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Tasting experiences on local apple cultivars with blind and sighted consumers

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ABSTRACT

Consumers increasingly address their attention to healthy fruits produced under organic agricultural managements. However, such produce may be less appealing in appearance influencing the purchase decisions of consumers. This research had the purpose to determine on three Italian local apple cultivars (Casciana, Rosa, Ruggine) the sensory appreciation of fruit through experiments conducted with blind (BC) and sighted (SC) consumers. The appreciation of apples differed between consumers with different visual ability. This aspect mainly concerned cvs Casciana and Rosa with contrasting fruit appearance traits. The BCs were inclined to better evaluate Casciana apples characterised by less attractive fruits. Conversely, the visual factor could have influenced the SCs' judgment, as they appreciated Rosa more by the best outer traits of fruits. Intriguing responses were obtained when SCs were blindfolded.

1. INTRODUCTION

In recent years, consumers increasingly seek healthy vegetable and fruit produces, free from pesticides and rich in phytochemicals. This latter is characteristic for organically cultivated fruit

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species, in response to biotic and abiotic stresses. However, a reduction or deprivation of chemical treatments against diseases may lead to fruits with imperfections in appearance, mainly due to peel injuries (i.e. brown spots and russeting).

Appearance plays a primary role in quality perception, and it is the main sensory characteristic that consumers consider during their fruit purchase decisions (Ares et al., 2009). In this regard, 'we eat first with our eyes' is a well known popular saying (Delwiche, 2012). The involvement of people with visual disability in sensory analysis of fruits showing defects allowed the blind consumer's acceptance to 'go beyond the appearances' (Bartolini et al., 2015, 2017).

To overcome the consumers' trend to judge the fruit quality mainly on the basis of external aspects, the current research aimed to focus on the sensory evaluation involving both blind and sighted consumers to investigate the potential differences in appreciation between panellists with different visual ability. For this purpose, apple local cultivars were chosen for their high anti-oxidant power as a common denominator, but differing in pomological characteristics and susceptibility to manifest morphological defects (Bartolini et al., 2015, 2017; Bartolini and Ducci, unpublished). Moreover, sensory evaluations were combined with instrumental determinations to verify the reliability of apple quality attribute measurements.

2. MATERIALS AND METHODS

2.1. Plant material and cultivation site

The research was conducted in 2018 on three autumn apple local cultivars, Casciana, Rosa, and Ruggine (*Malus domestica* Butch). These cultivars have been classified as ancient genotypes of the past (class A), which have still cultural and commercial importance for certain areas and markets (Sansavini and Gregori, 2016). They differ for fruit pomological traits and susceptibility to russeting and brown spots (RSS). Casciana has small, flat, and poorly red coloured skin fruit (Bartolini et al., 2015); Rosa has large, conical, red skin fruit, highly susceptible (HS) to RSS (Bartolini and Ducci, unpublished); Ruggine has small, yellow-brown skin fruit, HS to RSS (Bartolini et al., 2015).

Full fruiting trees, grafted onto MM111 rootstock and trained with a vase system (4 x 5 m), were considered. Orchards, located in Garfagnana (Tuscany Italy lat. 44°09′03″ N long. 10°24′42″ E altitude 466 s.l.m), were managed according to standard organic care. No thinning and irrigation practices were applied. Six representative trees per cv were selected for random collection of apples. The harvest time was from end of September (Ruggine) to mid-end of October (Casciana and Rosa). Apples were stored for about one month under cellar conditions (10–15 °C; 70–80% R.H.) to achieve the physiological maturity, ascertained by the starch-iodine conventional test.

2.2. Analytical analysis

Samples of apples ($n = 30$ per cultivar) were fresh weighted and subjected to physical and chemical determinations as follows.

The flesh firmness was evaluated with a manual penetrometer (Mod. 53205 TR Turoni & C. snc Forlì Italy) on two peeled opposite areas at the equatorial region of apples using an 11-mm-wide plunger. The force needed to break parenchyma cells was expressed in kilogram-force ($kg\ cm^{-2}$).

The total soluble solids (TSS) were measured on fresh tissue juice obtained by hand squeezing using a refractometer (Mod. 2369-Bertuzzi Milan Italy) and results were expressed as °Brix.

The titratable acidity (TA) was determined from fruit juice by titrating a known volume of juice with 0.1 N NaOH to an endpoint of pH 8.1. TA was expressed as milliequivalents of malic acid per 100 g of fresh weight (meq malic acid/100 g FW).

2.3. Sensory analysis

Apples of the three local cvs were subjected to sensory analysis involving blind and sighted consumers (BCs and SCs, respectively). In addition, the well-known Golden Delicious cv, grown under the same pedo-climatic conditions as the others, was considered as control. In this specific instance, the SCs were asked to assess samples with blindfolds, too (SCB).

Assessments were held on the Sant'Anna School premises able to accommodate up to 25 persons. The BCs belonged to the Italian Union of Blind (Lucca section), and the panel consisted of 22 assessors (9 females 13 males). Participants were 9.1% under 25 years, 36.4% between 26 and 45 years, and 54.5% over 45 years. The SC panel consisted of 59 people (32 females, 27 males) recruited among university students and their families. Tasters were aged as follows: 22.0% under 25 years, 13.6% between 26 and 45 years, and 64.4% over 45 years.

Before starting, assessors were explained the meaning of sensory attributes and rating scores. They occupied a separate workspace, where room temperature anonymous apples were served in a randomised order. Descriptors were considered as follows: size, shape, smell, texture, juiciness, sweetness, acidity, aroma, and overall appreciation. The intensity of attributes was evaluated using a continuous non-structured 9-point hedonic scale (1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely). BCs and SCBs were assisted in marking scores on paper forms. Panellists were firstly asked to evaluate the apple appearance (size and shape), which the BCs performed by tactile sensitivity. Then, apples were cut into wedges for olfactory estimation and, after tasting, for assessing the flesh attributes. Fruit wedges were immediately served to avoid the flesh browning and, between samples, unsalted crackers and mineral water were provided.

2.4. Data analysis

The GraphPadPrism software (version 5.00 for Windows GraphPad Software La Jolla San Diego CA USA) was used to carry out the statistical analysis. Data are reported as means $\pm$ standard errors (SE). Instrumental records were subjected to analysis of variance (one-way ANOVA) and Tukey's HSD multiple mean comparison test was used to state the differences among variables. Results between sighted and blind people were compared using the Mann–Whitney U test. Moreover, a two-way ANOVA analysis was performed to test the effects of panel and cultivar on the overall appreciation of apples.

To identify the strength of association among sensory attributes and overall appreciation, Spearman's correlations were performed. A linear regression analysis of instrumental determinations versus appreciation of sensory attributes was done. All procedures were performed at least at the significant level of $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. Instrumental determinations

During the crop season of 2018 the weather conditions were favourable for growing and ripening of apples, which showed pomological traits compliant to their standards. In this year, a rare incidence of peel imperfections (i.e. russeting, brown spots) was observed, also in susceptible cvs as Rosa and Ruggine. Data on the main physicochemical parameters are provided in Table 1.

The size of apple fruits by weight fell into their usual dimensions: small-medium size (about 100–125 g) for Casciana and Ruggine and big size (about 200 g) for Rosa. The flesh firmness was from 3.6 (Rosa and Ruggine) to 4.7 (Casciana) kg cm^{-2}. Values of this parameter fell within a range at which a good relationship with consumer acceptance has been found (Harker et al., 2008). Concerning the TSS, apples of the three cvs were characterised by a similar degree between about 15 (Rosa) and 16 °Brix (Casciana and Ruggine). Values of TA were in the range from 5.4 (Casciana) to 6.6 meq/100 g FW (Ruggine), without significant differences among cvs.

The TSS/TA ratio is considered a valuable parameter that contributes in defining organoleptic and flavour traits of fresh apples; values between 1 and 1.4 would indicate the best range for an ideal agreeability (Abbott et al., 2004). In our apple samples the TSS/TA resulted higher values, from 2.4 to 2.9, indicating an imbalance towards higher sugar contents.

3.2. Sensory analysis

In general, differences in appreciation between gender and age did not emerge. It was probably due to the limited number of assessors. However, a larger number of participants did not always ensure the identification of such differences between respondents (Bonany et al., 2013; Moor et al., 2014).

The overall appreciation of apples (Fig. 1) was expressed as the average degree of liking (1–9).

Scores ranged from 4.7 to 7.0, over the middle part of the hedonic scale. BC and SC panels agreed for Ruggine apples. On the other hand, panels significantly differed in judgment for Casciana and Rosa cultivars. Indeed, the BCs gave the preference to Casciana apples, while Rosa was preferred by SCs who rated them as Ruggine and Golden D. For this latter cv, evaluated by SCB assessors, too, no significant differences were detected among groups. Nevertheless, a trend was evidenced: the SCs gave lower ratings than when they were blindfolded, and BCs evaluated the cultivar similarly to results obtained with other apple cvs (Bartolini and Ducci, unpublished).

Table 1. Physicochemical apple traits of Casciana, Rosa, and Ruggine cvs

Cvs	FW	Firmness	TSS	TA	TSS/TA
Casciana	96.9 ± 4.6 a	4.7 ± 0.1 a	15.5 ± 0.1 ns	5.4 ± 0.1 ns	2.9
Rosa	191.6 ± 7.2 c	3.6 ± 0.2 b	14.6 ± 0.3	5.9 ± 0.4	2.5
Ruggine	123.1 ± 4.9 b	3.6 ± 0.1 b	15.6 ± 0.3	6.6 ± 0.3	2.4

Cvs: cultivars; FW: fresh weight (g); Firmness (kg cm^{-2}); TSS: total soluble solids (°Brix); TA: titratable acidity (meq malic acid/100 g FW). Mean values ± standard errors. Different letters in the same column indicate significant difference at $P \leq 0.05$; ns: not significant.
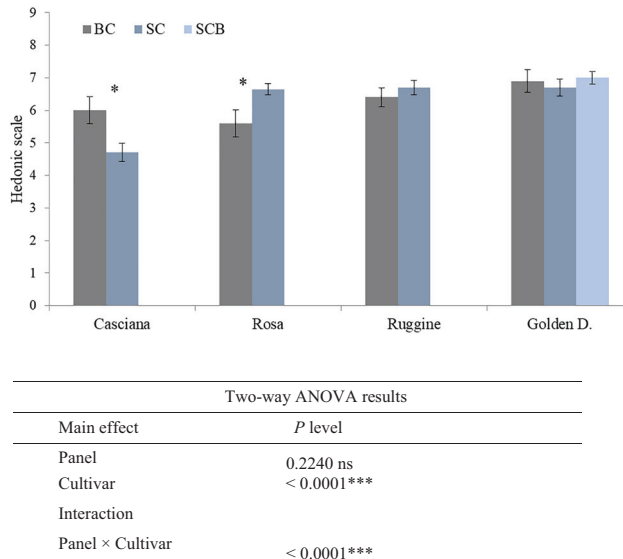
Two-way ANOVA results	
Main effect	*P* level
Panel	0.2240 ns
Cultivar	< 0.0001***
Interaction	
Panel × Cultivar	< 0.0001***

Fig. 1. Overall appreciation scores attributed to apples of Casciana, Rosa, Ruggine (local cvs) and Golden Delicious by blind (BC), sighted (SC), and sighted blindfolded (SCB) consumer panels. Means ± standard errors. Asterisks indicate significant differences between panels by Mann-Whitney *U* test (*P* ≤ 0.05). At the bottom of graph two-way ANOVA results are shown. ns: not significant

In order to focus on the influence of quality attributes (shape, size, smell, texture, juiciness, sweetness, acidic taste, aroma) on the overall appreciation rate, a multiple regression analysis was implemented using BC and SC data (Table 2).

The morphological attributes of fruits have been considered important quality factors for consumers, particularly the size, while the shape seems to be generally of minor importance (Jaeger et al., 1998). In both panels, apple size and shape positively correlated with the global appreciation of Rosa. Such a linkage was also found for Ruggine in SC group.

As regards the olfactory trait, the highest correlation coefficients were observed for Golden D., which is well known for its fragrance (Molina et al., 2006). In both panels, Rosa obtained similar results to Golden D., while connection between smell and overall appreciation was found for BC and SC in Casciana and Ruggine, respectively.

Concerning the taste descriptors, texture, juiciness, sweetness, and aroma were generally positively and significantly correlated with the appeal rate, confirming these attributes as the most important drivers of apple consumer preferences (Hoehn et al., 2003). The highest coefficients were obtained for aroma, a complex mixture of many volatile species-variety specific compounds.

For the acidic taste in the case of SC group, a negative correlation with global appreciation score was found, in agreement with the sensory results obtained for several apple cultivars (Molina et al., 2006). This occurrence would be in line with the tendency found for the majority of Mediterranean European countries, in which the best accepted apple varieties are characterised by sweetness and an average or lower than average acidity (Seppä et al., 2013).

Table 2. Correlation coefficients between apple scores recorded for overall appreciation and sensory attributes in Casciana, Rosa, and Ruggine (local cvs) and Golden Delicious cv.

Attributes	Casciana		Rosa		Ruggine		Golden D.	
	BC	SC	BC	SC	BC	SC	BC	SC
Size	0.1982	0.2772	0.4401*	0.3274*	0.2121	0.3165*	0.2480	0.2632
Shape	0.2012	0.2452	0.5329*	0.3579**	0.3006	0.3190*	0.2301	0.2549
Smell	0.5680*	0.1860	0.4711*	0.4725**	0.1649	0.4326**	0.6331**	0.6318**
Texture	0.6351**	0.3188*	0.7647***	0.5936***	0.4798*	0.8484***	0.8138***	0.8098***
Juiciness	0.7011***	0.7765***	0.7870***	0.5263***	0.6208**	0.8648***	0.8546***	0.8597***
Sweetness	0.4048	0.8872***	0.5724**	0.6985***	0.7490***	0.8740***	0.8826***	0.8804***
Acidic taste	0.3652	−0.015	0.4346*	−0.2302	0.2324	−0.4064**	0.3793	−0.3622
Aroma	0.9225***	0.9264***	0.8962***	0.8860***	0.6410**	0.9484***	0.9478***	0.9120***

Blind consumers (BC $n = 22$); sighted consumers (SC $n = 59$). Significant coefficients are denoted by asterisks (*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$).

The apple sensory profiles are reported as spider-graphs (Fig. 2). In a similar way to the overall appreciation, BC and SC panellists were quite in agreement for Ruggine, while they expressed different judgments for Rosa and Casciana. In general, the acidic taste appreciation significantly differed between panels: the BC expressed a greater sensibility in acidity perception. Intriguingly, such tendency was observed in the case of SC group when blindfolded for the assessing of Golden D. This complex aspect, currently difficult to explain, would deserve further investigation by specialists of sensorial, neurological, and psychological sciences.

As for Casciana, the BC group gave higher scores for sweetness and aroma, while Rosa was better appreciated by the SC group for texture, juiciness, and sweetness. The most attractive traits of Rosa apples, due to its red-coloured peel in addition to a large size, had a positive impact on SCs. For the same reason, they have penalised Casciana apple for its less attractive outer traits, such as small size and poorly red cover-colour of peel. It has been demonstrated that the external appearance of a product may affect appreciation, and visual cues may unknowingly condition the judgment of the assessors (Sipos et al., 2011). In particular, the colour has a significant influence on consumers (Spence, 2015). Specifically, the skin colour is determinant
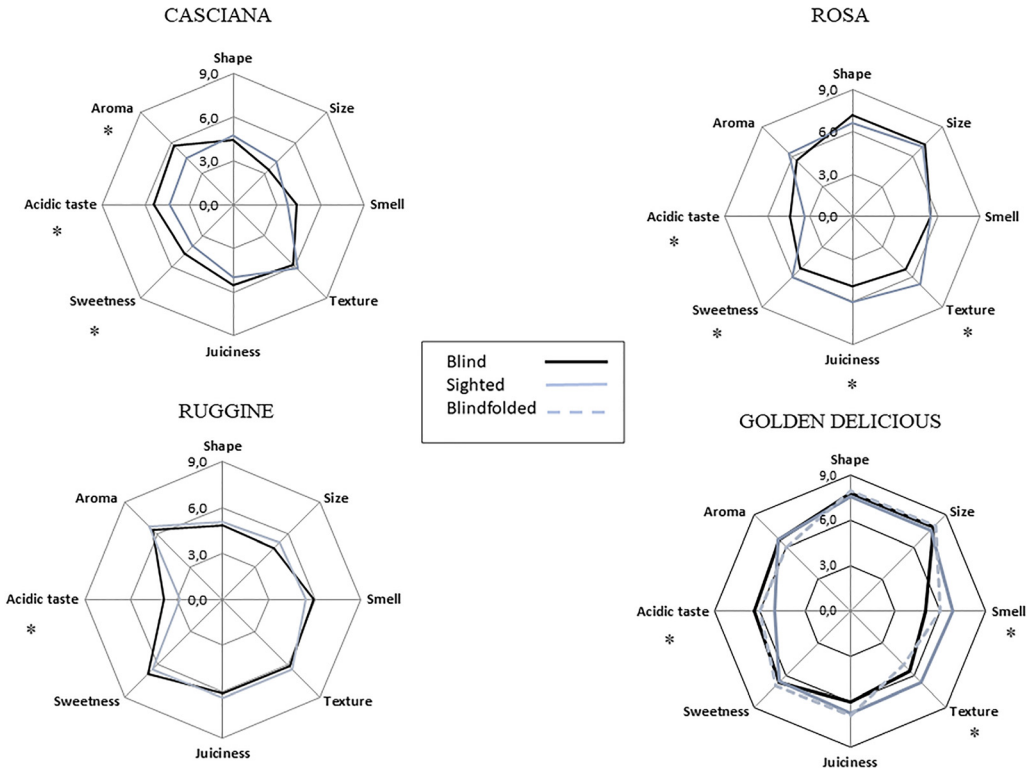

Fig. 2. Mean intensity scores attributed to apples of Casciana, Rosa, and Ruggine (local cvs) and Golden Delicious by blind (BC), sighted (SC), and sighted blindfolded (SCB) consumer panels. Asterisks indicate significant differences between panels by Mann-Whitney *U* test (*$P \leq 0.05$). In Golden Delicious, asterisks indicate significant differences between SC and BC-SCB

Table 3. Relationship (R^2 at $P \leq 0.05$) between instrumental (IN) determinations (TSS: total soluble solids; TA: titratable acidity; firmness) versus sensory (S) appreciation (sweetness; acidic taste; texture; overall appreciation) of apples (cvs Casciana, Rosa, Ruggine) related to blind (BC) and sighted consumers (SC). TSS/TA values versus overall appreciation and aroma are also shown

IN vs S	BC	SC
TSS – Sweetness	0.2114	0.4124
TA – Acidic taste	0.9948	0.9787
Firmness – Texture	0.0024	0.0063
TSS/TA – Overall appreciation	0.7539	0.5905
TSS/TA – Aroma	0.8848	0.6173

for apple preference, independently of people's age and gender (Moor et al., 2014). There is psychophysical evidence that visual cues may exert a crossmodal influence on olfaction gustation and/or on oral somatosensation, modulating people's perception of taste and flavour intensity rating (Koza et al., 2005). Our findings suggest that SCs were influenced by the visual appearance of Rosa apples, but did not allow establishing sensory ability differences from the BC group. The additional involvement of blindfolded SCs in testing Golden D. apples revealed that missing visual traits could lead towards evaluations close to BC, in agreement with Sipos et al. (2011).

The combination of instrumental determinations and sensory evaluations by a linear regression analysis is shown in Table 3. Moreover, considering that TSS/TA is considered a good parameter to predict the organoleptic quality of apples (Abbott et al., 2004), relationships between this ratio versus aroma and overall appreciation scores were measured, too.

In both panels, positive correlation coefficients with different goodness of fit were found. The closest connection was observed between TA and acidic taste ($R^2 = 0.9948$–0.9787), confirming titratable acidity as the best acidic taste predictor for apples (Włodarska et al., 2016). The TSS degree was not highly related to perceived sweet flavour. Harker et al. (2002) have evidenced a difficulty to predict the sweet flavour of apples finding relatively low correlations between sweetness and TSS; in particular, a difference in sweet taste has been difficult to predict when apple samples differed by less than 1 °Brix. This is what occurred in our trials, where apples of the three cvs poorly differed in TSS content. In this respect, attention on a larger number of genotypes would have allowed to obtain more consistent results.

The correlations between TSS/TA ratio and sensory ratings for overall appreciation and aroma of the fruit revealed interesting results, as the highest correlation coefficients were obtained with the BC group. This finding, not previously reported, could be of particular interest in predicting the organoleptic quality of apples.

4. CONCLUSIONS

This study constitutes the first attempt at collecting sensory impressions from blind and sighted consumers on local Tuscan apple cultivars (Casciana, Rosa, and Ruggine). Although most instrumental determinations did not reveal substantial differences among them, the evaluation of apples differed among consumers with different visual abilities. The lack of visual cues might have played a role in the judgment of blind assessors, who were inclined to better evaluate

Casciana apples, characterised by less attractive fruits. In this regard, albeit on a preliminary basis, trials conducted on the popular apple cv Golden Delicious indicated that blindfolded sighted consumers gave judgments similar to blind assessors.

Finally, the good relationship between aroma judgment and TSS/TA parameter suggests blind people could be valuable assessors for apple quality predicting. In particular, they could contribute to valorising suboptimal produce, based on intrinsic attributes rather than aesthetic ones.

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