Research Article

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Identifying promising accessions of cherry tomato: a sensory strategy using consumers and chefs†

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Abstract

BACKGROUND: An increased production of cherry and gourmet tomato cultivars that are harvested at advanced colour stages and sold at a higher price has been observed in the last 10 years. In this context, producers need information on the sensory characteristics of new cultivars and their perception by potential consumers. The aim of the present work was to obtain a sensory characterisation of nine cherry tomato cultivars produced under Brazilian organic cultivation conditions from a chef and consumer perspective. Nine organic cherry tomato genotypes were evaluated by ten chefs using an open-ended question and by 110 consumers using a check-all-that-apply question.

RESULTS: Both methodologies provided similar information on the sensory characteristics of the cherry tomato accessions. The superimposed representation of the samples in a multiple factor analysis was similar for consumers' and chefs' descriptions (RV coefficient 0.728), although they used different methodologies. According to both panels, cherry tomatoes were sorted into five groups of samples with similar sensory characteristics.

CONCLUSION: Results from the present work may provide information to help organic producers in the selection of the most promising cultivars for cultivation, taking into account consumers' and chefs' perceptions, as well as in the design of communication and marketing strategies.

Keywords: organic cherry tomatoes; CATA; chefs; consumers; preference; sensory description

INTRODUCTION

Tomatoes are one of the most popular vegetables worldwide, with a global production estimated at 146 million tons.[1,2] They are consumed fresh and in several processed forms, including dried, puree, sauce, soup, juice and canned whole-peeled.[1] From a nutritional point of view, tomatoes are a source of fibre, vitamins A and C and lycopene.[3,4] The antioxidant capacity of lycopene has been related to the beneficial effects of tomato consumption on human health, such as lowering the occurrence of cardiovascular disease[5,6] and certain types of cancer.[7,8]

Traditionally, tomato breeding programmes have been focused on increasing yield, improving resistance to diseases and transportation and increasing postharvest shelf life. In particular, pressures to reduce production costs have led to the large-scale production of cultivars that soften slowly and have a long shelf life but do not have acceptable flavour.[1] Moreover, many efforts have been made to improve visual quality to attract consumers, but internal quality attributes such as flavour, texture and nutritional content have not been much taken into account.[9,10] Although visual appearance is a critical factor that determines consumers' initial purchase, subsequent purchases are mainly determined by the whole sensory experience after eating the product.[11] The above trends have led to high consumer dissatisfaction related to tomato quality.[1] Many studies have reported that consumers have complained about tomato flavour for more than 15 years in many countries.[12–15] In a recent study conducted in Brazil with tomato buyers in a supermarket, 95.6% of the participants were not satisfied with the quality of the tomatoes available, while 70% of them would pay more for a tomato with ideal sensory characteristics.[16]

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Although several studies have been published on the sensory characterisation of tomato cultivars,[17–21] consumer research is still needed to provide information for the selection of cultivars that meet consumer demands. Research has shown that consumers clearly prefer tomatoes that are perceived as red, sweet, juicy and having fruity aroma and flavour, rejecting those that are perceived as mealy, sour or tasteless.[9,12,13,21–24]

One of the trends that have been observed in the last 10 years to provide consumers with an enjoyable eating experience with tomatoes is an increased production of cherry and gourmet tomato cultivars that are harvested at advanced colour stages and sold at a higher price.[1] Cherry tomato is reported as an appealing tomato variety and one of the most important for fresh consumption.[25] Cherry tomato cultivars are generally characterised by higher contents of sugars and organic acids than normal-sized fresh market tomato cultivars, which are major factors in determining the greater sweetness, sourness and overall flavour intensity of most cherry tomato varieties.[1,24–27] As the commercial importance of cherry tomatoes is continuously increasing, breeding programmes should focus on developing products with high sensory quality that meet consumer expectations.

Demand for organic food products has increased as a result of consumers' safety and environmental concerns.[28] Organic niche markets have become an excellent opportunity for small producers to sell their products at a premium price and obtain a higher income.[29,30] In Brazil the development of organic agriculture began in the 1980s, and there are currently 15 000 producers working in organic agriculture over an estimated area of 800 000 ha, concentrated in family production units.[31] However, in several parts of Brazil the cultivation of organic cherry tomatoes remains limited and thus might represent a good business opportunity, since it adds value to the product and consequently creates a profitable source of income.[32]

Organic foods produced should be able to satisfy expectations of consumers concerned with several aspects of food quality.[33,34] In this context, research on cherry tomato cultivars is required, since producers need information on the sensory characteristics of cherry tomato cultivars and their perception by potential consumers.

The most common approach to product optimisation involves asking consumers to rate their liking of a large set of products and characterising the sensory properties of those products using a trained assessor panel. Then both data sets are combined using regression analysis to identify the sensory characteristics of consumers' ideal product.[35] In these approaches, consumers are only asked about their liking, so information about how they perceive the sensory characteristics of the products is not gathered. However, in order to select cultivars that align as much as possible with consumers' preferences and assure acceptance, apart from knowing consumers' hedonic impression, it is necessary to determine how consumers perceive the sensory characteristics of different cultivars.[36] Moreover, it could be interesting to investigate consumer perception of the sensory characteristics of cherry tomato cultivars to develop communication and marketing strategies in order to commercialise single cultivars.

Several cost-effective methods for sensory characterisation, alternatives to descriptive analysis, have been developed recently.[37,38] These methods do not require training, can be performed by trained assessors or consumers and have been reported to be a good option when quick information about the sensory characteristics of a set of products is needed. One of the most novel methodologies that has been developed for gathering information about consumers' perception of the sensory characteristics of food products is the use of check-all-that-apply (CATA) questions.[39] These consist of a list of words or phrases from which respondents should select all they consider appropriate to describe a product. This approach has been recently reported to be a simple and reliable method to gather information about consumers' perception of the sensory characteristics of food products,[39–41] providing similar sensory maps to descriptive analysis with a trained assessor panel.[41–43]

Open-ended questions can also be applied for gathering information about the sensory characteristics of food products.[44–46] In this approach, assessors are asked to write down a free description of the sensory characteristics of the products. The main advantage of this approach is that it is commonly performed with experts, which makes it a trade-off between expert practice and methodologies from sensory and consumer science. There is an increasing communication between food science and culinary experts such as chefs, which has been mostly driven by market research.[47] In this context it is valuable to gather information about chefs' perception of the sensory characteristics of gourmet products such as organic cherry tomatoes.

The aim of the present work was to obtain a sensory characterisation of nine cherry tomato cultivars produced under Brazilian organic cultivation conditions from a chef and consumer perspective and to determine the characteristics that drive consumer preferences.

MATERIALS AND METHODS

Samples

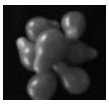
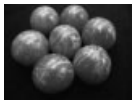
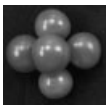
Nine organic cherry tomato genotypes cultivated in the experimental area of the Crop Science Department, Federal Rural University of Rio de Janeiro (UFRRJ) were used in this study. They varied in terms of shape, colour and size. Photographs of the tomatoes investigated can be seen in Table 1. Hand-picked tomatoes were transported to the laboratory, washed, packed in polyethylene boxes (300 g per box) and kept at room temperature ($23 \pm 2\,^{\circ}C$) until evaluation by chefs and consumers 1 day after being harvested.

Panels

Chefs

A panel of ten eco-chefs (six women and four men who work in restaurants that use only organic products in items offered on their menus) qualitatively evaluated the nine accessions using an open-ended task. Participants were seated at a large oval table and offered the cherry tomatoes in polyethylene boxes coded with three-digit numbers, one at a time. The eco-chefs were asked to list the sensory description and perceptions and the possible uses of tomatoes using single words or short phrases after tasting each genotype.[48] They were told to list as many words and phases as they thought would be necessary to reflect their perception of the genotypes. After tasting a sample and writing down his/her evaluation, the eco-chefs were allowed to talk among themselves and include any word he/she wanted. Although communication is not always allowed in open-ended tasks, this approach might have contributed to a nice environment during the study, and also to a broader elicitation of words and terms to describe samples, as well as ways of using the genotypes. They were asked to clean the palate with mineral water between samples.

Table 1. Number of mentions per sample for terms used by chefs to describe nine cherry tomato accessions, and results from chi-square per cell test

	Sample								
									
Term	ENAS 1012	ENAS 1013	ENAS 1017	ENAS 1019	ENAS 1031	ENAS 1033	ENAS 1037	JPR	Sweet Grape
Attractive	1	0	2	1	1	1	0	0	2
Beautiful	3	1	2	4	0	3	2	2	0
Thick	0	1	0	0	0	1	0	0	2 (+)*
Large	0	0	0	0	0	0	0	1 (+)***	0
Shiny	0	0	0	1 (+)**	0	0	0	0	0
Savoury, tasty	0	1	1	0	1	0	1	0	0
Standard of table tomato	0	0	0	0	0	0	0	4 (+)***	1
Regular size for cherry tomato	0	0	0	0	0	0	1 (+)***	0	0
Small size	0	0	0	1	0	0	0	0	0
Different size	2	1	0	0	0	0	2	2	1
Thick skin	1	0	1	1	0	0	0	0	1
Wild	0	0	0	1 (+)**	0	0	0	0	0
Different colour	0	0	3 (+)**	0	0	1	0	1	0
Sweet taste	1	0	0	6 (+)***	1	1	0	0	6 (+)**
Acid taste	2	3	2	0	0	2	1	1	2
Fruity taste	1	1	0	0	0	0	0	0	1
Salty	2 (+)***	0	0	0	0	0	0	0	1
Bitter skin	0	0	0	0	0	0	1 (+)***	0	0
No flavour	0	0	0	0	0	1	0	0	0
Sour	0	0	1 (+)**	0	0	0	0	0	0
Bitter	0	0	1	0	3 (+)***	0	0	0	0
Green flavour	0	0	2 (+)**	0	0	1	1	0	0
Few seeds	0	1	0	0	0	0	0	0	0
Characteristic cherry tomato flavour	1	2	0	0	3 (+)***	0	0	0	0
No characteristic cherry tomato flavour	0	0	0	0	0	3 (+)**	0	0	0
Pulpy	1	2	1	0	2 (+)*	0	1	0	0
Soft	0	0	0	0	1	2 (+)*	0	0	0
Crunchy	0	2	0	4	0	0	1	2	4
Firm	2	3	0	3	0	0	0	3	3
Smooth	1	0	1	0	4 (+)***	1	3 (+)*	0	0
Peel resistance to mastication	1	2	0	2	0	0	0	0	1
Sweet aroma	0	0	0	3	0	0	0	0	6 (+)***
Acidic aroma	2	3	2	0	0	2	1	1	1
Green aroma	0	0	0	0	0	1 (+)**	0	0	0
No characteristic aroma	0	0	0	0	0	2 (+)**	0	0	0

$^{+}$or (−) indicates that the observed value is higher or lower than the expected theoretical value according to the chi-square per cell test at a significance level of
$^{*}P \leq 0.05$, $^{**}P \leq 0.01$ or $^{***}P \leq 0.001$.

Consumers

One hundred and ten consumers (62 women and 48 men of ages ranging from 18 to 65 years) who liked and ate tomatoes took part in the study. They were recruited from employees and trainees at Embrapa Food Technology, Rio de Janeiro, RJ, Brazil. Samples were monadically presented to participants in sensory booths under white illumination, in white porcelain saucers coded with three-digit numbers, and served at room temperature. The order of presentation of samples was balanced to prevent carry-over effects and followed a complete block design.[49]

Participants were asked to evaluate how much they liked the organic cherry tomatoes after tasting them and to rate their liking on a nine-point structured scale varying from 1 (disliked extremely) to 9 (liked extremely). They also evaluated how much they liked the appearance of the fruits using a similar hedonic scale. The participants then evaluated the samples' sensory characteristics using the CATA methodology. A list with 21 sensory and hedonic attributes was presented to consumers and they were asked to mark those that described each sample according to their perception. The words were identified based on previous qualitative and quantitative studies developed with cherry tomatoes in the same laboratory, in which a trained panel described organic cherry tomatoes. The following terms were used: acid, crunchy, odd appearance, large, watery, smooth, nice aroma, overripe, nice flavour, different size, sweet, delicious, salty, pale, thick, bad taste, attractive colour, juicy, off-odour, shiny and small.

Demographic information (gender, age, education and income level) as well as frequency of tomato consumption was collected from participants.

Data analysis

Chefs' descriptions

The descriptions provided by the chefs in the open-ended question were qualitatively analysed. First a search for recurrent terms was performed. Terms with similar meaning were grouped into different categories within each cherry tomato genotype. This classification was performed by three researchers considering word synonymy. After the data had been individually evaluated, a meeting of the researchers was undertaken in order to check the agreement between their classifications. Frequencies in each category were determined by counting the number of chefs who used those words to describe each genotype.

A global chi-square test was used for testing the independence between rows and columns of the contingency table of chefs' descriptions for the nine genotypes. When the initial chi-square was significant, a chi-square per cell test could be used to identify the source of variation of the global chi-square.[50] In the present work, this test was carried out as suggested by Symoneaux *et al*.[46]

Correspondence analysis was applied in order to visualise the relationship between samples and descriptions. Correspondence analysis is a descriptive/exploratory technique designed to analyse simple two-way contingency tables containing some measure of correspondence between the rows and columns. Using this technique, row and column variables were spatially represented, which allowed a visual representation of the data.[51]

Check-all-that-apply (CATA) question

For the CATA question, the number of terms used by each participant for describing each sample and the frequency of mention were determined by counting the number of consumers that used that term. Cochran's *Q* test was carried out for each of the terms of the CATA question, considering sample and consumer as sources of variation, to evaluate if the CATA question was able to detect differences in consumers' perception of the evaluated cherry tomato accessions. Cochran's *Q* test is a nonparametric statistical test that is used in the analysis of two-way randomised block designs to check whether *k* treatments have identical effects when the response variable is binary.[52]

Correspondence analysis (CA) was used on the frequency table of CATA counts to get a visual representation of the samples as well as a relationship between terms and samples.

Multiple factor analysis (MFA) was performed on the frequency tables of chefs' descriptions and consumers' responses to the CATA question in order to identify relationships between the sample configurations provided by the two methodologies and to study relationships between the terms used by the two groups to describe the samples. The RV coefficient between the two sample configurations was also calculated.

Liking scores

Analysis of variance (ANOVA) was carried out on consumers' overall liking and appearance liking scores, considering sample and consumer as sources of variation. When differences were significant at a confidence level of 95%, Tukey's test was used for *post hoc* comparison between samples.

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.

External preference mapping

External preference mapping was used to link consumers' overall liking scores and sample configuration from the sensory characterisation performed using the CATA question. This analysis was carried out as proposed by Danzart *et al*.[53] using SensoMineR[54] in R language.[55] In order to determine the area of the map that maximised consumers' liking, a quadratic response surface was computed per consumer. The area of maximum liking for each consumer was determined as the area where predicted liking scores were higher than the mean score of all evaluated samples for that consumer. Then preference zones were delimited and finally superimposed for the whole consumer sample. This analysis was carried out considering sample coordinates in the CA performed on data from consumer responses to the CATA question.

All statistical analyses were performed using R language.[55] FactoMineR was used to perform CA and MFA.[56]

RESULTS

Description of samples provided by eco-chefs

The chefs were asked to provide a verbal description of the tomatoes by answering an open-ended question. Table 1 shows the terms provided by the chefs for the nine organic cherry tomato samples. One can see that they mainly provided sensory and hedonic terms, and the words beautiful, sweet taste, firm, crunchy, smooth, acid taste, acidic aroma, different size, sweet aroma, attractive and different colour were the most frequently used terms. Several of these have been used by trained assessor panels for sensory characterisation of tomatoes using quantitative descriptive analysis.[17–21]

Results from the global chi-square test performed on the contingency table (Table 1) showed that chefs' descriptions of the

genotypes were significantly different ($\chi^2 = 408.15$, $P \leq 0.0001$), suggesting differences in the sensory characteristics of the evaluated tomatoes. In order to identify differences between samples for each of the terms, the chi-square per cell test was used.[49] Significant differences between samples were found for 21 out of the 35 identified terms. No significant differences between samples were found for the terms attractive, beautiful, savoury, small size, different size, thick skin, acid taste, fruity taste, no flavour, few seeds, crunchy, firm, peel resistance to mastication and sour aroma.

According to the chefs' perception, ENAS 1012 was characterised by its higher salty taste, whereas ENAS 1017 was described as having a different colour, sourness and green flavour. ENAS 1019 was perceived as shiny, sweet and wild, whereas ENAS 1031 received a higher number of mentions for the terms bitter, characteristic cherry tomato flavour, pulpy and smooth. On the other hand, ENAS 1033 showed a differential sensory profile, being soft with green aroma and no characteristic cherry tomato flavour or aroma. ENAS 1037 was described as a regular-sized smooth cherry tomato, whereas JPR was mainly described as a standard table tomato. Finally, Sweet Grape was described as a thick and sweet tomato with sweet aroma.

CA was used to obtain a representation of the samples based on the descriptions provided by the chefs. The first three dimensions of the CA explained 60.0% of the total variation of the experimental data, corresponding to 25.4, 18.9 and 15.7% for the first, second and third dimensions respectively. Hierarchical cluster analysis was carried out to identify groups of samples with similar descriptions. Accession ENAS 1033 was located in a differential position in the first and second dimensions of the CA, being characterised by its softness, green aroma and lack of characteristic aroma and flavour. The chefs described ENAS 1019 and Sweet Grape by their shine, sweet aroma and sweet and fruity flavour. On the other hand, ENAS 1031 was located at the bottom right corner of the CA representation of the first and second dimensions (Fig. 1). In this figure the squares are tomato samples and the diamonds are sensory attributes elicited by chefs. This genotype was described as a regular-sized cherry savoury tomato with bitter taste and characteristic cherry tomato flavour. JPR appeared separated from the rest of the genotypes in the representation of the first and third dimensions of the CA. It was described as a standard table tomato. Two other groups of samples were identified: one composed of samples ENAS 1013 and ENAS 1012 and the other composed of samples ENAS 1017 and ENAS 1037. These genotypes showed intermediate sensory characteristics and were located at a central position in the CA representation.

Check-all-that-apply (CATA) question results

Consumers checked between 0 and 12 terms of the CATA question to describe the evaluated organic cherry tomato samples. The most frequently used terms were attractive colour, nice flavour, nice aroma, different size, smooth, thick, acid and juicy. Most of these attributes are positive for tomato sensory quality, which might indicate a positive hedonic perception from consumers. On the other hand, the least-used terms were off-odour, pale and overripe, which are negative sensory characteristics for cherry tomatoes.

Table 2 shows the frequency of the terms from the CATA question used to describe the evaluated cherry tomato accessions. According to Cochran's *Q* test, significant differences were found in 20 frequencies from the 21 terms used by participants. These results suggest that the attributes used in CATA were able to detect differences in consumer perception of the sensory characteristics of the evaluated cherry tomato accessions. The only term that no significant difference was found was salty, suggesting that consumers did not perceive differences in sample saltiness.

CA was carried out on CATA counts to obtain a visual representation of the samples based on consumer perception. As shown in Fig. 2, the first three dimensions of the CA accounted for 84.5% of the variance of the experimental data, corresponding to 36.5, 30.9 and 17.1% for the first, second and third dimensions respectively. As in Fig. 1, the squares are tomato varieties and the diamonds are sensory attributes and terms marked by consumers.

According to hierarchical cluster analysis performed on sample coordinates in the three first dimensions of the CA, the genotypes could be sorted into five groups with different sensory characteristics. ENAS 1019 and Sweet Grape were located at negative values of the first dimension, being described as sweet, delicious, small and crunchy, whereas ENAS 1017 and ENAS 1037 were located at the opposite position, being described by consumers as watery, overripe, smooth and having an odd appearance, bad taste and off-odour. On the other hand, JPR and ENAS 1031 were characterised by their attractive colour, juiciness, nice aroma and sourness. ENAS 1033 was separated from the rest of the samples in the representation of the first and second dimensions of the CA, being located at positive values of the second dimension as a consequence of being described as pale by consumers. ENAS 1012 and ENAS 1013 showed intermediate sensory characteristics and were located at a central position in the sample map (Fig. 2).

Comparison of sample maps provided by chefs and consumers

The RV coefficient between sample configurations provided by chefs and consumers was 0.728, suggesting a good agreement. The superimposed representation of the samples in the MFA allows the evaluation of their proximity for each sample. As shown in Fig. 3, sample configurations were very similar for consumers' and chefs' descriptions, although obtained from different methodologies. Conclusions regarding the similarities and differences between samples were similar according to both groups of assessors. Chefs and consumers agreed on sorting samples into five groups with similar sensory characteristics, as previously described. Figure 4 shows the representation of the terms used by chefs and consumers to describe samples in the MFA. The terms provided by the chefs to describe the evaluated genotypes were similar to those from the CATA question and were used similarly. Indeed, descriptions regarding sweetness, crunchiness, size, shine and thickness were highly correlated for chefs and consumers. Moreover, it is interesting to highlight that the term bad taste from the CATA question was correlated with the terms green flavour and green aroma from the chefs' descriptions. It might also be worth commenting on dimensions 1 and 2 in Fig. 4 as they relate to the emergent properties of flavour. Dimension 1 seems to characterise a relationship between the different taste modalities, while dimension 2 captures aspects of the more multimodal properties of flavour. Consumers and chefs seem to use colours or other visual cues (size and shine) to articulate aspects of flavour and aroma.

Consumer liking scores

Average overall liking and appearance liking scores for the nine genotypes are shown in Table 3. Significant differences between

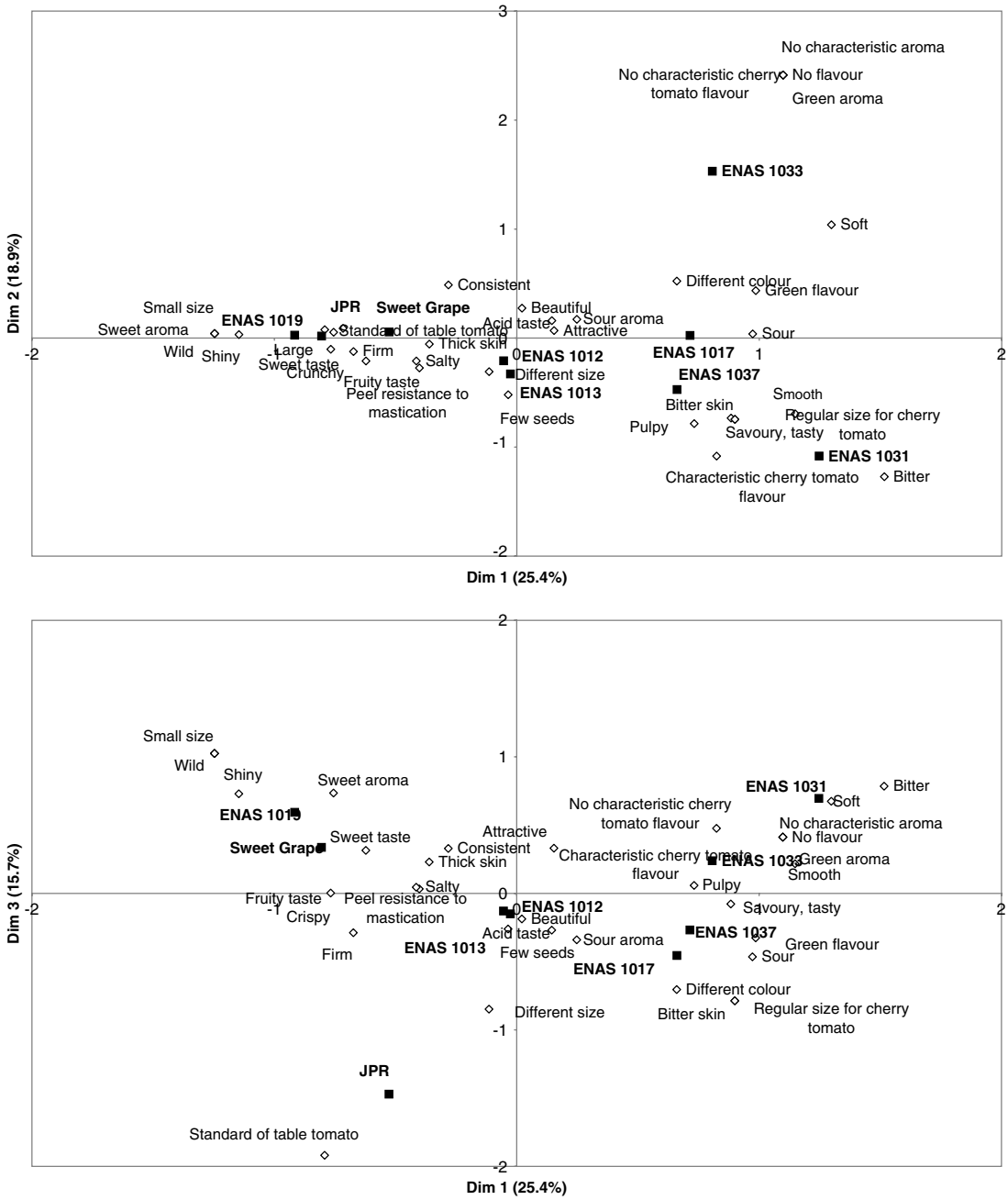


Figure 1. Representation of nine cherry tomato accessions in correspondence analysis performed on frequency table of chefs' descriptions: ■, tomato genotypes; ◊, sensory attributes used by chefs.

samples were found for overall liking ($F = 18.44$, $P \leq 0.001$) and appearance liking ($F = 22.53$, $P \leq 0.001$). As seen in Table 3, Sweet Grape, ENAS 1012 and ENAS 1019 showed the highest average overall liking scores and a very positive hedonic perception when the appearance liking was taken into account. On the other hand, ENAS 1033 and ENAS 1037 had the lowest overall liking scores, which were close to 5, suggesting a negative hedonic perception.

Average appearance liking scores ranged from 5.6 to 7.6. Samples were sorted into two groups according to their appearance liking. Consumers clearly preferred genotypes ENAS 1012, ENAS 1019, ENAS 1031, JPR and Sweet Grape, which received appearance liking scores higher than 7.

Two consumer segments with different preference patterns were identified: cluster 1 with 73 consumers and cluster 2 with 37 individuals. Cluster 1 preferred a group having five samples composed of ENAS 1012, ENAS 1013, ENAS 1019, JPR and Sweet Grape, whereas cluster 2 showed a strong preference for ENAS 1012, ENAS 1031 and Sweet Grape. It is interesting to highlight that ENAS 1012 and Sweet Grape were among the preferred samples for both consumer segments. Figure 5 shows the average overall liking scores of the nine cherry tomato accessions for the two identified consumer segments using hierarchical cluster analysis. According to the chi-square test, no significant differences between the two clusters were found in terms of their gender, age, education, economic income or frequency of tomato consumption.

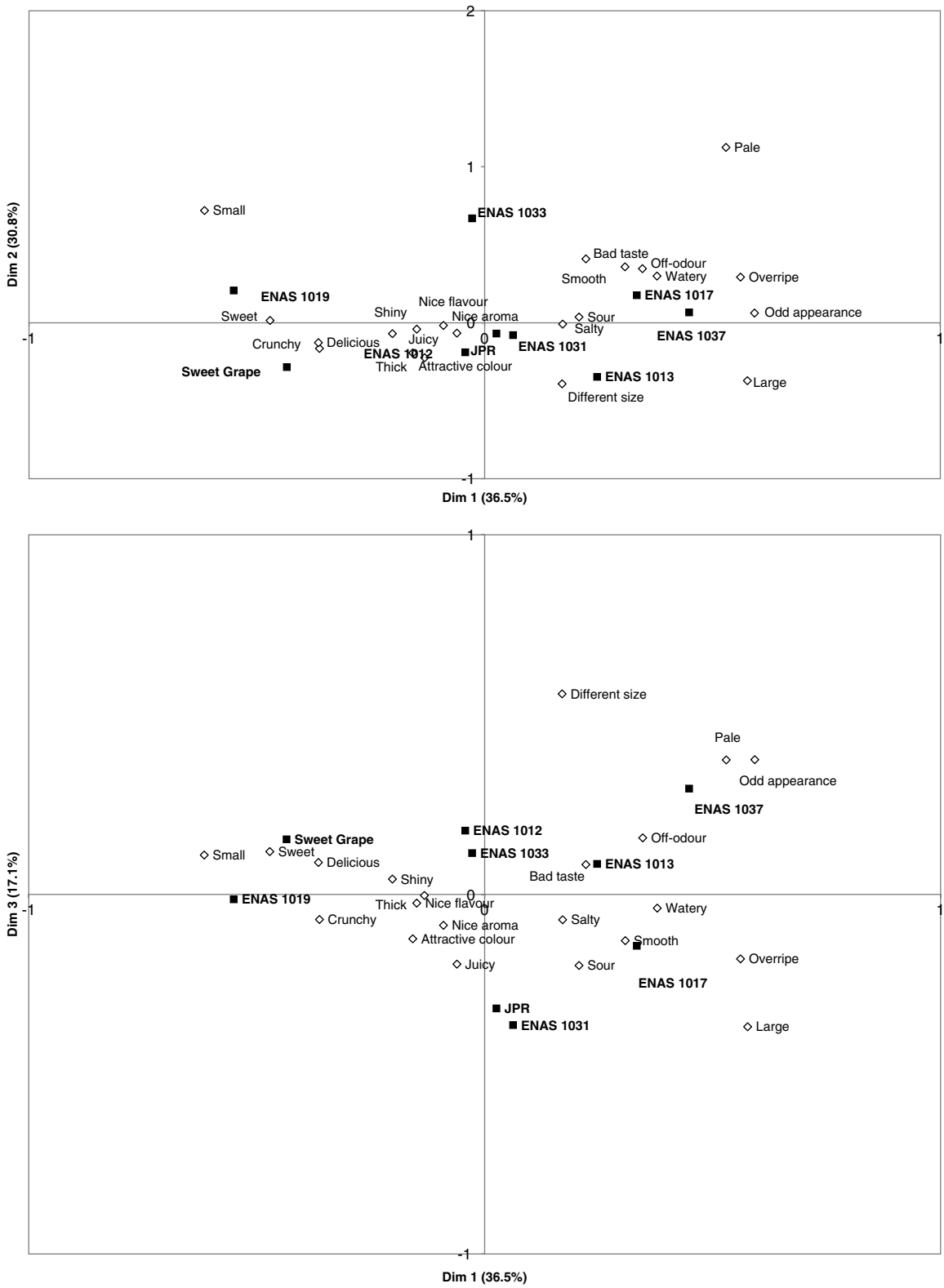


Figure 2. Representation of nine cherry tomato accessions in correspondence analysis performed on frequency table of consumers' responses to CATA question: ■, tomato genotypes; ◊, terms marked by consumers.

Table 2. Number of mentions per sample for terms of CATA question used by consumers to describe nine cherry tomato accessions, and results from Cochran's *Q* test

	Sample								
Term	ENAS 1012	ENAS 1013	ENAS 1017	ENAS 1019	ENAS 1031	ENAS 1033	ENAS 1037	JPR	Sweet Grape
Acid***	30	33	45	30	35	22	40	57	15
Crunchy***	32	24	21	40	21	12	5	31	46
Odd appearance***	23	41	39	1	4	24	42	6	11
Large***	8	65	33	0	46	0	30	42	6
Watery***	17	18	30	7	16	29	24	21	4
Smooth***	36	18	53	19	48	56	45	37	5
Nice aroma***	38	46	40	45	45	40	28	53	58
Overripe***	4	3	14	1	12	8	14	7	1
Nice flavour***	60	51	48	61	55	42	29	43	70
Different size***	79	78	13	21	10	11	82	16	61
Sweet***	13	11	14	25	15	25	8	14	55
Delicious***	18	18	11	21	14	16	6	14	40
Salty^{NS}	15	15	13	13	18	10	21	19	9
Pale***	0	4	9	0	2	26	13	2	0
Thick***	26	47	22	38	35	15	30	38	60
Bad taste***	5	12	16	17	12	27	31	18	7
Attractive colour***	63	58	27	59	73	27	33	69	75
Juicy***	41	32	34	33	44	24	16	45	36
Off-odour*	3	4	9	4	6	9	13	3	4
Shiny***	34	32	15	43	32	26	29	34	50
Small***	17	2	12	84	10	61	14	17	21

Asterisks indicate significant differences according to Cochran's *Q* test at
***$P \leq 0.001$ or *$P \leq 0.05$, while NS indicates no significant difference ($P > 0.05$).

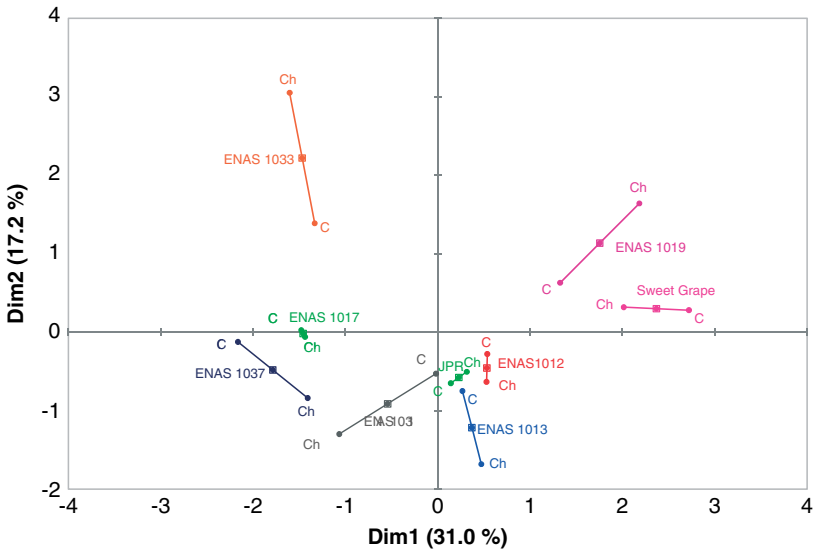


Figure 3. Partial representation of nine cherry tomato accessions in multiple factor analysis performed on chefs' descriptions and consumers' responses to CATA question: ■, tomato genotypes; C, consumers; Ch, chefs.

External preference mapping

Figure 6 shows the external preference map based on the samples' configuration in the CA of CATA counts. In the sensory map the samples are located according to their sensory characteristics, whereas the lines and colour represent zones of the map that correspond to different percentages of consumers who scored their overall liking higher than the average for all samples. The contour plot shows different lines corresponding to different percentages of consumers who scored their overall liking higher than their average score of all evaluated samples. For example, samples located on the line close to sample ENAS 1037 correspond to those for which only 30% of the consumers scored their overall liking higher than their average score for all samples. From right to left the percentage of consumers increased, going from 30 to 80% (Fig. 6), whereas the lighter the colour, the higher the percentage of consumers who liked the samples more than average.

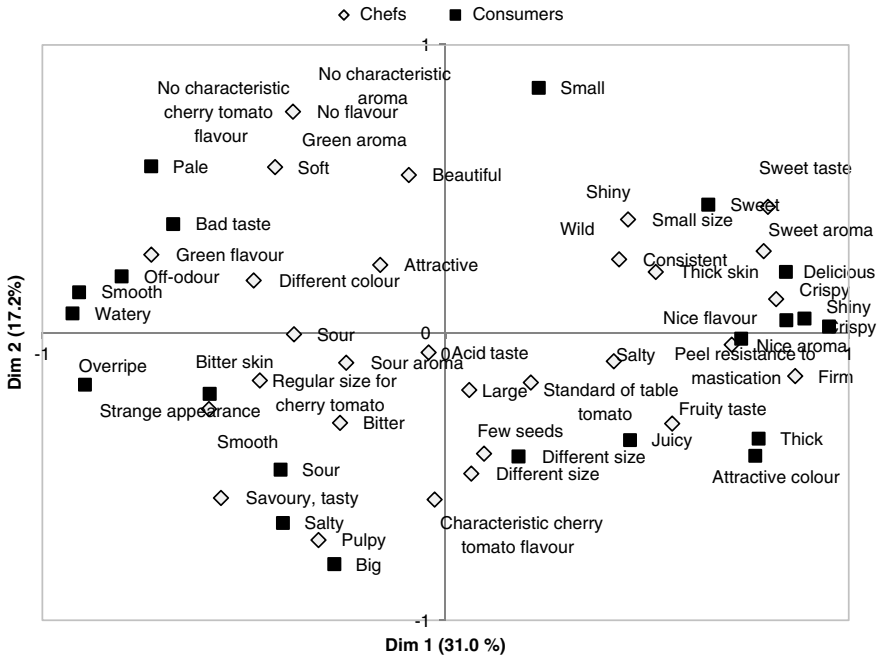


Figure 4. Partial representation of terms used to describe nine cherry tomato accessions in multiple factor analysis performed on chefs' descriptions and consumers' responses to CATA question.

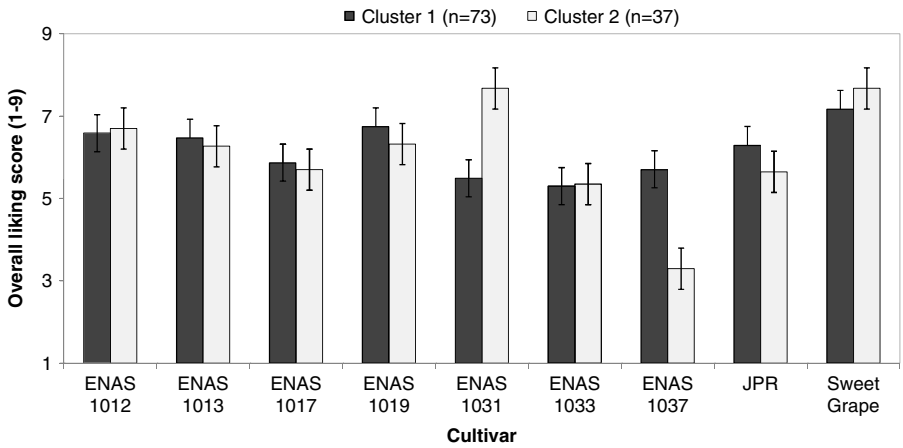


Figure 5. Average overall liking scores of nine cherry tomato accessions for two consumer segments identified using hierarchical cluster analysis.

The external preference map showed that genotypes ENAS 1017, ENAS 1033 and ENAS 1037 were located in an area where the percentage of consumers who liked them range from 20 to 40%, which is in agreement with their lower mean overall liking scores (Table 3) and the fact that they were not among the preferred samples for either of the identified consumer segments. On the other hand, the most liked samples (i.e. ENAS 1019, ENAS 1012 and Sweet Grape) were located close to zones where the percentage of consumers who scored their overall liking higher than the average score was higher than 70%, as shown in Fig. 6. Coincidentally, ENAS 1012 and Sweet Grape were among the preferred genotypes for both consumer segments.

Besides, Sweet Grape was located in the zone of optimum liking, suggesting that its sensory characteristics might satisfy the sensory expectations of the great majority of consumers. It is worth highlighting that there was only one area of maximum liking in the sensory space defined by consumer responses to the CATA question, suggesting that consumers' sensory preferences for the evaluated cherry tomato accessions were highly homogeneous.

The advantage of applying external preference mapping is that drivers of liking and disliking could be identified based exclusively on consumers' perception. As shown in Figs 2 and 6, samples located in the area of maximum liking of the sensory space were described by consumers as sweet, crunchy and delicious, which indicates that these are the main drivers of consumer preferences for cherry tomatoes. On the other hand, samples that were not accepted by consumers were located in areas of the sensory map associated with terms such as off-odour, pale, overripe, odd appearance, watery and smooth (Figs 2 and 6).

DISCUSSION AND CONCLUSIONS

Results from the present work allowed the identification of the sensory characteristics of nine organic cherry tomato genotypes as perceived by chefs and consumers, as well as consumer

Table 3. Average overall liking and appearance liking scores[a] for nine cherry tomato accessions

Accession	Overall liking	Appearance liking
ENAS 1012	6.6de	7.0b
ENAS 1013	6.4 cd	5.8a
ENAS 1017	5.8bc	5.6a
ENAS 1019	6.6de	7.2b
ENAS 1031	6.2 cd	7.6b
ENAS 1033	5.3ab	6.0a
ENAS 1037	4.9a	5.9a
JPR	6.1 cd	7.4b
Sweet Grape	7.4e	7.6b

Values within a column with different letters are significantly different according to Tukey's test at a confidence level of 95%.
[a] Evaluated on nine-point structured hedonic scales varying from 1 (disliked extremely) to 9 (liked extremely).

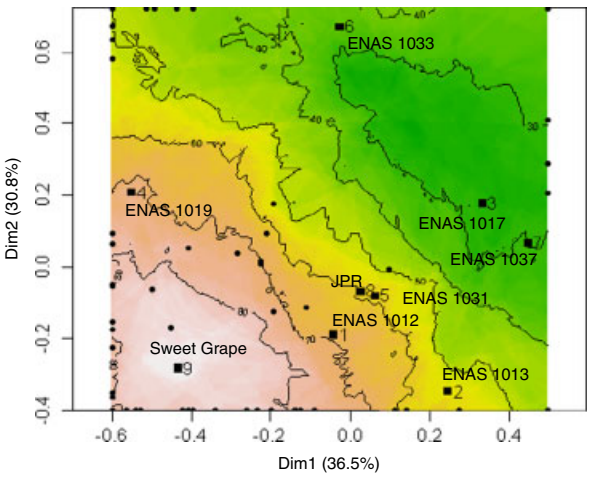


Figure 6. External preference map based on consumers' perception of sensory characteristics of samples. Sample coordinates are those from correspondence analysis of consumers' responses to CATA question.

preferences. These results may provide information to help organic producers select the most promising varieties for cultivation, taking into account consumer expectations. Most of the genotypes showed high overall liking scores, with average values ranging from neutral (5) to liked moderately (7). This suggests that organic production of cherry tomatoes might represent a good potential for small producers. Information on organic production has been reported to improve consumer preferences of tomatoes,[23] which could even increase consumer liking and purchase intention of the evaluated tomatoes. Despite the fact that consumers might purchase organic products for health, animal welfare and environmental reasons,[28] sensory quality plays a key role in determining loyalty and willingness to pay a premium price.[57] Therefore organic production of cherry tomato accessions with a high overall liking score might be an interesting market opportunity for an added value product.

Information on the sensory characteristics of the evaluated samples from a consumer and chef perspective could be useful for the design of communication and marketing strategies when commercialising single cherry tomato accessions.

Sweet Grape, characterised by its crunchiness and sweetness, was identified as the most preferred accession for consumers considering both overall liking and appearance liking scores. This result is similar to others reported in the literature,[21,23] which suggests that sweetness is a key driver of liking of fresh tomatoes. Pagliarini *et al.*[21] identified two consumer segments when evaluating eight fresh tomato cultivars in Italy. One segment preferred the Cherry-Pachino tomato, whose main characteristic was sweet taste and red colour, whereas the second segment preferred the Sardegna tomato, with high acidity and typical texture. Moreover, in a study conducted with French consumers by Lê and Ledauphin,[58] three consumer segments were identified. The first segment (39.8%) did not show any preference for regular-sized tomatoes or salad-type tomatoes, with firmness being one of the major drivers of purchase intention. Flavour, aroma and sweetness were the main drivers of liking for the second segment (39.6%), whereas sweetness was not an important attribute for the third segment (20.6%). In the present work, two consumer segments were identified but did not show such different preference patterns. For both consumer segments, Sweet Grape, characterised by its intense sweetness, was among the preferred samples.

It is important to take into account that, in real-life situations, consumer choices might not be determined solely by products' sensory characteristics, particularly when dealing with organic products. Consumer choices are determined by the specific situation, previous experiences with the product and available information, as well as by consumer attitudes and beliefs. In this context it might be interesting to study the influence of price and production system information on consumer liking and purchase intention of Sweet Grape cherry tomatoes produced under organic conditions.

The present study shows preliminary evidence of sensory differences and consumer preference for organic cherry tomato accessions. However, further studies should be carried out under different environmental conditions and several harvests to validate the recommendations for organic producers in Brazil.

From a methodological point of view, results from the present work suggest that the application of CATA or open-ended questions could provide valuable data for the sensory characterisation of new cultivars in breeding programmes, as previously reported by Lado *et al.*[36] Both methodologies enabled the identification of the main sensory characteristics of nine cherry tomato accessions, as well as similarities and differences between them. However, it is important to highlight that descriptive analysis with a trained assessor panel might have provided more accurate information owing to the fact that assessors are extensively trained in the identification and quantification of sensory attributes. Despite the high quality of the information provided, this methodology is expensive and time-consuming, which makes it difficult to apply in many everyday situations where there are constraints in terms of time and resources. In the particular case of breeding programmes, it might be difficult to have products with constant sensory characteristics for training the panel owing to the high variability of weather conditions. In this context, when quick non-detailed information about the sensory characteristics of agricultural products is needed and/or when there is not enough time or resources to train a panel for evaluating a specific product, consumer profiling methodologies seem a very good alternative. In these cases the cost and time involved in the selection and training of assessors might be higher than those needed to perform a consumer study with 50–150

participants. Moreover, consumer profiling methodologies could also be particularly interesting when conducting preliminary studies on the sensory characteristics of new cultivars or when performing a screening for the selection of products or conditions for the design of a larger experiment.

Despite the fact that different methodologies were used by consumers and chefs, similar sample maps were obtained, which indicates a relatively stable perception among the two panels. This information is in agreement with other studies reporting that sample configurations from chefs and consumers are highly similar.[47,59] Besides the different methods used in this study, it is also important to emphasise the context in which the samples were evaluated: chefs were together at a round table, as a group, in an open discussion environment; on the other hand, consumers evaluated tomatoes in sensory booths, i.e. in isolation, without talking to each other. Taking into account this situation and the importance that the context plays in product perception,[60–62] further studies should consider the role of the context involving consumers' evaluation. Would consumers choose similar attributes and terms in the CATA test if they were evaluating the cherry tomatoes in the context of a salad while sitting at a dinner table? Additional studies to answer such questions might be developed to help create ecologically relevant marketing terms and better understand consumers' views on and perception of organic cherry tomatoes.

Finally, sensory and consumer science have not extensively study culinary experts' perception of food products, which might be particularly relevant for the commercialisation and marketing of gourmet products such as organic cherry tomatoes.

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