



Genotypic difference in postharvest characteristics of hardy kiwifruit (*Actinidia arguta* and its hybrids), as a new commercial crop Part II. Consumer acceptability and its main drivers

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ABSTRACT

Actinidia arguta, called also hardy kiwifruit, is an exotic fruit of *Actinidia* genus which have obtained commercial interest in recent years. Its high frost hardiness, relatively short vegetation period and pro-healthy properties make it very interesting, especially in cold regions. The aim of the presented study was to identify main drivers of postharvest consumer acceptability of *A. arguta* (and its hybrids with *A. purpurea*) fruit among its sensory (flavour and texture) attributes and appearance characteristics (size and colour). To achieve that goal nine genotypes were assessed by over 200 consumers during two-year experiment. In order to perform a possibly broad research the chosen genotypes included five of the popular *A. arguta* cultivars grown around the world, two promising genotypes selected at Warsaw University of Life Sciences (WULS) as well as two hybrids (*A. arguta* × *A. purpurea*) from the same source. The study consisted of the consumer assessment of external (appearance) and internal (flavour and texture) fruit liking. The results showed general positive consumer acceptance of hardy kiwifruit with low differentiation of its genotypes. No segment of consumers disliking fruit appearance was found and segments disliking their taste and flavour constituted only about 14% in 2005 and 6% of consumers in 2006, respectively. Study indicated a significant effect of fruit size on consumers as it was highly correlated with the mean liking scores in each of consumer segments. The pink-red skin colour has also large positive impact on consumer's *Actinidia* choice observed in outstanding acceptance of small 'D11' genotype. The most preferable fruit should moreover have sweet taste and odour as these features are significant for most of consumers. Genotypes best meeting consumer preferences were pointed, including *A. arguta* × *A. purpurea*, which should obtain special breeders' focus.

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1. Introduction

In recent years, many research works have focused on looking for fruits rich in bioactive compounds and showing evident pro-healthy properties (Vijaya Kumar Reddy, Sreeramulu, & Raghunath, 2010; Gayosso-García Sancho, Yahia, & González-Aguilar, 2011; Da Silva Campelo Borges et al., 2010). *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. seems to fit into that category. The origin of *A. arguta* species as well as current status of its world production was discussed in the first part of this study focusing on sensory and physicochemical characteristics of hardy kiwifruit (Latocha et al., 2011). This exotic species is very interesting and promising because of horticultural advantages, especially the high frost hardiness and relatively short vegetation period (Latocha, 2008), as well as because of nutritional values, high content of

vitamin C, phenolics, carotenoids and various minerals (Nishiyama et al., 2004; Okamoto & Goto, 2005; Fisk, Mc Daniel, Strik, & Zhao, 2006; Latocha, 2007; Latocha & Krupa, 2008; Latocha, Krupa, Wołosiak, Worobiej, & Wilczak, 2010). Thanks to these characteristics hardy kiwifruit may become a significant extension of the domestically grown fruit diversity on fruit market. Commercially grown hardy kiwifruit should be harvested when physiologically mature and stored in refrigeration but locally grown fruit can also be picked at the eating ripeness stage when they naturally develop their nutritive and sensory features. Moreover, the time interval between harvest and fruit consumption may be very short.

The basic condition which must be met in order to exploit the above advantages is consumer acceptability of the available hardy kiwifruit. It is crucial for their success on the fruit market. In the case of products novel to the consumers, such as *A. arguta* fruit, the marketing effect related to their appearance is of special importance. The fruit has to attract consumers with their size, shape and colour. Next, they have to meet consumer flavour and texture expectations.

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Therefore, it is of high importance to identify the fruit characteristics most desirable by consumers. Knowledge of those characteristics may lead to breeding programs aimed in breeding new cultivars better meeting consumer expectations. Finally, the year-to-year stability of the fruit characteristics is of importance for the quality “memorability” by the consumers. Namely, if a new cultivar meets consumer expectations they “memorise” its quality pattern and looks for it on the market to repeat pleasant experience. When the same cultivar considerably changes in the next season and the consumer finds it worse, the negative disconfirmation occurs resulting in the loss of interest in that cultivar (Koster, 2005; Mojte & Köster, 2005).

Various authors performed analysis of instrumental and sensory characteristics of kiwifruit combined with the assessment of their consumer acceptance (Gorini, Testoni, & Lasorella, 1990; Crisosto & Crisosto, 2001; Jaeger, Rossiter, Wismer, & Harker, 2003; Burdon et al., 2004; Wismer et al., 2005; Harker et al., 2009). Though some of the analysis discussed above included *A. arguta* fruit, to our knowledge, so far no comparative consumer research on its cultivars has been performed. The most trustworthy method to meet that goal is via consumer tests. Such tests estimate consumer acceptability of the examined genotypes/cultivars, which is a result of the complex interplay of fruit quality with such factors as consumer experience, eating and cultural habits and many others.

The presented study, basing on the experiment conducted in years 2005 and 2006, had two main aims. Firstly, general consumer acceptance of hardy kiwifruit was examined. Secondly, main drivers of consumer liking of the examined fruit basing on physicochemical measurements and sensory assessment presented in the first part of the study were indicated.

2. Materials and methods

2.1. Fruit used in the experiment

The experiment was held in the years 2005 and 2006 at the experimental field of the Department of Environmental Protection, WULS at Warsaw, Poland. The investigation included 5 cultivars of *A. arguta*: ‘Ananasnaya’, ‘Geneva’, ‘Jumbo’, ‘Weiki’ and ‘74-49’; and four genotypes selected in breeding program held at WULS: two hybrid genotypes (D11 and D14) and two genotypes of *A. arguta* (L1 and M1) (Latocha & Krupa, 2007). For the cv. Ananasnaya abbreviation ‘Anna’ will be used in the presented figures. High resolution photograph of all examined genotypes can be found in the Supplementary Material to the first part of the study. The temperature and precipitation at the experimental field were routinely recorded during both years of the experiment.

Fruit were picked at their eating ripeness stage with the choice of the harvest date experience-based on the tactile assessment of fruit softness. As beginning of ripening various *A. arguta* genotypes differed, the harvest date was chosen at the moment when at least 15–20% of soft fruit were observed at plants of each cultivar. Only soft fruit were collected. The harvest lasted for a few days. The time period between the harvest and consumer evaluation was 4–5 days. Within that time fruit were stored in cold air store at +1 °C but twelve hours before the evaluation the fruit were taken out to the ambient temperature (± 22 °C).

2.2. Consumers

Consumer testing was performed by the groups of 99 and 112 adult individuals in 2005 and 2006, respectively (each year different individuals). Consumers were recruited among WULS students, academic and technical staff as well as among Warsaw citizens according to their sex and age. All consumers declared regular consumption of various fruit. Consumers represented three age groups: young (15–25 years), middle-aged (26–50 years) and older (>50 years). Each group consisted of about 30 to 40 people: about half of them were female and the other half male.

2.3. Consumer evaluation procedure

Consumer tests were performed in the university laboratory rooms, providing enough space and comfortable conditions for individual evaluation of fruit samples by each consumer. Testing sessions were performed in afternoon hours. Before the evaluation session consumers were instructed about the aims of the experiment as well as about the procedure of fruit assessment and recording results on assessment sheets. Consumers evaluated coded samples using 10 cm structured linear hybrid hedonic scale anchored “Disliked very much” and “Liked very much” (Villanueva & Da Silva, 2009). First, each consumer evaluated the degree of liking of external appearance of fruit samples presented on separate table (each sample consisted of about 20 fruit on the tray); then they proceeded with the hedonic assessment of internal fruit palatability (characterized as an overall degree of liking of aroma, consistency and taste/flavour) of each individual coded and randomly presented fruit sample consisting of two or three fruits, typical for given genotype.

2.4. Statistical analysis of the data

All analyses were performed using Matlab ver. 6.5.0 (The Math-Works, Inc. 1998–2002) and XLSTAT ver. 7.5.2 (Addinsoft 1995–2004).

The calculation of descriptive statistics for consumer liking data for each genotype expressed as histograms of individual consumer scores was performed to describe the consumer attitude towards evaluated cultivars. The normality of consumer score distributions was checked using the Shapiro–Wilk test.

To check whether consumer internal and external assessments depended significantly on cultivar, the Kruskal–Wallis test was applied. Tukey’s Honestly Significant Difference (HSD) multiple comparison procedure at the $p < 0.05$ significance level was performed in order to check which of the evaluated cultivars were distinguishable in hedonic dimension. Homogeneous groups of cultivars were established. Wilcoxon rank sum test was applied to test the season dependence of each cultivar’s consumer assessment.

Agglomerative Hierarchical Clustering (AHC) method with the Euclidean (non-standardised) distance and Ward linkage was applied to cluster consumers (according to their similar preference pattern). Clustering was performed for the raw data with no standardization as well as for the data standardised by subtracting each consumer mean liking score from his/her liking results. The standardization was performed in order to remove the possible consumer bias resulting from different use of the liking scale by different consumers. As the choice of the number of clusters is somewhat subjective, and usually depends on common sense, we used the automatic truncation available in XLSTAT (at the point at which dissimilarity significantly decreased) and examined correctness of the obtained clusters using the silhouette plots obtained in Matlab. Chi-square test was used to check the demographic characteristics of consumer clusters.

Internal Preference Mapping (Carroll & Chang, 1970; Greenhoff & MacFie, 1999) was used to show preferences within the consumer clusters. Pearson correlations between consumer scores and fruit attributes were calculated to indicate drivers of consumer acceptance.

3. Results

3.1. Summary of the postharvest physicochemical and sensory variability study

The results of the current, second part of study, must be analysed in combination with the results presented in its first part which focused on physicochemical and sensory characteristics of *Actinidia* fruit examined during the same experiment (Latocha et al., submitted to *Food Research International*). In the first part of the study fruit characteristics were evaluated for the same set of nine *Actinidia* genotypes. Fruit masses, two shape indicators — length/width and width/depth proportions,

background and blush colours, firmness (FF), soluble solid content (SSC), and titratable acidity (TA) were recorded and 17 internal (texture and flavour) sensory attributes were evaluated each year of experiment.

The study indicated that vine ripe hardy kiwifruits are characterized with high variability of the examined physicochemical characteristics observed between fruit of individual genotypes, among different genotypes as well as in two years of the experiment. In the sensory evaluation case the only significant difference observed was the seasonal one (variability of sensory features of individual genotypes was not studied).

Importantly for the consumer choice, in the case of some physicochemical characteristics genotypes can be separated into groups of similar features. They divide into those of high, medium and low firmness; into groups of small, medium and big fruits; and into fruit of strongly or slightly elongated, nearly circular or oblate longitudinal section. Finally, considering fruit colour, the background colour of all pure *A. arguta* genotypes varies smoothly from light- to dark-green, that of 'D14' hybrid is a mixture of green and red components and 'D11' is totally pink-red. The blush colour may vary from earth-yellow or brown-green, through red-brown to cherry or rose-red. The external characteristics of the examined *Actinidia* genotypes are summarized in Table 1.

According to sensory evaluation, hardy kiwifruits are characterized with soft, sour and averagely astringent skin with additional irritating note. The taste of the soft, jelly-like pulp is dominated by fruity and sweet tastes with low admixture of irritating, vinous, astringent and sour tastes. The sensory attributes were divided into three groups: astringent-irritating stimuli (skin and pulp "irritating" and "astringent" notes, "skin bitter taste", "acidic odour" and "odour of cut grass"), the consistency attributes ("skin resistance", "pulp consistency" and "pulp vinous flavour") and the sweet stimuli group ("sweet-nectar odour" and "pulp sweet taste"). The sensory attributes according to which genotypes differ most strongly are the "sweet-nectar odour", "sweet pulp taste", "sour skin taste", "fruity artificial pulp flavour" and "pulp consistency".

3.2. Consumer acceptability of hardy kiwifruit

The average consumer scores for the external and internal characteristics of the examined *Actinidia* genotypes are presented in Table 2. All genotypes, except 'Geneva' (only in the external evaluation case in the year 2005), were scored above mid-point of the scale, in its "liked" part.

Table 1
Summary of the physicochemical characteristics of the examined *Actinidia* genotypes evaluated in the years 2005 and 2006.

Genotype	Physicochemical characteristics
Ananasnaya	Most firm, highest TA, medium size, slightly elongated shape ^a , and yellow-green colour with strong red blush.
Weiki	Most firm, highest TA, medium size, slightly elongated shape ^a , and green colour with strong red blush.
Jumbo	Less firm, lowest SSC, big size, strongly elongated shape ^a , and green or light-green colour without blush.
Geneva	Less firm, small size, nearly circular shape ^a , and green colour with or without slight red-brown blush.
74-49	Less firm, high SSC, small size, nearly circular shape ^a , and green colour with or without slight red-brown blush.
D11	Most firm, highest SSC, small size, nearly circular shape ^a , uniformly rose-red colour depending on fruit maturity; and rose-red colour pulp.
D14	Medium firm, medium/small size, strongly elongated shape ^a , and light green colour with strong red blush.
L1	Medium firm, big size, nearly circular shape ^a and green colour with or without light brown-green (rarely reddish) blush.
M1	Medium firm, lowest TA, medium/small size, oblate shape ^a , and green colour with or without light brown-green blush.

^a The shape in the longitudinal section of the fruit. Fruit of all genotypes are oblate in the cross section.

The scores range from 4.8 to 7.6 and from 6.4 to 8.2 for the external and internal evaluations, respectively.

The span of the consumer scores, represented by the standard deviations of the mean values, equals about 2.0 for all genotypes as well as for both, internal and external evaluations. It is comparable with the span of the average external scores for different genotypes in both years of the experiment and with the span of the average internal scores in the year 2005. It is much larger than the range of the average internal scores in 2006.

The homogenous groups of genotypes based on consumer evaluation are presented in Table 2. Only in the year 2005 we observe clear structure of four homogenous groups in the case of both external and internal liking scores. In 2006, no statistically significant differences between consumer internal liking of various genotypes were observed and though four groups of genotypes were separated in the external evaluation case, the groups are strongly overlapping.

The distributions of consumer liking scores were tested for normality showing that only in the external evaluation case two of them are not significantly different from the Gaussian distribution while all internal distributions lack normality.

Histograms of consumer external scores, presented in Figs. 1 and 2, are symmetrical (and closer to being normal) for genotypes with lowest average consumer liking but become skewed, with dominance of high scores (7–10) over the low ones (1–4), for genotypes with higher average liking. Histograms of consumer internal scores, Figs. 3 and 4, show a small number of low scores and a great contribution of high scores (7–10) each year of the experiment and for each tested genotype.

Four (in 2005) or three (in 2006) clearly distinctive clusters of consumers could be distinguished applying the AHC method to the raw liking data in the case of the external fruit characteristics. The histograms of average consumer liking scores presented in Fig. 5 show that each year hierarchy of various genotypes was similar (had similar pattern) in each consumer segment and agreed with the hierarchy established for the combined data (presented in Figs. 1 and 2). Such segmentation does not reveal specific preferences of any group of consumers but rather reflects a difference in the level of liking. The consumer clusters can be roughly ranked as "highly liking" (clusters denoted as 1), "moderately liking" (cluster 2 in 2005), "rather liking than disliking" (clusters 3 in 2005 and 2 in 2006) and "disliking" (clusters 4 in 2005 and 3 in 2006). Importantly, the consumers who generally disliked its fruit constituted a small fraction of all consumers (about 14% in 2005 and below 6% in 2006).

In the internal fruit characteristics again either four (in 2005) or three (in 2006) clearly distinctive clusters of consumers could be distinguished basing on the raw liking data. As can be noticed in the corresponding histograms of consumer acceptance, Fig. 5, again the main driver of consumer separation is their general attitude towards the examined *Actinidia* fruit. The consumer clusters can be roughly ranked as "highly liking" (clusters denoted as 1), "moderately liking" (clusters 2 and 3) and "neither liking nor disliking" (cluster 4 separated only in 2005). Importantly, there is no "disliking" cluster and even in the "neither liking nor disliking" one the lowest average scores for any genotype exceeded 4 and five of nine evaluated genotypes obtained average scores exceeding 5. Finally, the histograms of internal liking scores presented in Fig. 5 suggest that in both years clusters denoted as 1 contain consumers who accept all genotypes nearly equally high.

3.3. Consumer acceptability of individual hardy kiwifruit genotypes

The consumer liking scores presented in Table 2 allow postulating the following hierarchy of genotypes, based on decreasing consumer acceptance of their appearance:

1. 'Jumbo', 'D11', 'D14', and 'L1',
2. 'Ananasnaya' and 'Weiki',
3. 'Geneva', '74-49', and 'M1'.

Table 2

Mean consumer scores of the external (appearance) and internal (flavour/texture) *Actinidia* fruit characteristics and their standard deviations. The homogenous groups of genotypes in each year indicated with the same letters. Significance of the Wilcoxon rank sum t-Student test for each genotype indicated.

Genotype	External characteristics					Internal characteristics				
	mean $\pm$ S.D. hom.gr.		Shapiro–Wilk test		Wilcoxon rank sum	mean $\pm$ S.D. hom.gr.		Shapiro–Wilk test		Wilcoxon rank sum
	2005	2006	2005	2006		2005	2006	2005	2006	
Ananasnaya	5.7 $\pm$ 2.0 bc	5.7 $\pm$ 1.8 bcd	*	*	ns	6.4 $\pm$ 2.0 e	6.9 $\pm$ 1.9 a	*	***	*
Weiki	5.9 $\pm$ 2.0 b	6.0 $\pm$ 2.0 bc	*	*	ns	6.4 $\pm$ 2.0 e	7.1 $\pm$ 1.5 a	*	**	*
Jumbo	7.6 $\pm$ 1.8 a	6.4 $\pm$ 2.4 ab	***	**	***	7.5 $\pm$ 1.6 ab	7.3 $\pm$ 2.1 a	**	***	ns
Geneva	4.8 $\pm$ 2.0 c	5.3 $\pm$ 2.1 cd	a	*	a	6.6 $\pm$ 2.0 cde	7.4 $\pm$ 2.1 a	**	***	**
74-49	5.6 $\pm$ 1.6 bc	5.2 $\pm$ 1.9 cd	***	a	ns	7.5 $\pm$ 1.6 bc	7.5 $\pm$ 1.9 a	**	***	ns
D11	7.0 $\pm$ 2.0 a	7.2 $\pm$ 2.1 a	***	***	ns	7.1 $\pm$ 1.9 bcde	7.2 $\pm$ 1.8 a	**	***	ns
D14	7.2 $\pm$ 1.9 a	5.7 $\pm$ 2.1 bcd	***	*	***	7.2 $\pm$ 1.8 bcd	7.0 $\pm$ 1.8 a	**	**	ns
L1	7.4 $\pm$ 1.8 a	6.0 $\pm$ 2.0 bc	**	ns	***	8.2 $\pm$ 1.5 a	7.5 $\pm$ 1.8 a	***	***	**
M1	5.1 $\pm$ 1.8 bc	5.2 $\pm$ 2.0 d	ns	*	ns	6.6 $\pm$ 1.9 de	7.3 $\pm$ 1.9 a	***	***	**

ns = not significant.

a = significant for $p < 0.1$.

* = $p < 0.05$.

** = $p < 0.01$.

*** = $p < 0.001$.

and flavour and texture:

1. 'Jumbo', 'L1', and '74-49',
2. 'D11' and 'D14',
3. 'Ananasnaya', 'Geneva', 'Weiki' and 'M1'.

Of course, while making their opinion on fruit of a given genotype, consumers simultaneously take into account their internal and external characteristics. Still, the above separate hierarchies of genotypes may be useful in establishing which characteristics of the examined genotypes need improvement via new cultivation schemes or via further breeding. Moreover, it helps to identify that 'Jumbo', 'D11', 'D14' and 'L1' represent higher than the remaining genotypes external as well as internal palatability.

The Wilcoxon rank sum test shows considerable seasonal differences for the 'Jumbo', 'D14' and 'L1' in the external evaluation case, see Table 2. In the internal assessment case such changes were less profound. The genotypes, whose internal consumer scores significantly varied, are 'Ananasnaya', 'Weiki', 'Geneva', 'L1' and 'M1', Table 2. All significant appearance changes were negative while all flavour/texture changes, apart from the 'L1' genotype, were positive. As discussed above, they led to weaker discrimination among genotypes in 2006 in comparison to 2005.

3.4. Drivers of consumer acceptability

In order to indicate the main drivers of consumer acceptance of the hardy kiwifruit the correlations of the average consumer liking scores

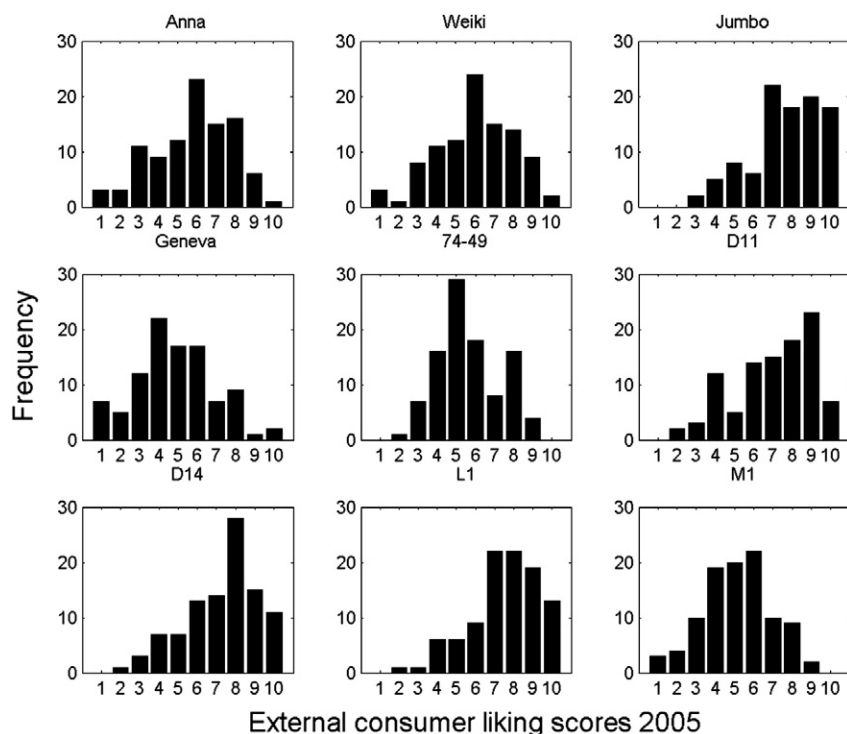


Fig. 1. External consumer evaluation (appearance). Histograms of individual consumer liking scores of each examined genotypes in the year 2005.

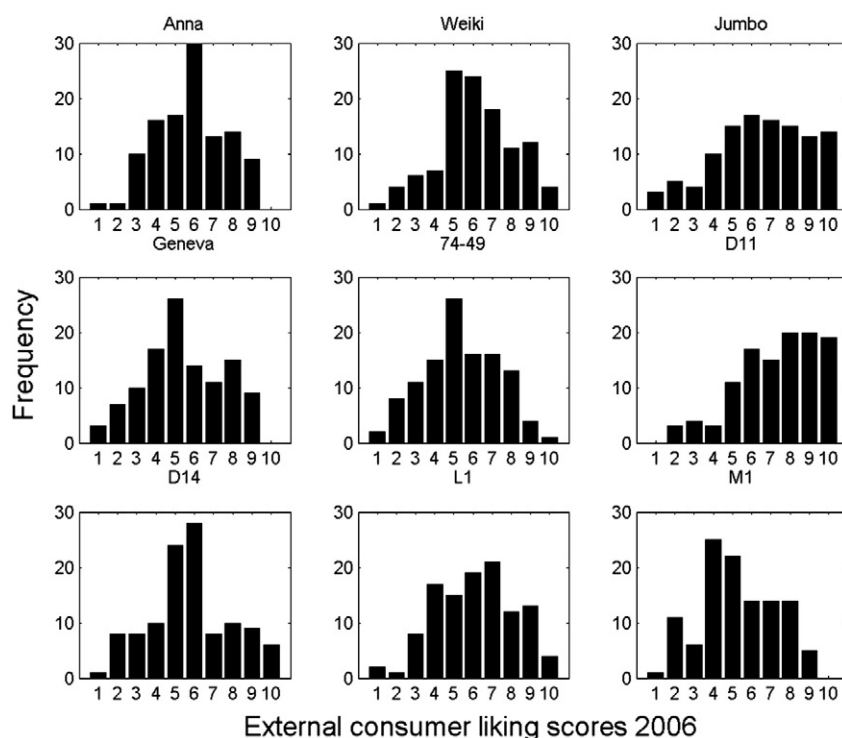


Fig. 2. External consumer evaluation (appearance). Histograms of individual consumer liking scores of each examined genotypes in the year 2006.

of the examined genotypes with the results of the physicochemical and sensory evaluations were computed.

In the case of the external characteristics the only significant correlation was observed between the consumer's liking and fruit mass in the year 2005 (correlation coefficients equal to 0.78 at $p < 0.05$). Though, no significant correlations between the consumer liking and fruit skin background or blush colour parameters were observed the impact of fruit colour on consumer assessment was

observed in the indirect way. Namely, the correlation values increased after excluding from the analysis the 'D11' genotype, the only among the examined ones with totally red-rose skin colour, easily distinguishable from other genotypes. After such exclusion the consumer liking of the remaining eight genotypes was positively correlated with mass (0.90 and 0.88 at $p < 0.01$ in 2005 and 2006, respectively), length/width proportion (0.62 and 0.70 at $p < 0.1$ in 2005 and 2006, respectively) and width/depth proportion (0.69 at $p < 0.1$ in 2005) of

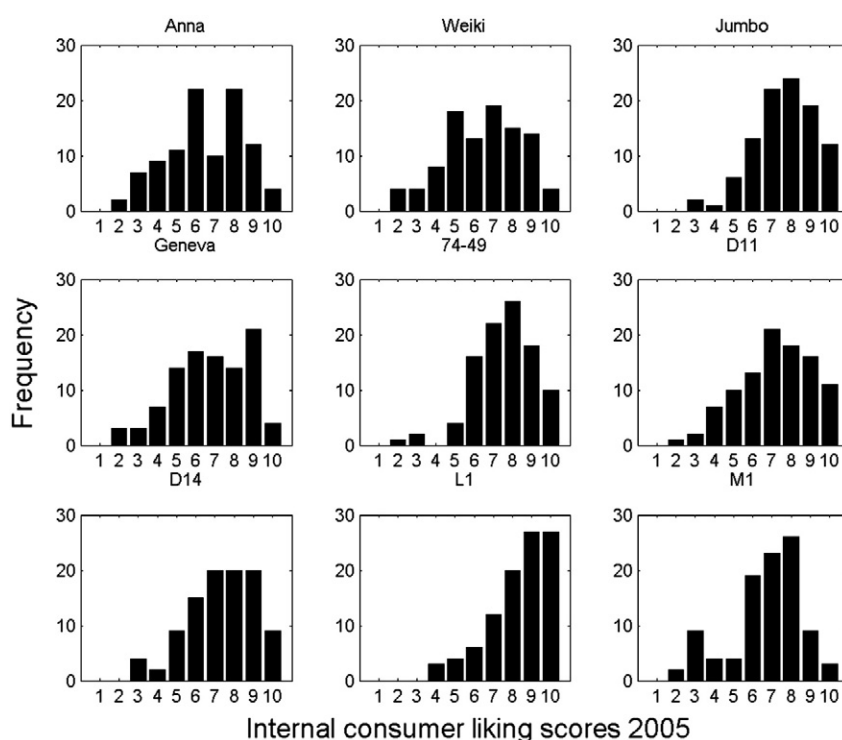


Fig. 3. Internal consumer evaluation (flavour/texture). Histograms of individual consumer liking scores of each examined genotypes in the year 2005.

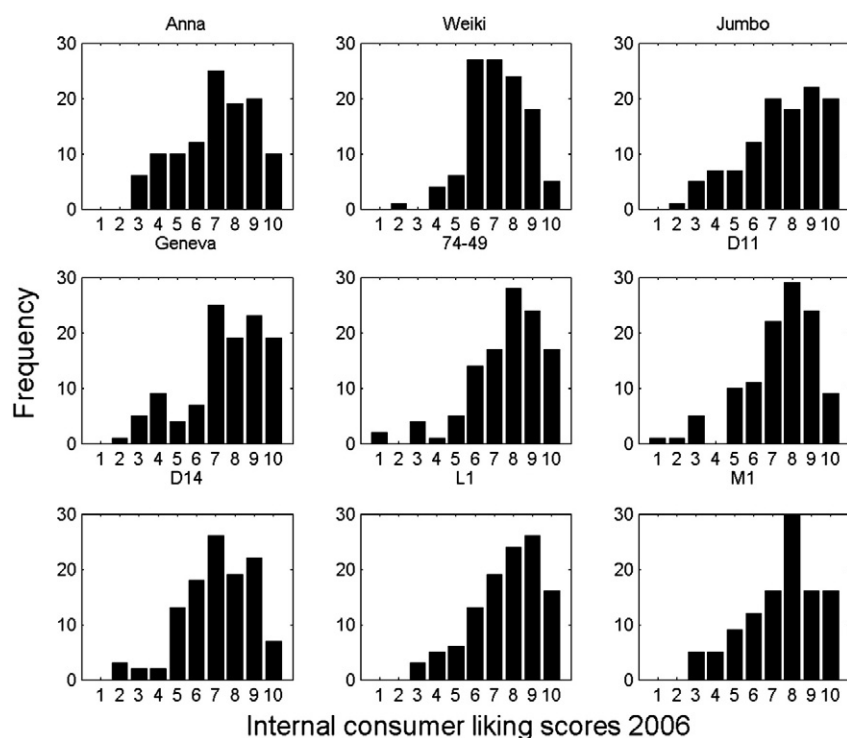


Fig. 4. Internal consumer evaluation (flavour/texture). Histograms of individual consumer liking scores of each examined genotypes in the year 2006.

the fruit. Therefore, it may be reasoned that the main drivers of visual hardy kiwifruit attractiveness are fruit size (big fruit are more attractive), colour (fruit with pink-red skin are preferred) and shape (fruit elongated in the longitudinal section and oblate in the cross-section are more attractive).

In the internal characteristics case, only data from the year 2005 were considered as only that year consumers discriminated groups of genotypes. No significant correlations with firmness, SSC, TA or SSC/TA proportion were observed. The relation of consumer scores with the sensory fruit attribute values showed that attributes from the sweet stimuli group: the “sweet-nectar odour” and “sweet pulp taste” attributes were positively correlated with the average internal liking consumer scores (correlation coefficient equal to 0.73, 0.78 at $p < 0.05$ and 0.90 at $p < 0.001$, respectively) indicating these attributes as main internal liking drivers.

3.5. Segmentation of consumers according to their preferences

The consumer clustering using the raw liking data has been performed in order to examine the overall acceptance of the hardy kiwifruit by consumers. In order to check their segmentation due to individual preferences we apply the standardised data in which the possible bias resulting from different use of the liking scale by different consumers is removed. Such analysis is important because distributions of consumer liking scores can result from superposition of numerous distributions corresponding to consumers with different preferences. Therefore, the overall average scores may not predict the real consumer's attitude to the examined genotypes and hence may not exactly reflect their attitude to fruit external and sensory features (Carbonell, Bayarri, Navarro, Carbonell, & Izquierdo, 2009). The analysis of consumer segments may verify the results obtained in the previous section and reveal additional hardy kiwifruit attributes as drivers of acceptability in these segments.

Three clearly distinctive clusters of consumers could be distinguished in both years applying the AHC method to the standardised liking data in the case of the external fruit assessment. The corresponding histograms of average consumer liking scores are

presented in Fig. 6. In order to characterize the consumer clusters the average consumer liking scores in each cluster were correlated with the mass and shape measurements of the fruit. As no significant correlations between consumer scores and fruit colour parameters were observed, the influence of fruit colour on consumer assessment was again examined by excluding the ‘D11’ genotype from the analysis.

In the year 2005 all clusters are of similar size, containing about one third of consumers each. The consumers in the clusters may be assigned clear drivers of fruit acceptability. Consumers in cluster 1 are not influenced by the fruit colour but only by its size and shape: the corresponding correlations are not influenced by ‘D11’ exclusion. Correlation coefficients equal 0.81 at $p < 0.01$ for mass, 0.68 at $p < 0.05$ for length/width proportion and 0.59 at $p < 0.1$ for width/depth proportion. Consumers in remaining clusters 2 and 3 are influenced by fruit colour. Exclusion of ‘D11’ significantly increases their correlations with the fruit mass from primary 0.65 at $p < 0.1$ to 0.90 at $p < 0.01$ for cluster 2 and from 0.59 at $p < 0.1$ to 0.89 at $p < 0.01$ for cluster 3, respectively. Additionally, exclusion of the ‘D11’ genotype from the analysis reveals that consumers in clusters 2 and 3 prefer fruit oblate in the cross-section. This preference is slightly more important for consumers in cluster 3 (correlation equal to 0.81 at $p < 0.05$ for the width/depth proportion) than for consumers in cluster 2 (0.69 at $p < 0.1$). No such clear identification of consumer acceptability in clusters distinguished in the year 2006 is possible. Only cluster 3 may be clearly related to the fruit colour and size. Its correlation coefficient with the fruit mass increases after exclusion of the ‘D11’ genotype from primary 0.59 at $p < 0.1$ to 0.91 at $p < 0.01$.

In the case of the internal fruit assessment three and four clusters of consumers could be distinguished in year 2005 and 2006, respectively, applying the AHC method to the standardised liking data. Unfortunately, only clusters separated in the year 2005 could be related to clear consumer preferences. Therefore, only these results will be presented. The histograms of average consumer liking scores in the clusters from the year 2005 and the corresponding external preference map are presented in Fig. 7. According to the preference map and the correlations of the average consumer scores in each

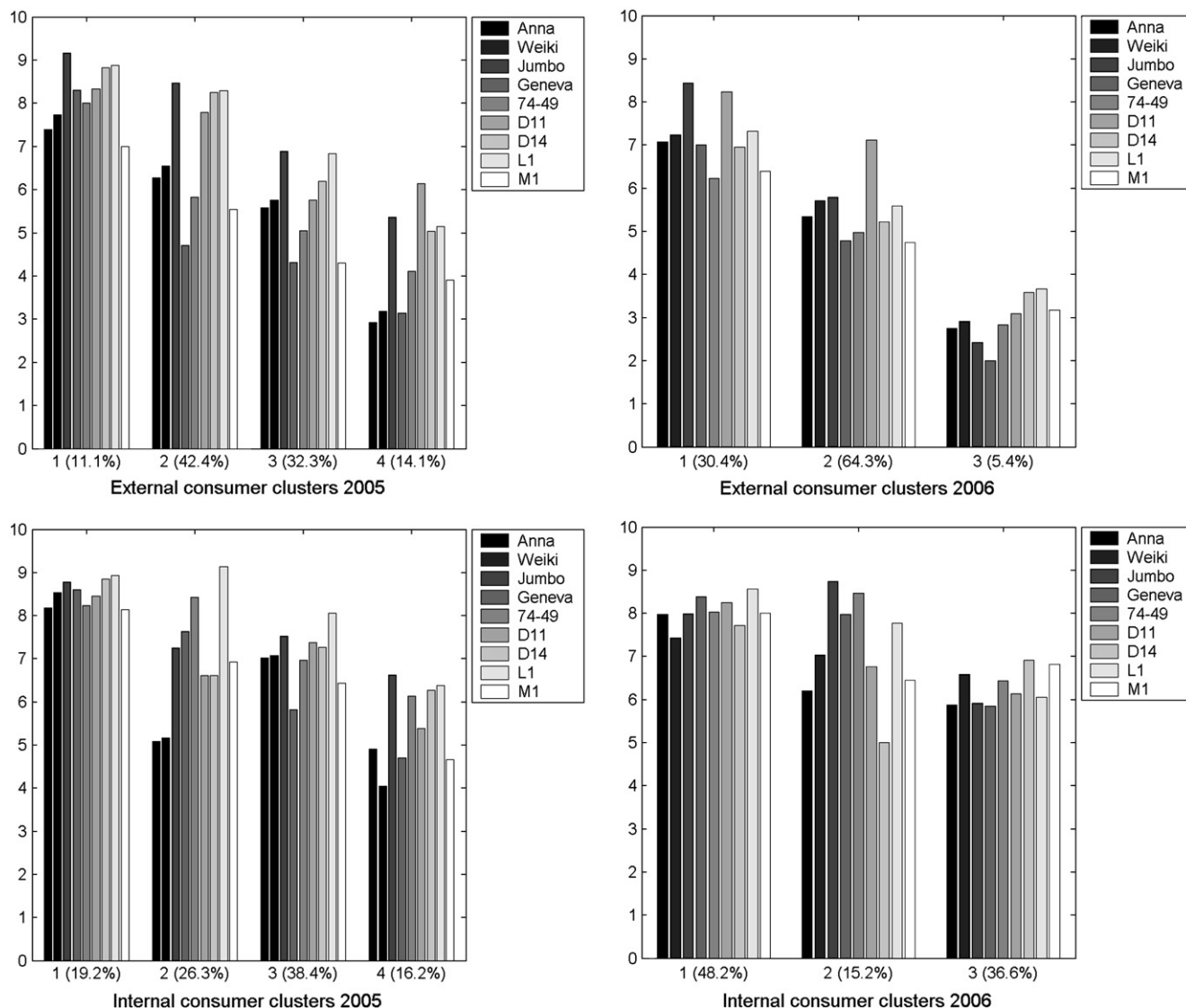


Fig. 5. Histograms of the average consumer liking scores in consumer clusters obtained for the liking data with no standardisation. Upper row: external consumer evaluation (appearance). Lower row: internal consumer evaluation (flavour/texture). Cluster sizes given in percentage.

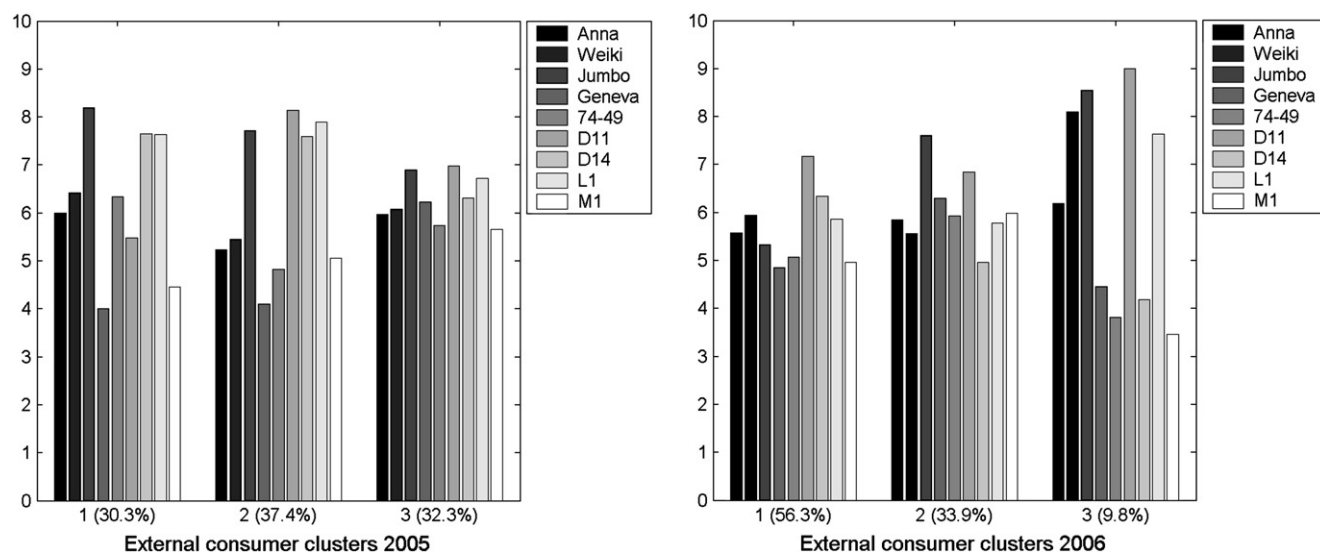


Fig. 6. Histograms of the average consumer liking scores in consumer clusters obtained for the standardised liking data. External consumer evaluation (appearance). Cluster sizes given in percentage.

cluster with the fruit sensory attributes the main drivers of fruit acceptability may be postulated. The consumers in cluster 1 (29% of consumers) like *Actinidia* fruit characterized with high “sweet pulp taste” (at 0.89 $p < 0.01$) and “sweet-nectar odour” (0.75 at $p < 0.05$), and with low “sour pulp taste” (-0.75 at $p < 0.05$). According to the preference map the above sensory features are also important for consumers in clusters 2 and 3 but are not their only preference drivers. Consumers in cluster 2 (50% of consumers) choose softer fruit with high values of “skin resistance” (correlation coefficient equal to 0.62 at $p < 0.1$), “pulp consistency” (0.65 at $p < 0.1$) and “pulp vinous flavour” (0.66 at $p < 0.1$), and with low values of the astringent-irritating stimuli such as “pulp astringent chemesthetic” (-0.70 at $p < 0.05$), “bitter skin taste” (-0.61 at $p < 0.1$) and “cut grass odour” (-0.67 at $p < 0.05$). On contrary consumers in cluster 3 (20%) seem to prefer firmer fruit with higher astringent-irritating stimuli and additionally with strong “fruity pulp flavours” but as no significant correlations were obtained for this cluster all related conclusions may be drawn only from the preference map in Fig. 7.

According to the results of the Chi-square test for cluster composition dependence on sex and age of consumers presented in Table 3, the significant dependence was observed in the year 2005. Composition of clusters based on external characteristics depends on consumer's sex. Results show that much higher percentage of women than men belongs to cluster 1 not influenced by fruit skin colour. Constitution of clusters based on internal characteristics depends on their age. The increasing age corresponds to increasing representation of consumers in cluster 2 related to softer fruit with low values of the astringent-irritating stimuli.

4. Discussion

The presented results show generally positive consumer acceptability of the examined *Actinidia* fruit, which can be concluded from the fact that the fruit of various genotypes obtained mean liking scores ranging from average (about 5 points) to good (about 7.5 points) for external appearance and good scores (from about 6.5 to 7.5) for internal flavour and texture. The observation of high acceptability of hardy kiwifruit is supported by results of consumer segmentation based on raw data. The consumers were dominated by those who liked or moderately liked all evaluated fruit. Only in the case of the

Table 3

Sex and age characteristics of the consumer clusters in the year 2005. Percentage of consumers of given sex or age group belonging to each cluster. Only results significant according to the Chi-square test are presented.

Cluster	External liking		Internal liking		
	Sex— $p < 0.05$		Age— $p < 0.01$		
	Female (%)	Male (%)	<25 (%)	26–50 (%)	>50 (%)
1	42	17	47	27	11
2	34	41	26	54	75
3	25	41	26	19	14

external liking clusters of consumers who disliked the examined fruit were found but these clusters consisted of only 5% (2005) to 14% (2006) of all the consumers.

Small differences of average liking scores between different genotypes, similar or lower than standard deviations of the individual genotype scores, may suggest weak genotype differentiation by consumers. That may be related, apart from other factors, to the fact that consumers evaluated a novel fruit and therefore had no established distinctive “memory pattern” for the hardy kiwifruit characteristics.

The lowest differentiation between internal liking consumer scores for the evaluated fruit was observed in 2006. In that year no separation of the tested genotypes according to their flavour and texture was observed. The degree of liking in 2005 was more diverse between the genotypes than in 2006 in both, internal and external liking cases.

The study indicated main drivers of consumer general preferences for the examined fruit. The results of consumer external evaluation showed that in the case of most of the tested genotypes consumer acceptance of fruit appearance is related to their size and shape. Bigger, elongated in the longitudinal section and oblate in the cross-section fruit were visually more attractive to the consumers. Interestingly, an exception from the size dependence scheme was observed for the case of the ‘D11’ genotype, the only examined genotype with red-pink skin colour, which may resemble a familiar colour associated with various ripe fruits. For that reason, each year of

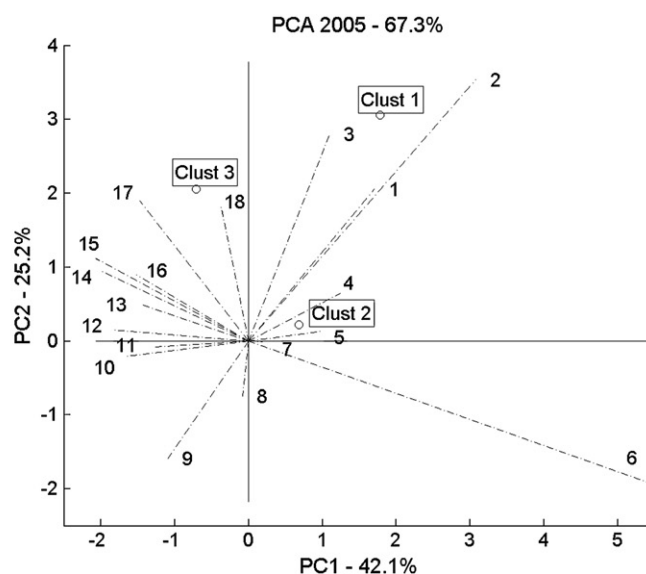
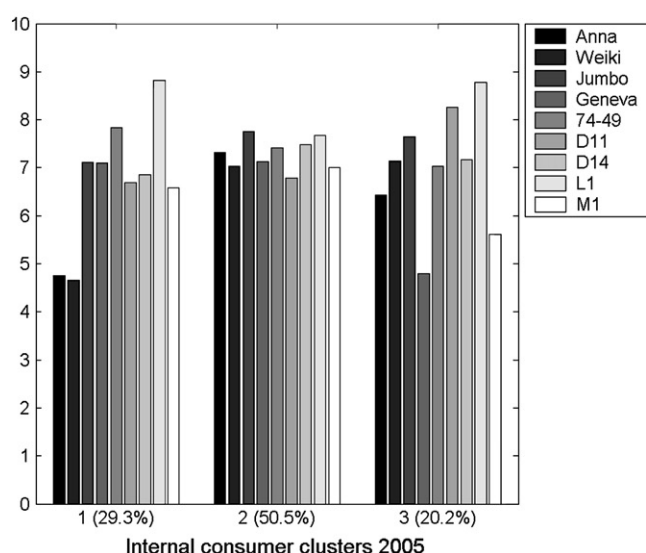


Fig. 7. Internal consumer evaluation (flavour/texture), year 2005. Left: histograms of the average consumer liking scores in consumer clusters obtained for the standardised liking data. Right: corresponding external preference map. S1 = “sweet-nectar odour”; S2 = “cut grass odour”; S3 = “acidic odour”; S4 = “pulp consistency”; S5 = “pulp fruity, natural flavour”; S6 = “pulp fruity, artificial flavour”; S7 = “pulp vinous flavour”; S8 = “pulp sweet taste”; S9 = “pulp sour taste”; S10 = “pulp bitter taste”; S11 = “pulp astringent chemesthetic”; S12 = “pulp irritating chemesthetic”; S13 = “skin resistance”; S14 = “skin sour taste”; S15 = “skin bitter taste”; S16 = “skin astringent chemesthetic”; and S17 = “skin irritating chemesthetic”.

the study the genotype 'D11' obtained higher consumer scores than indicated by its small size: in both years 'D11' obtained an outstanding high average consumer score being at the same time the second smallest of the examined fruit. Basing on the above observation it may be concluded that red-pink colour is a separate driver of consumer acceptability, independent of the fruit size and shape. Basing on results from the year 2005 it may be postulated that the importance of the above acceptability drivers differs among the consumers. Three groups of consumers may be distinguished: first liking big, elongated in the longitudinal section and oblate in the cross-section fruit with no colour preferences, second preferring big, oblate in the cross-section and red-pink fruit, and third liking same kind of fruit but with weaker shape preferences.

The correlations of the consumer scores with the sensory attribute scores suggest that the main internal drivers of consumer acceptance for fruit are all attributes belonging to the sweet stimuli group: the "sweet-nectar odour" and "sweet pulp taste". That fact may have an important consequence: it means that the sensory profiling by laboratory panel can be used instead of expensive, time and material consuming consumer tests for general prediction of consumer acceptability of new genotypes of hardy kiwifruit. Moreover, the importance of sweetness in the consumer liking of the hardy kiwifruit shows similar consumer attitude towards this species as in the kiwifruit case where also increase of sweetness (and ripe SSC) increases consumer liking (Jaeger et al., 2003; Wismer et al., 2005; Crisosto & Crisosto, 2001; Burdon et al., 2004; Harker et al., 2009). Still, in the hardy kiwifruit case the consumer assessment and fruit SSC were not directly related but SSC values were correlated with the "sweet pulp taste" of the fruit. Consumer clustering performed for the data from year 2005 revealed that for many consumers fruit softness and level of the astringent-irritating stimuli are additional acceptability drivers. The largest group of consumers (about 50%) chose fruit that are not only sweet but also soft and with low values of the astringent-irritating stimuli. On the other hand, the smallest group of consumers (about 20%) preferred sweet, firm fruit with relatively higher astringent-irritating stimuli values.

The year-to-year postharvest variability of the fruit features being drivers of consumer preferences has direct impact on the variability of consumer acceptance of the examined genotypes. The observed negative differences in the 'D14', 'L1' and 'Jumbo' average external acceptability scores can be explained by the considerable decrease of their average sizes between 2005 and 2006. Less profound seasonal variation of internal consumer scores of some genotypes is, as discussed above, related with changes in their sweet stimuli. Decrease of 'L1' "sweet-nectar odour" and "sweet pulp taste" corresponds to decrease of its internal liking, while increase of these attributes in the case of 'Ananasnaya', 'Weiki', 'Geneva' and 'M1' corresponds to increase of their consumer acceptance.

The year-to-year changes of the *Actinidia* fruit characteristics can be reduced by improvement of cultivation methods as, though genetically determined, they may be influenced by such environmental factors as weather conditions, soil moisture, productivity, trimming and cultivation methods (Snelgar & Martin, 1997; Vasilakakis, Papadopoulos, & Papageorgiou, 1997; Strik, 2005). For example crop load influences the average fruit mass, especially in the case of the genotypes with bigger fruit (Snelgar & Martin, 1997). That way the mass variation, observed especially for 'D14', 'L1', and 'Jumbo', can be explained by higher crop load in 2006. In addition, because of being a dioecious and entomophilous plant, size of hardy kiwifruit is related with effectiveness of flower pollination (González, Coque, & Herrero, 1997). As the two years in which the presented experiment was held differed most profoundly in level and distribution of precipitation over the vegetation season, it may be expected that proper irrigation and pruning scheme may improve fruit external and internal year-to-year stability.

Apart from good general consumer acceptability of the hardy kiwifruit, the study may indicate its most promising genotypes. The

genotypes most suitable for fruit production or breeding projects, apart from such factors as productivity or frost-resistance, should have both: external attractiveness, which makes fruit interesting during their selection on the market, and satisfying taste and texture, confirming the consumer's good choice during fruit consumption. The homogenous groups of genotypes established in this study allow to point genotypes fulfilling both these criteria; the most interesting genotypes among the tested ones are 'Jumbo', 'D11', 'D14' and 'L1'. After consideration of additional factors, such as stability of fruit characteristics and their pro-healthy features, we conclude that 'D11' is the genotype with best characteristics among the examined ones owing to its superior sensory features, distinctive red-pink colour, good year-to-year stability and exceptionally high content of vitamin C (Latocha, 2007; Latocha & Krupa, 2007). The remaining genotypes of high attractiveness, 'Jumbo', 'D14' and 'L1', are characterized with lower stability of either mass and size ('D14', 'L1', and 'Jumbo') or sensory features ('Jumbo').

Let us finally notice that 'D11' and 'D14' are hybrids of the same *A. arguta* and *A. purpurea* parents. 'D11' is the one whose characteristics are dominated by the *A. purpurea* features such as red-pink colour of skin and pulp. In comparison, 'D14' has more *A. arguta* external features such as green skin colour with blush and light green colour of pulp. The fact that consumers find both hybrids very attractive shows a high potential in combining *A. arguta* and *A. purpurea* species. Moreover, our study indicates that hybrids with dominance of *A. purpurea* features may be the most attractive for consumers and therefore interesting for the growers, wholesalers and retailers.

5. Conclusions

There is general positive consumer acceptance of the hardy kiwifruit. Therefore, we conclude that it has a potential to become a commercial instead of an exotic fruit.

The main acceptability drivers are fruit size, shape and colour for the external evaluation and "sweet-nectar odour" and "sweet pulp taste" for the internal evaluation. The most preferable fruit should be possibly big, elongated in the longitudinal section and oblate in the cross-section with red-pink skin colour and sweet taste and odour. For many consumers the fruit softness and level of the astringent-irritating stimuli are additional acceptability drivers with greater number of consumers choosing soft fruit with low astringent-irritating stimuli values.

'D11' was found as the most promising among the examined genotypes according to its high consumer acceptability, stability of fruit characteristics over the years of the experiment and parallel the best pro-healthy features. The following three genotypes of the highest consumer acceptability include another hybrid 'D14' indicating large potential of *A. arguta* and *A. purpurea* hybrids which should be exploited in the future breeding programs.

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