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A study to guide breeding of new cultivars of organic cherry tomato following a consumer-driven approach

Mariella de C. Rocha [a], Rosires Deliza [b,*], Fabio M. Corrêa [c], Margarida G.F. do Carmo [a], Antonio C.S. Abboud [a]

[a] Departamento de Fitotecnia, Universidade Federal Rural do Rio de Janeiro (UFRRJ), 23890-000 Seropédica, RJ, Brazil
[b] Embrapa Agroindústria de Alimentos, Av. das Américas, 29501, CEP 23020-470 Rio de Janeiro, RJ, Brazil
[c] Departmento de Estatística, Universidade Federal de Lavras (UFLA), 37200-000 Lavras, MG, Brazil

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ABSTRACT

Agricultural studies focusing on the development and/or improvement of new varieties of fruits and vegetables usually prioritize the productivity, disease resistance, response to fertilization, and higher nutrient content. However, new product development needs to take into account not only flavour preference, but also consumer preference for appearance since without tasting products, consumers have to make decisions based on the way a product looks. The present study evaluated the sensory characteristics and consumer preference of ten promising accessions of organic cherry tomato for fresh consumption aiming at identifying the sensory attributes related to appearance that contributed to consumer liking/disliking the fruit. More specifically, the objective of the study was to guide producers regarding the target appearance attributes that play a role on consumer acceptance of cherry tomatoes. Ten accessions of organic cherry tomatoes were evaluated by a trained panel using the QDA methodology, and also by 80 tomato consumers for the acceptance of appearance and intention to purchase. The results achieved after integrating these two data sets (from the trained panel and consumers) in a multidimensional map allowed the elucidation of consumer liking of tomatoes in relation to the appearance, i.e. drivers of liking/disliking were identified. Results revealed that tomatoes with round shape and red colour (reddish) (cultivar ENAS 1031, ENAS 1010, 'Perinha Agua Branca', Super Sweet, and 'Joana') were the most liked cherry tomatoes. Those genotypes were also liked by the smallest segment (17.5% of participants) but for them unusual shapes (oblong and pear), orange-yellow colour, and bigger size were also liked. Despite the small number of participants in this study (80 consumers), new shapes and colours for the organic cherry tomatoes could be considered promising alternatives in the Brazilian market, and can be an opportunity for the producers of the state of Rio de Janeiro.

1. Introduction

Consumers' demands and competition imposed by the globalized market have forced the provision of high standard foods, with better sensory characteristics and nutritional value. The quality of fruits and vegetables can be characterized by attributes such as appearance, flavour, texture, nutritional value and safety. Appearance is one of the most important since it determines the product commercialization value (Chitarra & Chitarra, 2005; Gamble, Jaeger, & Harker, 2006), and it is a critical factor driving the initial purchase (Deliza & MacFie, 1996).

Within the *Solanum lycopersicum* species, there is a huge variation in the characteristics of the flavour and aroma of the fruit, a diversity which is already much exploited in developed countries such as France and the United States. In these countries, tomatoes known as heirloom are always present in the supermarkets, besides being served and valued in restaurant menus (Abboud et al., 2005; Rocha et al., 2009). On the other hand, Brazilian consumers are unaware of the existence of tomatoes with differentiated aroma, colour, shape, texture and flavour. However, the fact that a product is unknown to consumer does not necessarily imply its rejection. The product presentation can create a positive expectation on consumer, and contribute to an increasing consumption (Deliza & MacFie, 1996). Therefore, investigating how consumers react towards tomatoes with unfamiliar characteristics is a fundamental issue in studies to find new cultivars to target markets. Studies performed with various products such as apples, pears, kiwis, and tomatoes have shown the valuable contribution of sensory analysis to the identification of the most promising varieties for consumption (Daillant-Spinnel, MacFie, Beyts, & Hedderley, 1996; Gamble et al., 2006; Jaeger, Rossiter, Wismer, & Harker, 2003; Pagliarini, Monteleone, & Ratti, 2001). More recently Rodríguez-Burruezo, Prohens, and Fita (2011) reported appropriate breeding strategies for improving the commercial potential of pepino, which is considered a neglected Andean crop.

Despite tomato's versatility and popularity in Brazil, it has been observed over the last three decades, consumers' dissatisfaction with the table tomato for fresh consumption, where price and quality were described as the most crucial factors (Chabriat & Sarazin, 2010; Kader,

* Corresponding author. Tel.: +55 21 3622 9766; fax: +55 21 3622 9713.
E-mail address: rosires.deliza@embrapa.br (R. Deliza).

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Morris, Stevens, & Albright-Holton, 1978). According to Andreuccetti, Ferreira, and Tavares (2005), who analysed the profile of fresh tomato buyers in a supermarket of Campinas, SP, Brazil, 95.6% of the participants were not satisfied with the quality of the fruits, and 70% of them would pay more for a tomato with the ideal appearance; thus, suggesting that a proper cultivation, selection, classification and presentation of the fruits are crucial points to be addressed in order to obtain products to please consumers.

Tomato production, however, depends also on agrochemicals, some of them with high toxic effects. Thus, there is the need for improving tomato production, and delivery better quality and flavour that meet consumer's expectation (Baldwin, Scott, Shewmaker, & Schuch, 2000; Causse, Buret, Robini, & Verschave, 2003; Ruíz et al., 2005; Stolz, Stolz, Janssen, & Hamm, 2011). Organic produce is an excellent alternative to the consumer market since there is concern not only with the quality of food products, but also with environmental and social issues (Pieniak, Aertsens, & Verbeke, 2010). In Brazil, the development of organic agriculture began in the 1980s, mainly in the southern and southwestern states. Fifteen thousand producers currently work in organic agriculture over an estimated area of 800,000 ha, concentrated in family production units (Brasil, 2008; Nogueira, Rosado, & Gomes, 2009). Demand for organically produced tomatoes, for example, has increased due to frequent media disclosures about product contamination by agrochemical residues (ANVISA, 2005). The organic market is, therefore, in a process of rapid expansion. On the other hand, there is insufficient evidence to recommend organic over conventional vegetables in terms of public health (Hoefkens et al., 2010); however, results achieved by Hallmann (2012) revealed that the organic growing affected the tomato nutritional value and phenolic content. Her findings demonstrated that organic tomatoes cultivated in 2008 and 2009 presented a higher content of vitamin C and total flavonoids, 3-quercetin rutinoside, and myricetin in comparison with the conventional fruits.

Geneticists usually prioritize the productivity, disease resistance, response to fertilization, and higher nutrient content when developing vegetable products such as fruits, and leafy vegetables (Maul et al., 2000; Moretti, Baldwin, Sargent, & Huber, 2002; Ruíz et al., 2005). Tomato is classified as a functional product due to the high levels of lycopene, a carotenoid responsible for the red colour of the fruit that suppresses the formation of free radicals. Its consumption is inversely proportional to the incidence of some types of cancer, such as prostate and lung (Causse et al., 2003; Ellinger, Ellinger, & Stehle, 2006; Giovannucci, 2005; Willett, 2010). Nonetheless, such characteristics do not guarantee quality in relation to the aroma, flavour, and texture of the fruit (Azodanlou, Darbellay, Luisier, Villettaz, & Amadò, 2003). Therefore, it is important to guide horticultural new product development not only by flavour preference, but also by appearance and nutritional quality (Gamble et al., 2006; Saha et al., 2010), taking into account that without tasting products, consumers are obliged to make decisions based on the way a product looks like, and any possible information provided. A classic example was the substitution of traditional tomato cultivars by longer storage period ones, such as 'Carmen' and 'Débora Plus' hybrids, considered less tasty (Beckmann, Paula, Duarte, Schuck, & Mendez, 2004; Rocha, 2009).

Research designed to characterize and investigate the acceptance of different cherry tomato cultivars, especially those under Brazilian organic cultivation conditions is still poorly developed. In the state of Rio de Janeiro, for example, the cultivation of organic cherry tomatoes remains limited, and demands further investigation. It may open a range of marketing opportunities as it adds value to the product and, consequently, creates a profitable source of income to small producers (Rocha, 2009). The present study evaluated the sensory characteristics of 10 promising accessions of cherry tomato for fresh consumption, aiming at identifying the sensory attributes related to appearance that contributed to consumer liking/disliking the fruit in order to guide small producers.

2. Material and methods

2.1. Organic cherry tomatoes

Seven accessions of organic cherry tomatoes cultivated at the experimental area of the Crop Science Department, Federal Rural University of Rio de Janeiro (UFRRJ) were used in this study. Three other cultivars named 'Perinha Água Branca', 'Joanna', and the hybrid Super Sweet were acquired. The criteria used for the selection of the 10 cultivars were based on previous studies, which focused on agronomic and sensory aspects using a larger amount of cultivars (Rocha, 2009). After harvesting, samples were transported to the laboratory, cleaned, packed in polyethylene bags, sealed and kept at room temperature until the evaluation by a trained panel and consumers in the following day.

2.2. Sensory evaluation by a trained panel

Eleven individuals previously selected for the ability to evaluate colour and sweet taste, aged between 21 and 50 years, evaluated the samples by Quantitative Descriptive Analysis (QDA) (Stone & Sidel, 2004). All subjects had previous experience in sensory evaluation, as they participated in several studies at the Lab. During the first sensory evaluation session, the objective of the work was explained to the group. Following the standard protocol, the sensory descriptive terms were elicited by participants. This step of the study was carried out by showing participants samples of fresh cherry tomatoes with different sensory characteristics regarding the ripening stages, colour, shape and size. The aim was to provide the panellists with the greatest diversity of sensory characteristics to facilitate the identification of key sensory words, and to determine, by consensus, the attributes that characterized samples, as well as their definitions and references of the unstructured scale used (varying from 1: "weak" and "a little" to 9 "strong" and "a lot"). Sixteen sensory attributes were elicited by panellists, six of which were related to appearance (round shape, oval shape, pear shape, size, colour and green shoulder), three to aroma (characteristic aroma of cherry tomatoes, sweet aroma and acid aroma), three to flavour (characteristic flavour of cherry tomatoes, sweet taste and acid taste) and four to texture (crispness, juiciness, resistance to chewing and firmness). The definition of the attributes and the references of the scales are shown in Table 1. After eliciting the attributes, daily training sessions were carried out for four weeks.

The samples were served in a white porcelain saucer coded with a three-digit number at room temperature, together with mineral water to clean the palate between samples. Participants were asked to write down all descriptive terms. During the definition of the attributes' references, the sensory panel decided that tomatoes would be presented whole to evaluate the appearance and aroma, whereas for the evaluation of flavour and texture the fruits would be transversely cut. For the evaluation of the attributes related to appearance, the samples were presented under white light, and for the others they were served under red light in the Embrapa Food Technology Sensory Lab., Rio de Janeiro, RJ/Brazil. Samples were coded with three digit numbers, presented in a monadic way, and the order of presentation followed a complete balanced block design (MacFie, Bratchell, Greenhoff, & Vallis, 1989). Samples were evaluated in triplicate by the sensory panel.

2.3. Consumer evaluation

Fruits of the same 10 accessions of cherry tomatoes used in the QDA were used for the consumer acceptance and intention to purchase evaluation. The consumer study was carried out simultaneously with the QDA evaluation to be sure the trained panel and consumers evaluated samples in similar conditions. Only the appearance of the fruits was considered in the evaluation of 80 consumers (37 men and 43 women who buy and eat cherry tomatoes), using the structured hedonic scale, ranging from 1: extremely disliked to 9: extremely liked. Purchase intent was investigated

Table 1
Sensory attributes definitions and references established by the sensory panel for fresh cherry tomato.

Attributes	Definitions	References
Appearance		
Round shape	Circular, with a longitudinal diameter smaller or equal to equatorial.	Weak: accession ENAS 1008 Strong: accession ENAS 1031
Oval shape	Oblong, with a longitudinal diameter larger than the equatorial.	Weak: accession ENAS 1007 Strong: accession ENAS 1013
Pear shape	The base has the equatorial diameter larger than the apex, presenting a typical pear shape.	Weak: accession ENAS 1012 Strong: accession ENAS 1029
Size	Relationship between the longitudinal and equatorial diameters.	Small: accession ENAS 1008 Large: accession ENAS 1013
Colour	External uniform colour staining on the fruit surface.	Weak: accession ENAS 1029 (yellow) Strong: accession ENAS 1008 (brown)
Green shoulder	Concentric green staining found in the fruit apex.	Absent: hybrid Super Sweet Intense: accession ENAS 1008
Aroma		
Characteristic aroma of the cherry tomato	Expected/typical aroma of the fresh cherry tomato.	Weak: accession ENAS 1029 Strong: accession ENAS 1013
Sweet aroma	Aromatic compounds related to the fruit, which produce the sweet sensation.	Weak: accession ENAS 1013 Strong: hybrid Super Sweet
Acid aroma	Striking aroma related to the presence of acids in the fruit.	Weak: accession ENAS 1008 Strong: accession ENAS 1012
Flavour		
Characteristic flavour of the cherry tomato	Characteristic flavour of the fresh cherry tomato.	Weak: accession ENAS 1029 Strong: hybrid Super Sweet
Sweet taste	Taste stimulated by the presence of saccharose and other sugars of the fruit.	Weak: accession ENAS 1029 Strong: hybrid Super Sweet
Acid taste	Taste stimulated by the presence of organic acids characteristic of the fruit.	Weak: accession ENAS 1010 Strong: variety 'Joanna'
Texture		
Crispness	Crisp sensation perceived during chewing.	Weak: accession ENAS 1008 Strong: cultivar 'Perinha Água Branca'
Juiciness	Wet sensation caused by the product after its compression between the teeth.	Weak: accession ENAS 1029 Strong: accession ENAS 1008
Resistance to chewing	Sensation perceived during chewing caused by the tomato skin.	Weak: accession ENAS 1029 Strong: accession ENAS 1031
Firmness	Force required to compress a substance between the molars (for solids) or between the tongue and the palate (for semi-solids)	Weak: accession ENAS 1008 Strong: cultivar 'Perinha Água Branca'

using a structured seven point scale (1: certainly would not buy and 7: certainly would buy). Participants were recruited among employees and trainees at Embrapa Food Technology, Rio de Janeiro, RJ.

The samples were monadically presented in a white saucer, coded with three digit numbers and served at room temperature in individual sensory booths. The order of sample's presentation followed a complete balanced design (MacFie et al., 1989) to prevent first sample and carry over effects.

2.4. Data analyses

The data were firstly submitted to the Levene's test to check the homogeneity of variances, when ANOVA was applied. The data from the QDA was analysed through the Analysis of Variance (ANOVA) considering assessors and tomatoes as source of variation using the SISVAR software (Ferreira, 2000). The significance of these effects was tested with Tukey tests at 5% level. Principal Component Analysis (PCA) was also performed using the XLSTAT-MX (2005) software.

The consumer data were first processed by registering the scores given by participants in an Excel spreadsheet, and then submitted to statistical analyses. The acceptance scores were first analysed for sample and consumer effects by ANOVA ($p<0.05$) and Tukey test to check differences among means; by frequency distribution of scores, and also by the Preference Mapping and Cluster Analysis (MacFie, 2007). Internal preference mapping is a principal component analysis (PCA) of a data matrix, consisting of samples (objects) and consumers (variables). Consumers were segmented by cluster analysis on the overall liking scores to understand participants' preferences. Hierarchical cluster analysis was performed on overall liking data in order to identify groups of consumers with different preference patterns. Euclidean distances and Ward's aggregation method were considered. The External Preference Mapping was also used. This method allows relating the preferences shown by consumers to some sensory characteristics of the products (MacFie, 2007). The intention to purchase data were analysed by ANOVA and frequency distribution. All the statistical analyses performed on consumer data were carried out using procedures from the XLSTAT software (Addinsoft, France, Version 10).

3. Results and discussion

3.1. Trained panel evaluation

Table 2 presents the results from the QDA. They suggest that the sensory attributes elicited to describe samples were adequate, because it was possible to observe a differentiation among samples, especially considering the attributes "characteristic flavour of fresh cherry tomato", "acid taste", "firmness", "crispness" and "chewing resistance". It is worth commenting the low average score for the characteristic aroma of cherry tomato achieved by ENAS1029. Considering the flavour and texture attributes, it is possible to observe that the attribute acid taste differed ($p<0.05$) among genotypes, being the ENAS1029 the least acid, and the ENAS1012 evaluated as the most acid. Crispness was also very different among tomatoes with means varying from 1.9 (ENAS1008) to 6.3 (ENAS1012). Similar results were observed for firmness, having ENAS1008 low firmness (mean 1.9), and ENAS1012 an average of 5.5 for such attribute. On the other hand, ENAS1008 presented high juiciness (mean 7.5). Pagliarini et al. (2001) reported 21 sensory attributes to describe their tomato cultivars, and 14 appeared in the PCA loading plot. Although they didn't comment on the seven attributes that were not presented in the PCA, the 14 sensory attributes have also allowed separating samples according to the degree of ripeness, from firm to juicy, from acid to sweet, and from astringent to fruity.

The QDA, a classical method to describe samples, was used in the present study because the assessor panel was well-trained as they took part in other studies in our lab; therefore, they were very familiar with the sample category (cherry tomato). Although there are several

Table 2
Sensory attribute means[§] of cherry tomatoes.

Sensory attributes	LSD[*]	Super Sweet	"Perinha Água Branca"	"Joanna"	ENAS 1007	ENAS 1008	ENAS 1010	ENAS 1012	ENAS 1013	ENAS 1029	ENAS 1031
											
Round shape	1.1	8.4^{a}	2.2^{bc}	8.5^{a}	2.8^{b}	8.5^{a}	2.9^{b}	1.2^{cd}	1.0^{d}	1.1^{cd}	8.0^{a}
Oval shape	1.3	1.0^{d}	6.7^{ab}	1.0^{d}	6.0^{b}	1.0^{d}	6.2^{b}	2.3^{cd}	8.1^{a}	2.5^{c}	1.0^{d}
Pear shape	0.8	0.9^{b}	1.0^{b}	0.9^{b}	0.9^{b}	0.9^{b}	0.9^{b}	8.3^{a}	1.4^{b}	8.9^{a}	0.9^{b}
Size	1.1	1.2^{e}	4.4^{c}	2.3^{de}	7.0^{ab}	1.7^{e}	7.0^{ab}	3.4^{cd}	7.5^{a}	3.2^{d}	6.0^{b}
Colour (yellow to brown)	0.6	6.4^{bcd}	6.5^{bc}	6.6^{b}	8.3^{a}	8.7^{a}	5.9^{e}	4.4^{de}	6.0^{cde}	1.0^{g}	5.8^{e}
Green shoulder	0.8	0^{c}	0^{c}	0^{c}	7.6^{a}	6.6^{b}	0^{c}	0.1^{c}	0.1^{c}	0^{c}	0^{c}
Aroma											
Characteristic aroma of the cherry tomato	1.7	5.7^{ab}	5.4^{ab}	6.4^{a}	4.9^{ab}	4.3^{b}	5.4^{ab}	5.7^{ab}	5.6^{ab}	2.5^{c}	6.3^{a}
Sweet aroma	1.7	4.4^{a}	4.4^{a}	4.4^{a}	4.1^{a}	4.1^{a}	3.8^{a}	4.4^{a}	3.6^{a}	3.0^{a}	4.6^{a}
Acid aroma	2.0	4.0^{ab}	3.6^{ab}	4.5^{a}	3.4^{ab}	3.0^{ab}	3.3^{ab}	4.3^{ab}	4.0^{ab}	2.5^{b}	4.5^{ab}
Flavour											
Characteristic flavour of the cherry tomato	1.5	5.6^{ab}	4.9^{abcd}	6.1^{a}	3.5^{d}	4.8^{abcd}	3.9^{cd}	5.3^{abc}	4.1^{bcd}	1.8^{e}	5.6^{ab}
Sweet taste	1.7	5.0^{a}	4.9^{a}	5.4^{a}	4.5^{a}	5.2^{a}	4.8^{a}	3.7^{a}	3.9^{a}	4.3^{a}	4.6^{a}
Acid taste	1.8	5.6^{ab}	3.3^{cd}	4.8^{abc}	3.2^{cd}	3.9^{bcd}	3.3^{cd}	6.0^{a}	4.5^{abcd}	2.8^{d}	5.3^{ab}
Texture											
Crispness	1.9	4.0^{bcd}	5.3^{abc}	2.5^{de}	3.5^{cde}	1.9^{e}	4.2^{bcd}	6.3^{a}	5.8^{ab}	1.9^{e}	3.2^{de}
Firmness	1.6	3.8^{bcd}	5.0^{ab}	2.7^{cde}	3.4^{bcde}	1.9^{e}	4.3^{abc}	5.5^{a}	4.9^{ab}	2.4^{de}	3.6^{bcd}
Juiciness	1.5	6.8^{ab}	4.5^{cd}	6.8^{ab}	5.8^{bc}	7.5^{a}	4.4^{cd}	5.3^{bcd}	4.0^{d}	4.6^{cd}	6.7^{ab}
Resistance to chewing	1.9	5.2^{ab}	4.3^{abc}	5.3^{ab}	3.9^{abc}	4.7^{ab}	3.3^{cd}	5.5^{a}	4.3^{abc}	2.4^{c}	5.4^{a}

Same letters on the same line do not significantly differ among each other ($p \leq 0.05$) by the Tukey test.
[§] Evaluated in non structured scale, ranging from 0: absence, 1: a little, weak, to 9: strong, intense.
[*] LSD = least significant difference.

novel methods for describing and characterizing products (Varela & Ares, 2012), the experience of our panel and the high specialization of assessors should be taken into account and valued. Such characteristics, according to Moussaoui and Varela (2010) allow getting very detailed, consistent, and reproducible results within a sensory space. Similar approach was adopted by Latocha, Jankowski, and Radzanowska (2011) when evaluating genotypes of hardy kiwi. They have chosen QDA for the panel experience in descriptive analysis of vegetables, fruits and spices. Besides, the common practice to analyse data using PCA, and visualize descriptive results through sensory mapping is useful to separate samples based on the similarities and differences in the intensity of the investigated sensory attributes.

Fig. 1 shows the results of the PCA. It can be observed that the first and second components explained 71.1% of the variance (PC1 explained 42.0%, while PC2 explained 29.1%). Fig. 1b reveals that PC1 can be considered an appearance (shape)/aroma and flavour dimension, with the sensory attributes characteristic flavour of cherry tomatoes, sweet and characteristic aroma of cherry tomatoes, juiciness, acid aroma and acid taste located in the right side of the Fig. 1b, and pear shape in the left side, mostly contributed to the variability associated with PC1. PC2 can be seen as a texture dimension having the attributes firmness and crispness important role in characterizing cultivars. These results allow one to identify the attributes that described each investigated accession, according to those presented in Table 1. The location of the accessions on the PCA (Fig. 1a) demonstrated the similarity between ENAS 1031, the hybrid Super Sweet and the cultivar 'Joanna', being such tomatoes similar to each other, and characterized by the acid aroma, characteristic aroma of cherry tomatoes, sweet taste, chewing resistance, characteristic flavour of cherry tomatoes, sweet aroma, round shape, juiciness and sweet taste. Such similarities can be seen also in Table 2. It should be emphasized that these attributes were the most important to the products' characterization, taking into account the size of the vectors (Fig. 1b). The Italian cultivar Cherry-Pachinowas also described as red, sweet and juicy by the Italian trained panel (Pagliarini et al., 2001). On the other hand, fruits of the accession ENAS 1008 were described by the attributes round shape, colour, sweet taste and juiciness, ENAS 1007 by the attribute green shoulder, and the accession ENAS 1029, which is distant from the other accessions, was characterized by the low values of the attributes related to PC1. The fruits of the accessions ENAS 1010 and 1013 were characterized by the attributes oval shape and size, and ENAS 1012 and the cultivar 'Perinha Água Branca' by firmness and crispness (Fig. 1). Average means presented in Table 2 also demonstrated similarities for the mentioned attributes.

3.2. Consumer results

The acceptance means of the ten genotypes of fresh cherry tomatoes are shown in Table 3, as well the percentage of scores higher and lower than five ("neither liked nor disliked" on the hedonic scale). Significant differences were observed among the accessions regarding the consumer acceptance, ranging from 1 (disliked extremely) to 9 (liked extremely), with emphasis to ENAS 1031, the Super Sweet and 'Perinha Água Branca', with 96.2, 86.1 and 88.7% of approval, followed by ENAS 1010 and 'Joanna', with 85.0 and 81.2% of approval. Italian consumers also preferred the variety having round shape and red colour (Cherry-Pachino) (Pagliarini et al., 2001). The preference for more conventional genotypes in terms of appearance may reveal the consumption habit of participants, and demonstrates the role of context on consumer likes (Deliza & MacFie, 1996; Meiselman, 2007). The ENAS 1013, ENAS 1012 and ENAS 1029 showed an acceptance lower than the previous ones. However, the least preferred were ENAS 1008 and ENAS 1007 which an approval rate 33.75% and 20%, respectively. In general, the fruits of the accessions ENAS 1031, ENAS 1010, ENAS 1013, ENAS 1012 and ENAS 1029, the hybrid Super Sweet, the cultivars 'Perinha Água Branca' and 'Joanna' had more than 50% approval, that is, scores higher than five, and a disapproval rate of less than 35%. Only the fruits of the accessions ENAS 1008 and ENAS 1007 showed a disapproval rate over 50%.

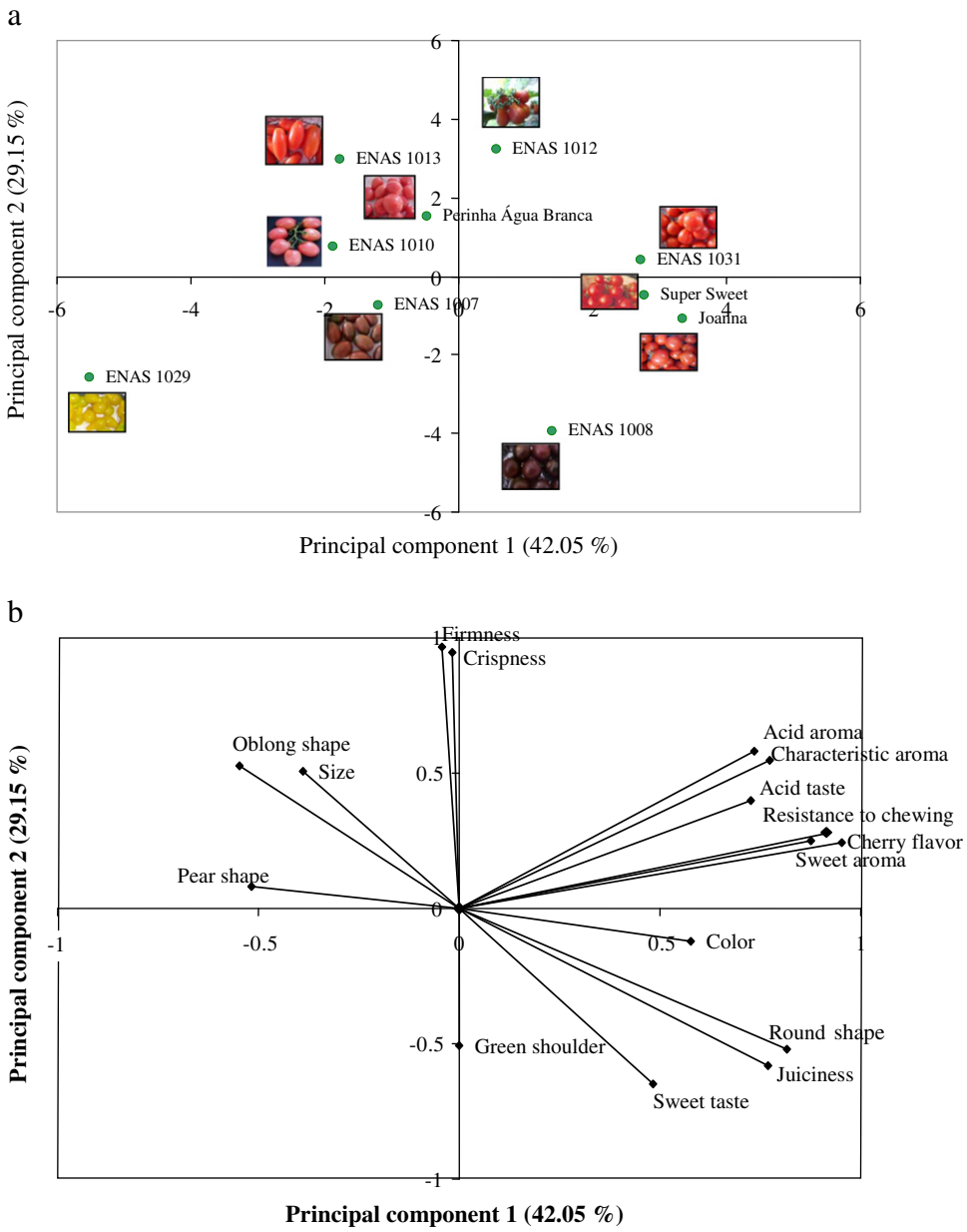

Fig. 1. Principal Component Analysis (PCA) of the samples of the cherry tomatoes, showing (a) position of samples, and (b) position of the 16 sensory attributes.

The results of the preference test obtained through the ANOVA do not provide individuals' perceptions of consumers because the results are presented as means. This univariate way of analysing data is considered limited since it does not reflect the actual performance of each accession in terms of preference (MacFie, 2007). Consumer's segmentation may be an appropriate alternative to better interpret the results, and to investigate whether distinct segments of tomato consumers could be detected in the population. In order to identify and evaluate the different segments of consumers of fresh cherry tomatoes, the Internal Preference Mapping (IPM) and Cluster Analysis were used.

3.2.1. Internal preference mapping (IPM) results and segmentation of consumers by similarity of preference

The IPM generated through preference data was built to graphically represent the acceptance of tomato samples, taking into account the individual preference of each of the 80 consumers. In this study, data of all consumers were considered, even those who were not able to differentiate samples or equally liked or disliked all tomatoes, because, according to MacFie (2005) they are part of the "real" consumer market. The first and second dimensions generated by the preference mapping explained 52.6% and 11.8% of the total variability of consumer responses, respectively. Fig. 2a displays the position of 10 tomatoes evaluated in this study. The first dimension separated the accessions ENAS 1007 and ENAS 1008 from the ENAS 1031, "Perinha Agua Branca", "Super Sweet", "Joana", and ENAS 1010 and, to a lesser extent, ENAS 1012, ENAS 1013 and ENAS 1029. On the second dimension, ENAS 1029, ENAS 1013, ENAS 1007, and, to a lesser extent ENAS 1010 were separated from the remaining accessions. Fig. 2b displays the position of the 80 consumers who took part in the study in the space defined by the first and second dimensions. The contribution of each consumer to the preference map can be seen by the length of the vector. Consumers with shorter vectors have preference data which are contributing less information to the sample map than those with longer preference vectors. The most liked cherry tomatoes were those located in the right side of the map ('Perinha Agua Branca', Super Sweet, and ENAS 1031), and the least liked samples were genotypes ENAS 1007 and ENAS 1008.

Table 3
Consumer evaluation (mean) of fresh cherry tomato.

Samples	Acceptance[a]					
	Acceptance[a] (n = 80)	% of approval (scores > 5)	Segment 1 (n = 28)	Segment 2 (n = 14)	Segment 3 (n = 38)	Intention to purchase[b] (n = 80)
ENAS 1031	7.7^{a}	96.2	7.1^{aB}	7.8^{aA}	8.1^{aA}	6.4^{a}
Super Sweet	7.3^{a}	86.2	6.7^{aB}	6.4^{abB}	8.1^{aA}	5.9^{b}
'Perinha Água Branca'	7.3^{a}	88.7	6.2^{aB}	7.1^{aB}	8.2^{aA}	5.8^{b}
ENAS 1010	7.0^{b}	85.0	6.4^{aB}	7.1^{aAB}	7.5^{aA}	5.8^{b}
'Joanna'	6.8^{b}	81.2	6.1^{aC}	5.1^{bB}	7.9^{aA}	5.2^{c}
ENAS 1013	6.0^{c}	67.5	3.8^{bB}	7.5^{aA}	7.2^{aA}	4.8^{d}
ENAS 1012	6.0^{c}	66.2	4.2^{bB}	6.4^{abA}	7.2^{aA}	4.8^{d}
ENAS 1029	5.9^{c}	65.0	3.6^{bC}	6.3^{abB}	7.5^{aA}	4.5^{d}
ENAS 1008	4.1^{d}	33.7	1.6^{cC}	3.6^{cB}	6.1^{bA}	3.2^{e}
ENAS 1007	3.3^{e}	20.0	1.8^{cB}	3.9^{cA}	4.2^{cA}	2.4^{f}

Means that share a common small letter in the same column, and the same capitalize letter in the rows (for the acceptance segment means) are not significantly different ($p \leq 0.05$).
[a] Evaluated in structured hedonic scale ranging from 1 = extremely disliked to 9 = extremely liked.
[b] Evaluated in structured scale ranging from 1 = would not definitely buy to 7 = would definitely buy.

The consumer's segmentation was carried out to better understand the preference of certain genotypes by particular individuals. Cluster analysis was carried out on the 10 accessions of organic cherry tomatoes × 80 consumers' matrix of consumer data. Three consumer segments with 28, 14 and 38 individuals were identified through cluster analysis, and the dendrogram is shown in Fig. 3. Table 3 presents the samples' means for each segment of consumer. It was observed that consumers of segment 1 preferred the accessions ENAS 1031, Super Sweet, ENAS 1010, 'Joanna', and "Perinha Agua Branca", whereas individuals of segment 2 preferred these same genotypes excluding 'Joana', and also liked the ENAS 1029, ENAS 1013 and ENAS 1012. Participants from the segment 3 liked most of the tomatoes, however, they gave a lower score for the genotype ENAS 1008 (6.1), and didn't like the ENAS 1007 (mean score 4.2). The preferences of the three consumer segments were obtained, but no socio-demographic information on consumers (age, gender, and income) was collected. This can be considered a limitation of the study because it is not possible to propose a marketing strategy, according to the needs of the consumer segments. On the other hand, therefore, there is a need to conduct new studies that allow consumers with different acceptance of the tomatoes to be identified.

The preference mapping along with the cluster analysis enabled to observe the segmentation of consumers regarding their tomato acceptance. These results may help the producer to know the most promising varieties for cultivation. Similar studies were carried out by Pagliarini et al. (2001) in Italy. The authors identified two groups of consumers when evaluating eight fresh tomato cultivars. The first group was composed of individuals who preferred the Cherry-Pachino tomato, whose main characteristic was sweet taste and red colour. The second group preferred the Sardegna tomato, with high acidity and typical texture. These findings corroborated those of Johansson, Haglund, Berglund, Lea, and Risvik (1999), which indicated that sweet taste and the red colour were attributes most valued by tomato consumers.

The cluster centroids of the three identified consumer segments (variables) for the 10 cherry tomatoes (samples) were afterwards used to carry out a PCA. Additionally, the appearance attributes data (variables) were also included in the PCA to investigate the relationships between these attributes and the consumer segments related to liking. The appearance data consisted of the attributes elicited by the trained panel and were the most used terms to describe cherry tomatoes considering visual appearance. The results contributed to the interpretation of the preference, revealing which appearance descriptors drove the referred preference for each consumer segment. Fig. 4 shows the map of the fresh cherry tomatoes, taking into account the attributes of appearance, and consumers' segments. It can be seen in Fig. 4 that there were some appearance attributes that characterized each sample and, therefore, correlated well with the consumer segments, and played a role on their acceptance. For segments 1 and 3, which comprised the majority of participants (82.5%), the attributes round shape and colour (reddish) were well appreciated, and might have driven their preference, therefore, genotypes ENAS 1031, ENAS 1010, 'Perinha Agua Branca', Super Sweet, and 'Joana' were the most liked cherry tomatoes. On the other hand, consumers in segment 2 (the smallest group with 17.5% of participants) liked samples with the referred characteristics, but for them the oval (oblong) and pear shape, orange-yellow colour, and bigger size were also liked. It is possible to see in Fig. 4 that the accessions ENAS 1012, ENAS 1029, and ENAS 1013 were liked by this segment. It is clear in Fig. 4 that the attribute green shoulder was rejected by participants, as on e can see that the genotypes ENAS 1007 and ENAS 1008, both having such characteristic, were not appreciated by any of the segments of consumers.

A study conducted with French consumers enabled the separation and classification of the market in three types of consumers. The first segment (39.8%) was composed by people who frequently ate cherry tomatoes sold in bunches or in 'cocktails' (mixtures) of tomatoes, i.e., fruits in various shapes and colours. This first segment did not show any preference for regular-sized tomatoes or salad type tomatoes, firmness being one of the major factors affecting purchase. The second segment (39.6%) comprised mainly young people aged between 18 and 29, who had no specific preference for the oval type tomatoes, and did not consider colour as an important criterion for purchase, but highly prized the attributes flavour, aroma and sweetness. The third segment (20.6%) was formed by people aged between 40 and 65 who preferred a firmer texture tomato and an oval shape or for the salad shape (round). In this segment, sweetness was not an important attribute and the "cocktails" of tomatoes or the fruits of the cherry type were not prized (Lê & Ledauphin, 2006). Although our study did not take into account flavour and texture attributes, the appearance ones (mainly shape and colour) corroborate the findings observed in Lê and Ledauphin study.

The consumer intention to purchase means for the 10 accessions of cherry tomatoes are shown in Table 3. It is observed that fruits of the ENAS 1031 reached the highest mean ($p<0.05$) followed by the Super Sweet, ENAS 1010 and 'Perinha Água Branca' genotypes which did not differ among each other ($p>0.05$). "Joana" came next with average 5.2, which differed ($p<0.05$) from the ENAS 1012, ENAS 1013, and ENAS 1029. ENAS 1008 and ENAS 1007 had the lowest means, 3.2 and 2.4, respectively. As expected, the intention to purchase followed a pattern similar to acceptance, which is normally observed in studies that do not consider a real buying situation, as reported by Baixauli, Salvador, Hough, and Fiszman (2008).

4. Conclusions

The joint analysis of the sensory and consumer data identified green shoulder and the red-brownish colour as key attributes driving consumer disliking of cherry tomatoes. On the other hand, the results indicated that the accessions ENAS 1013 and ENAS 1029, which have particular shapes (pear and oblong) and colour (yellow) were promising genotypes

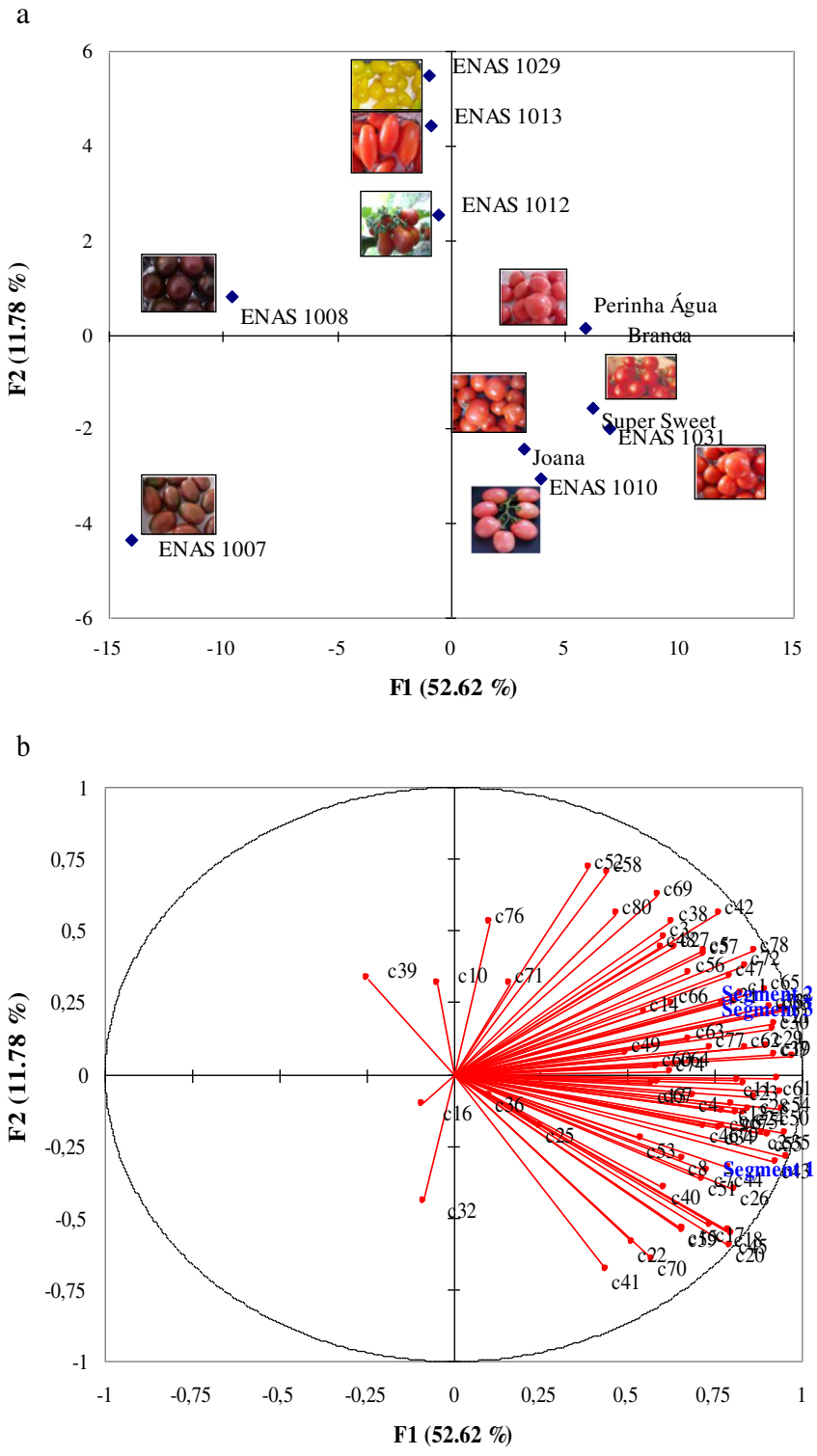

Fig. 2. Graphic representation of the dimensions 1 and 2 of the Internal Preference Mapping showing (a) the position of the cherry tomatoes, and (b) the consumers' positions, in the space defined by the first and the second dimensions.

with regard to their inclusion in the consumer market. However, the most accepted tomatoes were characterized by having red and pink-red colour, and round shape. The study provided important information that can be passed on to tomato producers in the state of Rio de Janeiro, who will be able to diversify their production and increase sales, hence causing a positive economical impact on the region. Besides, consumers might have a wide range of choice for cherry tomatoes in the market place bringing them nutritional benefits. Despite the indication that there is a possible market for the unusual yellow colour of cherry tomato in the Brazilian market, as well as novel shapes, further studies should be carried out taking into account flavour and texture characteristics in the consumer products' evaluation. It is also relevant to consider experimental

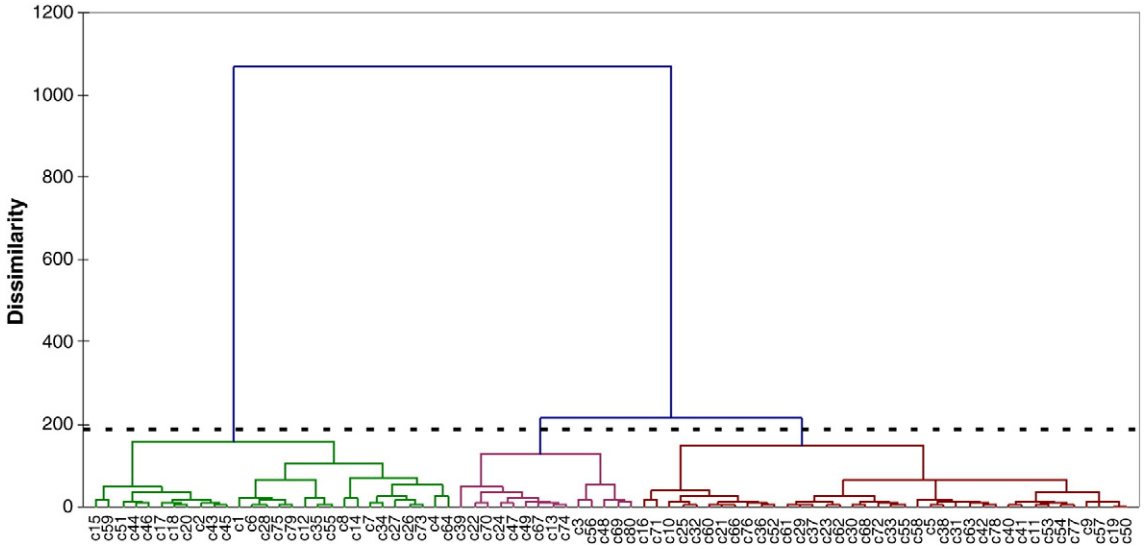

Fig. 3. Preference cluster dendrogram (Ward's method. Euclidean distance, n = 80 consumers).

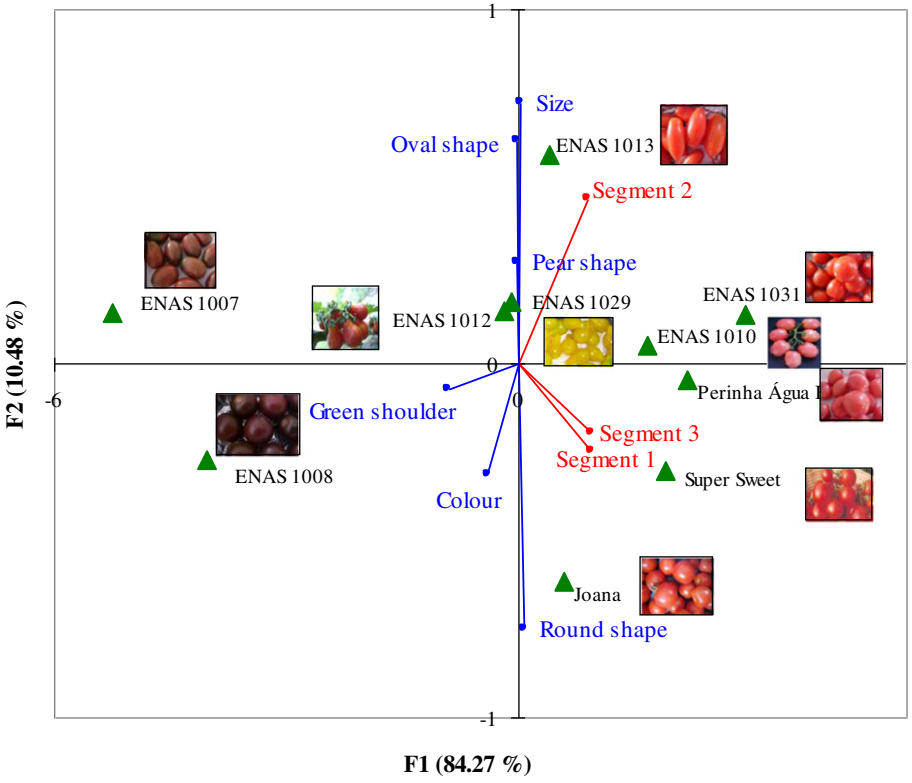

Fig. 4. Preference mapping showing the 10 cherry tomatoes (▲) the three segments of consumers (red vectors), and the six appearance attributes (blue vectors) correlated to the fist two dimensions (dimensions 1 and 2).

auctions, which use real products and money to investigate the relative monetary value of such products to a given market (Grunert et al., 2009).

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