtle and occurs within these groups and may be very difficult to elucidate.

The segment of consumers preferring acidic, hard and juicy products chooses apples of Type 2. Groups of such consumers were indicated by Daillant-Spinnler et al. (1996) (British consumers preferring acidic and juicy apples), Tomala et al. (2009) (Polish consumers preferring firm, juicy and rather acidic apples like cv. Topaz), Kühn and Thybo (2003) (Danish children preferring highly sour, high malic acid apples like cv. Gloster), Seppä et al. (2013) (Finish consumers describing their ideal apple as sour and firm) and most recently Bonany et al. (2014) (consumers in six European countries preferring acidic, firm, juicy and crisp with mid-range values for sweetness apples).

According to the literature, groups of consumers choosing high quality apples of Type 1 can also be indicated. Groups of such consumers were shown by Daillant-Spinnler et al. (1996) (sweet and crisp apple), Tomala et al. (2009) (sweet apple with pronounced ripe apple flavour and moderate firmness, like cv. Ligol), Kühn and Thybo (2003) (highly crisp, hard and moist apple with tough skin like cvs Granny Smith and Mutsu), and Bonany et al. (2014) (highly sweet apple with low acidity, mid-range to high values for crispness and juiciness).

Two groups presented in the literature can be related to apples of Type 4 – Kühn and Thybo (2003) (highly sweet, low sour and low malic acid

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Table 2. HSD multiple comparison of apple cultivar clusters (C1–C4) at successive terms of sensory profiling (times T1 to T4) following the one-way ANOVA applied for each sensory attribute separately

Aroma/odours								**Texture**	
acidic		ripe apple		other fruit		cut grass		firmness	
C3-T2	1.94^{a}	C3-T4	2.88^{a}	C2-T2	0.33^{a}	C3-T2	0.42^{a}	C4-T2	1.63^{a}
C1-T4	2.23^{ab}	C2-T1	2.84^{ab}	C4-T2	0.27^{ab}	C4-T2	0.42^{ab}	C4-T3	2.22^{ab}
C1-T2	2.30^{ab}	C2-T3	2.50^{abc}	C4-T3	0.41^{ab}	C1-T2	0.52^{ab}	C4-T4	2.98^{abc}
C4-T2	2.26^{abc}	C2-T4	2.58^{abc}	C3-T4	0.49^{ab}	C4-T4	0.57^{abc}	C3-T2	3.45^{bcd}
C4-T1	2.41^{abc}	C2-T2	2.96^{abc}	C3-T1	0.57^{ab}	C1-T4	0.64^{a-d}	C3-T1	3.51^{cd}
C4-T3	2.43^{abc}	C4-T3	2.86^{abcd}	C2-T3	0.32^{abc}	C4-T3	0.69^{a-d}	C3-T4	3.83^{cde}
C4-T4	2.44^{abc}	C1-T3	3.34^{a-d}	C2-T1	0.49^{abc}	C3-T1	0.75^{a-d}	C3-T3	4.06^{c-f}
C1-T3	2.45^{abc}	C3-T3	3.35^{a-d}	C4-T4	0.52^{abc}	C2-T2	0.76^{a-d}	C4-T1	4.12^{c-g}
C1-T1	2.50^{abc}	C4-T2	3.61^{a-d}	C2-T4	0.61^{abc}	C3-T3	0.80^{a-d}	C2-T3	4.80^{c-i}
C2-T2	2.76^{abc}	C4-T4	3.61^{a-d}	C3-T3	0.61^{abc}	C3-T4	0.80^{a-d}	C2-T2	4.47^{d-h}
C3-T3	2.76^{bc}	C1-T2	3.78^{bcd}	C1-T3	0.61^{abc}	C2-T4	1.06^{a-e}	C1-T4	5.37^{f-i}
C3-T1	2.83^{bc}	C3-T2	3.89^{bcd}	C3-T2	0.75^{abc}	C2-T3	1.06^{a-e}	C1-T3	5.37^{ghi}
C3-T4	2.91^{bc}	C3-T1	3.86^{cd}	C1-T2	0.81^{abc}	C4-T1	0.94^{b-e}	C1-T2	5.56^{hi}
C2-T1	3.20^{bc}	C4-T1	4.03^{d}	C1-T4	0.88^{abc}	C1-T3	0.96^{cd}	C2-T4	5.68^{e-j}
C2-T3	3.34^{bc}	C1-T4	4.09^{d}	C4-T1	0.94^{bc}	C1-T1	1.11^{de}	C1-T1	6.36^{ij}
C2-T4	3.61^{c}	C1-T1	4.14^{d}	C1-T1	1.11^{c}	C2-T1	1.48^{e}	C2-T1	7.47^{j}

Texture		**Taste\Flavour**							
juiciness		sweetness		sourness		astringent		ripe apple	
C4-T2	2.46^{a}	C2-T3	2.66^{a}	C4-T4	1.36^{a}	C4-T4	0.49^{a}	C4-T4	3.30^{a}
C4-T4	3.41^{ab}	C2-T1	2.87^{a}	C3-T2	1.65^{a}	C3-T2	0.53^{a}	C2-T4	3.17^{ab}
C4-T3	3.67^{bc}	C2-T4	3.16^{abc}	C4-T2	1.84^{ab}	C4-T2	0.49^{ab}	C3-T4	3.80^{ab}
C2-T2	4.14^{bcd}	C2-T2	3.29^{ab}	C4-T1	2.05^{ab}	C4-T1	0.67^{abc}	C2-T3	3.41^{abc}
C3-T2	4.25^{bcd}	C3-T4	3.99^{bcd}	C3-T3	2.30^{ab}	C4-T3	0.69^{abc}	C4-T2	3.69^{abc}
C3-T4	4.38^{cd}	C4-T3	4.04^{b-e}	C1-T4	2.18^{abc}	C3-T1	0.84^{a-d}	C2-T1	3.87^{a-d}
C2-T3	4.44^{b-f}	C3-T1	4.21^{cde}	C4-T3	2.49^{a-d}	C1-T2	0.88^{a-d}	C3-T2	4.01^{a-d}
C3-T1	4.74^{de}	C1-T3	4.32^{cde}	C3-T4	2.87^{b-e}	C3-T3	0.93^{a-d}	C3-T3	4.19^{a-d}
C3-T3	4.76^{de}	C4-T2	4.37^{cde}	C1-T2	2.91^{b-f}	C1-T4	0.91^{a-e}	C4-T3	4.23^{a-d}
C1-T4	4.97^{def}	C4-T4	4.39^{cde}	C3-T1	3.36^{c-g}	C3-T4	1.03^{b-e}	C2-T2	4.32^{a-d}
C2-T4	5.03^{c-g}	C3-T3	4.60^{de}	C1-T3	3.60^{d-g}	C1-T3	1.13^{cde}	C3-T1	4.60^{b-e}
C4-T1	5.37^{efg}	C3-T2	4.60^{def}	C1-T1	3.85^{efg}	C1-T1	1.29^{de}	C1-T4	4.82^{c-f}
C1-T2	5.38^{efg}	C1-T2	4.65^{de}	C2-T4	4.27^{d-h}	C2-T2	1.43^{ef}	C1-T2	4.87^{de}
C1-T3	5.75^{fgh}	C1-T1	4.86^{ef}	C2-T2	3.96^{fgh}	C2-T4	2.10^{fg}	C4-T1	4.95^{def}
C2-T1	6.20^{gh}	C1-T4	4.90^{ef}	C2-T3	4.88^{gh}	C2-T3	2.33^{g}	C1-T3	5.43^{ef}
C1-T1	6.61^{h}	C4-T1	5.48^{f}	C2-T1	5.16^{h}	C2-T1	2.36^{g}	C1-T1	5.85^{f}

homogenous groups of factor levels (P < 0.05) are denoted by the letters in superscript; for each attribute, double lines indicate division of clusters into three groups: consisting of low, medium and high mean value of the attribute

apple, like cv. Gala), and Seppä et al. (2013) (sweet and soft apple).

The remaining groups of consumers presented in the discussed articles could choose apple either of Type 3 or Type 4 – Kühn and Thybo (2003) (sweet apple with high apple flavour and high mealiness, like cvs Jonagold and Elstar), Seppä et al. (2013) (medium sweet and medium soft apple), and Bonany et al. (2014) (highly sweet apple with fruitiness and flowery flavour, relatively independent of

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Table 3. Main sensory features of the apple cultivar clusters based on results presented in Table 2

	Attribute	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Odours/aroma	acidic	medium after cold storage – T1, T3/low after shelf life – T2, T4	high at T1, T3, T4/ medium at T2	high at T1, T3, T4/ low at T2	medium
	ripe apple	high at T1, T2, T4/ medium at T3	low	high after 2 months of storage – T1, T2/low at T4/medium at T3	medium at T2, T3, T4/ high at T1
	other fruit	medium at T2, T3, T4/ high at T1	medium at T1, T3, T4/ low at T2	low at T1, T4/ medium at T2, T3	low at T2, T3/medium at T4/high at T1
	cut grass	high after cold storage – T1, T3/low at T2/ medium at T4	medium at T2, T3, T4/ high at T1	medium at T1, T3, T4/ low at T2	low at T2, T4/medium at T3/high at T1
Texture	firmness	High	medium at T2, T3/ high at T1, T4	medium	low at T2, T3, T4/ medium at T1
	juiciness	high at T1, T2, T3/ medium at T4	medium at T2, T3, T4/ high at T1	medium	low at T2, T3, T4/ high at T1
Taste/flavour	sweetness	high at T1, T2, T4/ medium at T3	low	medium at T1, T4/ high at T2, T3	medium at T2, T3, T4/ high at T1
	sourness	high after cold storage – T1, T3/medium after shelf life – T2, T4	high	low at T2, T3/ medium at T1, T4	low at T1, T2, T4/ medium at T3
	astringent, tart	medium at T2, T3, T4/ high at T1	high	medium at T1, T3, T4/ low at T2	low
	flavour of ripe apple	high	medium after 2 months – T1, T2/low after 4 months – T3, T4	medium at T1, T2, T3/ low at T4	low after cold storage – T2, T4/medium at T3/ high at T1

for each attribute, clusters, distinguished at the successive terms of sensory profiling (times T1 to T4), were divided into three groups: consisting of low, medium and high mean value of the attribute; T1 – after two months at 1°C; T2 – after two months at 1°C and 10 days at room temperature; T3 – after four months at 1°C; T4 – after four months at 1°C and 10 days at room temperature

the acidity and firmness scores and with mid-range values for juiciness and crispness) and (highly sweet apple with relatively low values for acidity and firmness and mid-range scores for juiciness and crispness).

The differences in the derived apple typology in comparison to the typology proposed by Sansavini et al. (2004), description of sensory preferences in various consumer segments, as well as the assignment of the same apple cultivars to different consumer segments may result from various factors such as: the choice of different varieties of apples for the analysis, the use of different dictionaries of attributes, different sensory characteristics for the same varieties grown in different countries or regions, or different fruit maturity at the time of sensory and consumer evaluation in various analyses (discussed for instance by Kühn and Thybo (2001)).

Sensory characteristics of individual apple cultivars

Sensory characteristics of individual apple cultivars in the proposed procedure are based on the apple typology discussed in the previous section. The summary of the procedure results is given in Table 4, where clusters to which individual cultivars belonged at the following times of sensory profiling and in both years of the experiment are given. Cultivars can be grouped according to the pattern of similar sensory features at evaluation times T1 to T3:

Group 1 – Elise, Ligol, Melrose, Mutsu and Topaz – cultivars belonging to the apple Type 1 in either all or most of the evaluation times T1 to T3; Group 2 – Boskoop, Idared and Gloster – cultivars related to apple Type 2; Group 3 – Elstar, Holiday and Rubinola – cultivars which depending on time and year of

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evaluation belong to either apple Type 1 or 3; Group 4 – 5656, Decosta, Gala, Golden Delicious, Novomac, Selena, Šampion – cultivars interchangeably related to apple Types 3 and 4, with possible membership in Type 1; Group 5 – Sawa and Wars – cultivars undergoing drastic deterioration of quality during a prolonged storage; Group 6 – Rajka and Rubin – cultivars whose sensory characteristics seem to be unpredictable.

The above six groups can be used to indicate scab-resistant cultivars which may replace the traditional ones on the market. Cv. Topaz, the scab-resistant cultivar most often recommended for organic orchards (Konopacka et al. 2012), is the only scab-resistant cultivar within Group 1. Its advantage is that it preserves its sensory features until the final evaluation moment T4. There are no definitely sour scab-resistant cultivars in Group 2. Group 3 contains scab-resistant cv. Rubinola, reported as one of two most promising cultivars for organic growing in Sweden (Jönsson, Tahir 2004). The four scab-resistant cvs 5656, Novomac and Selena belong to Group 4. Cvs Sawa and Wars could be assigned to Group 4 if not for their very poor storage properties during the prolonged cold storage. The remaining cv. Rajka could not be assigned to any group because of strong dependence of its sensory characteristics on the storage and climatic conditions.

Table 4. Clusters to which apple cultivars belonged at the successive terms of sensory profiling

Cultivar	T1		T2		T3		T4	
	2004	2005	2004	2005	2004	2005	2004	2005
Ligol	1	1	1	1	1	1	1	1
Mutsu	1	1	1	1	1	1	1	1
Elise	1	1	1	1	1	1	3	1
Topaz	1	2	1	1	1	1	1	2
Melrose	1	1	2	1	1	1	3	3
Boskoop	2	2	2	2	2	2	3	2
Idared	2	2	2	2	3	2	3	3
Gloster	2	2	2	2	1	1	3	3
Elstar	1	3	1	3	1	3	3	3
Holiday	1	3	1	3	3	3	1	3
Rubinola	3	3	1	1	3	3	4	3
5656	3	3	4	3	4	4	3	3
Selena	3	4	3	3	3	3	4	3
Novomac	3	x	2	x	4	4	3	x
Decosta	4	4	1	3	3	3	1	3
G. Delicious	4	4	1	1	3	3	4	3
Gala	4	4	3	3	3	3	4	4
Šampion	4	4	4	4	4	4	4	4
Sawa	3	3	4	4	4	4	x	x
Wars	4	3	3	4	4	4	x	x
Rajka	3	3	3	1	4	3	2	4
Rubin	1	3	2	2	3	1	3	3

x – cultivar was not evaluated at a given term; grouping of cultivars according to the similarity of their characteristics is indicated with double lines; scab-resistant cultivars are written in italics; T1–T4 – times

In comparison, none of the market leaders included in the study belongs to Group 1, which following Sansavini et al. (2004) may be described as high quality apples being consumers "first choice apples". The entire Group 2 consists of market leaders: cvs Boskoop, Idared and Gloster. One market leader, cv. Elstar, belongs to Group 3. Two cultivars with the highest production in EU: Gala and Golden Delicious and additionally cv. Šampion belong to Group 4. The fact that the examined market leaders do not belong to the most attractive group can be explained in the following way: the position in the marketplace does not depend solely on the sensory quality of apples but also on many other aspects such as productivity, disease resistance, ease of transport or consumer and producer habits.

Individual cultivars could either change their sensory type during the same year of storage or over the two years of the experiment. Significant changes might suggest sensory instability of a cultivar. As shown by Table 4, characteristics of most of the examined cultivars are stable as far as the clusters to which they belong are considered. The three cvs Ligol, Mutsu and Šampion remained in one cluster during all eight evaluations proving that they harbour the least variable sensory characteristics during storage. In the case of cvs Elise and Boskoop, only one change of cluster was observed at T4 in the year 2004. The most profound variability of sensory features can be observed in cvs Rajka and Rubin. Finally, cvs Sawa and Wars showed the worst storability as they could not be evaluated at the final term of the experiment (T4) in either year because of their drastic quality deterioration before that time.

CONCLUSIONS

QDA analysis successfully presented a set of sensory profiling evaluations forming a procedure

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for the verification of the sensory quality of apple fruit. The method is based on the creation of apple typology and comparison of the sensory features of newly examined cultivars with the well-known ones. The method was applied to compare sensory characteristics of chosen scab-resistant and traditional apple cultivars and indicated that most of the analysed scab-resistant cultivars could replace the conventional ones of similar sensory features.

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