Original article

Exploring through CATA (Check-All-That-Apply) method the Italian consumers' perception towards off-season nectarine imported from Chile

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Summary

The Chilean fresh nectarine industry is focused on proposing off-season fresh fruit on foreign markets. Chilean nectarines for European markets would require fruits that should be kept in cold chambers for up to 35 days, due to the transcontinental trip for reaching the market.

Samples of eight nectarine genotypes harvested in Chile between end of December and January 20th, were sent to Bologna, Italy, for testing them in February. The batch included some traditional varieties and some yellow- and white-fleshed nectarines selected in the Chilean breeding program, for tolerance to long storage and transport. Test participants were requested to execute a CATA (Check-All-That-Apply) test on visual and eating attributes, expressing also an overall liking evaluation. At the same time a trained panel performed a descriptive analysis to compare consumer assessments with judges' evaluation.

CATA results indicated that the most appreciated visual attributes were size, color, shape and lightness. As related to eating attributes, the most cited terms were positive flavor, sweetness and freshness. The white-fleshed nectarine 6B168 recorded both the highest frequency of citation of attributes and the highest hedonistic evaluation (7.03) described as aromatic, with positive flavor, soft, melting, juicy and sweet. Other varieties as 'Andesneccuatro' and 'Andesneccuno', recorded positive evaluations. Consumers' evaluation through CATA resulted in agreement with trained panel judgments, indicating the suitability of this method for reaching a reliable sensory characterization of fresh nectarines.

Keywords

Chilean nectarines, consumer test, fruit, trained panel test, quality, sensory evaluation

Introduction

The Chilean fresh nectarine industry is focused on proposing off-season fruit on foreign markets. Due to intercontinental fruit markets, exporting Chilean nectarines to Europe would require fruits that could be kept in cold chambers for up to 35 days. One of the most important problems of the Chilean peach and nectarine industry is that fruit is prone to chilling injury which affects its quality (Lurie and Crisosto, 2005; Pedreschi and Lurie, 2015). This situation causes the

Significance of this study

What is already known on this subject?

- There are few studies of sensory consumer science performed on fruit produced in other continents, which have been submitted to transport and cold storage for a long period. There is practically no information on how nectarines behave in terms of eating quality after prolonged cold storage. Further, these varieties have been bred for standing long postharvest periods, so this is also an attribute that should be evaluated properly and with real target consumers.

What are the new findings?

- New varieties of nectarines produced in Chile have better quality characteristics than traditional varieties; this means that the Chilean nectarine breeding program has been successfully addressed. In terms of methods, the Check-All-That-Apply (CATA) analysis appears as an effective tool for defining the potential of new nectarine varieties in target markets.

What is the expected impact on horticulture?

- This study reveals, for the first time, that there is a new group of nectarine varieties that could be the base for building a global market for fresh nectarines that will be able to allow the round-year fruit supply. On the other hand, the study is useful to assess the market potential of new nectarine varieties from the Southern Hemisphere to be consumed in Europe, according to consumers' hedonistic judgments and attitudes, regarding off-season fruit consumption.

disappointment of the consumers, so it turns into an economic problem. For that reason, breeding programs play an important role to resolve it. The new varieties that are created for a global market must consider maintaining the highest sensory quality after long postharvest periods. Sensory profile and instrumental analyses are useful tools to assess product quality and market potential (Infante et al., 2008b). However, previous studies showed differences in consumer preferences about peaches and nectarines produced in Europe and consumed in the same European countries (Bonany et al., 2014; Giacalone et al., 2006). Actual Rapid Sensory Methods (Delarue, 2015; Ares and Varela, 2018) are adequate to integrate instrumental measurements and trained panel evaluations with consumers' judgments.

To explore commercial potential of nectarines it is of great importance to assess both consumers' expectations related to visual appeal, and the confirmation of choice at consumption, since visual appeal of fruits is of relevance for buying choices (Mora et al., 2011; Kelley et al., 2015), but it can be confirmed or disconfirmed after consumption (Piqueras-Fiszman and Spence, 2015). Check-All-That-Apply (CATA) (Adams et al., 2007) is a sensory analysis method adequate for exploring this issue. CATA is a type of sensory analysis in which consumers (50–100) are asked a certain question and respond by selecting one or more applicable answers from a list of words. This method has the advantage of allowing multiple options to be selected, and is considered to be a fast and easy method for the collection of information about consumer perception of the sensory characteristics of food products (Varela and Ares, 2012; Bruzzone et al., 2015; Ares and Varela, 2018).

There are few studies of CATA analysis applied to fresh fruits, but an interesting example is the use of this method for assessing the quality of fresh strawberry genotypes derived from a breeding program (Lado et al., 2010). The results showed that CATA questions could be an interesting and simple approach to gain insight into consumer perception of new fruit varieties. It was also observed that consumers' responses to the CATA questions were in agreement with physic and chemical differences between the samples, which suggests the validity of consumer data in assessing the sensory characteristics of the evaluated strawberry varieties (Lado et al., 2010).

The objective of the study was to assess the market potential of new nectarine varieties and selections developed in the Southern Hemisphere to be consumed in Italy, integrating physical and chemical measurements associated to a trained panel sensory evaluation and to consumers' hedonistic judgments.

Materials and methods

Samples of eight nectarine genotypes, harvested in Chile between the end of December and January 20th, were sent to Bologna, Italy, for trained panel and consumer tests to be conducted during February. Harvest was performed in accordance with ripening of the cultivars used in this trial. Nectarines were harvested when the flesh reached a range of firmness, measured with a hand-portable penetrometer (Effegi, Alfonsine, Italy), between 11 and 12 kg in a sample of fruits. Fruits were kept in cold storage (0°C and 90% R.H.), even during the air transport in a special container, until three days before test, when they were conditioned at room temperature (20 ± 2°C) to simulate a shelf-life period. Fruits were weighted and the diameter was measured. Representative fruits of each genotype were used to determine flesh firmness and total soluble solids (TSS). Firmness and TSS were determined on a sample of 15 fruits per each genotype, and measured with a hand portable penetrometer (Fruit tester, Effegi, Alfonsine, Italy) fitted with an 8.0-mm probe, after removing a piece of skin, on diametric opposite "cheeks" of each fruit. TSS was determined on a fruit juice sample using a portable refractometer (Brixstix, Techniquip Corporation, Livermore, CA). Titratable acidity was also assessed (Titralab AT1000, Hach, Loveland, Colorado).

Trained panel test

A trained panel of 10 judges, with experience in fresh fruit sensory evaluation, received a further specific training on how to recognize and evaluate each descriptor on nec-

tarine samples, by using intensity scales (ISO 8586:2012). Sensory analysis, by trained panel, was performed at appropriate temperature conditions, in individual booths with notebooks equipped with a specific software for sensory data acquisition (FIZZ Biosystèmes, France), in line with the standard protocol UNI 8589:1990. Tests were carried out in duplicate, under the conditions described in the standard UNI 13299:2016 for the descriptive analysis.

For the evaluation, fruit were cut in slices about 1 cm width, and put into plastic dishes. Each tested nectarine genotype was coded with a three-digit number. Judges evaluated by Descriptive Analysis (DA) all the samples/varieties in a randomized sequence, rating all the attributes using a 9-point intensity scale from 1 = "absence of perception" and 9 = "maximum perception". The descriptors established for the DA test were: peach odor, crunchiness, firmness, juiciness, melting, fibrousness, mealy, sweet, acid, bitter, astringent, peach flavor, floral flavor, grass (green) flavor (Belisle et al., 2017), freshness (Péneau et al., 2009) and overall quality (Konopacka et al., 2014). The meta-descriptors freshness and an overall quality score were request to judges in order to evaluate the consistency with consumer hedonic judgment (Péneau et al., 2007; Massaglia et al., 2019; Dinella et al., 2014).

To avoid odor mingling, smell evaluation was conducted by placing whole fruits of single varieties in a booth, while having judges moving, to smell each sample in a randomized order, and to sign the perceived intensity on a score sheet.

Consumer test

Consumers ($n=85$, 45 females, 40 males, aging 26–63 year) evaluated all the samples in a randomized order, expressing for each sample a hedonistic judgment (scale 1: dislike extremely; 9: like extremely) and executing a CATA (Check-All-That-Apply) test, first on visual and then on eating attributes of the sample. Before starting the session, the consumers received from the panel leader detailed instructions on how to answer the CATA questionnaire, and a short description of each visual and taste/flavor aspect cited. Participants were asked to check all the terms that they considered appropriate to describe each sample, without any constraint on the number of attributes they could select. The CATA questionnaire included 37 attributes addressed to describe the sensory characteristics perceived. The terms considered were the following:

- visual aspects: brightness, lightness, large blush, little blush, color equilibrium, color homogeneity, size (large, regular, small), shape (typical, round, elongated, anomalous), turgidity, regular surface, bumps and wrinkle;
- eating traits: aromatic odor, firmness, hardness, crunchiness (first bite), crunchiness (eating), soft, mealy, melting, juiciness, sweet, fibrousness, acid, bitter, astringent, peach flavor, floral flavor, grass flavor, negative flavor, positive flavor, fresh.

These attributes were established based on attributes evaluated by trained assessors and also from previous studies (Infante et al., 2008a; Péneau, 2007).

The presentation order of the terms was counterbalanced between and within participants for each category (visual and eating traits), with the samples' order randomized to prevent any statistical effects of order or carryover (Ares et al., 2014).

Statistics

Statistical analysis was performed using R version 3.5.3 (© 2019, The R Foundation for Statistical Computing) with

statistical significance determined using an alpha value of 0.05 unless otherwise stated.

One-way analysis of variance (ANOVA) followed by *post hoc* Tukey test was performed on physical and chemical analyses. Two-way analysis of variance followed by *post hoc* Tukey test was performed on sensory descriptive analyses data scores considering sample and replication effect. One-way analysis of variance (ANOVA) followed by *post hoc* Tukey test was performed on the overall liking scores of consumer test considering sample as fixed source of variation and consumer as random effect.

Correlation analysis (Pearson correlation) was performed on freshness and quality score (from trained panel test) for their correlation with sensory attributes.

Principal Components Analysis (PCA) was performed to sensory profiles data and partial least square regression (PLSR) analysis were used to study the relationship between sensory profiles defined by trained panel, instrumental analyses and consumer liking. PLSR analysis was performed considering sensory profiling data as X matrix and average liking scores by product as Y matrix (hedonic data).

Frequency of use of each sensory attribute was determined by counting the number of consumers that used that term to describe each sample. Cochran's Q test was carried out to identify significant differences between samples for each of the terms included on the CATA question (Parente et al., 2011). Correspondence analysis (CA) was used to get a bidimensional representation of the samples and the relationship between samples and terms from the CATA question. This analysis was performed on the contingency table containing the samples in rows and the terms from the CATA question on the columns. Multiple factor analysis (MFA) was conducted using FactoMineR in R to examine the similarities between the descriptive profiles performed by trained panel and CATA counts and overall liking performed by consumers.

Results

Physical and chemical analyses

A marked genetic variability between varieties is shown in Table 1. The tested nectarine genotypes varied in weight, with 'Ruby Diamond' being the lighter, while 'Andesneccuatro' (+39%), 'Magique' (+47%), and especially 24B106 were the heaviest (+69%), recording also the largest diameter. The varieties 'Andesneccuatro', 'Andesnectres', 'Andesnecuno' and 'Venus' exhibited the highest flesh firmness, while 'Ruby Diamond', 'Magique' and 6B168 were softer. The variety 'Andesneccuatro' recorded the highest TSS, while having a TSS/

acidity ratio similar to 'Venus', due to the low TSS and acidity levels recorded for the latest.

Trained panel test

Genotypes were clearly differentiated by judges for most of the proposed attributes (Table 2). Regarding peach odor, 'Andesneccuatro' and 'Andesnecuno' recorded significant lower scores compared to the other varieties. These two varieties had the highest firmness, but not significantly different from 'Venus' and 'Andesnectres'. The variety 'Venus' resulted the crunchiest fleshed variety, while 'Ruby Diamond', 'Magique' and 6B168 had low firmness and low crunchiness. The selection 6B168 was clearly the juiciest, followed by 'Magique' and 24B106, and the most melting, with only 'Magique' and 'Ruby Diamond' recording relevant scores for this attribute. Only 'Ruby Diamond' recorded a noteworthy level of mealy. The genotypes 'Ruby Diamond', 'Magique' and 6B168 had the lowest levels of fibrousness.

The selection 6B168 clearly prevailed for being the sweetest, while the varieties 'Magique' and 'Andesnecuno' had the highest acidity. The bitter taste was generally not very intense, but was significantly higher in 'Venus' and 'Andesneccuatro'. This last variety showed being also the most astringent. The selection 6B168 recorded the highest scores for peach and floral flavors, while no differences were found for grass flavor. The selection 6B168 had also the highest evaluation for freshness, comparable to 'Andesnecuno' and 'Magique', and prevailed in the evaluation of the overall quality score. Freshness and quality scores showed a significant positive correlation (0.74; $p < 0.001$). Both freshness and quality resulted positively correlated with peach odor and flavor, juiciness, melting, sweetness and floral flavor, and negatively with mealy and bitter. The quality score was also positively correlated with grass flavor; data not shown. PCA analysis (Figure 1) shows how dimension 1 (55% of the variance), sets on the positive side (right) the genotypes characterized by sweetness, correlated to attributes peach flavor, floral flavor, juiciness, and freshness.

In particular, the selection 6B168 appears defined by this dimension. In the negative side (left), find a place the varieties 'Venus' and 'Andesneccuatro' that are characterized by their hard texture (firmness, crunchiness, fibrousness) and a bitter taste. The dimension 2 (19% of the variance) outlines in the positive quadrants (up), varieties resulting acid, astringent with a green (grass) flavor as 'Andesnecuno'. The negative quadrant of the dimension 2 (bottom) includes genotypes with a relevant peach odor and mealy, as 24B106, 'Ruby Diamond' and 'Andesnectres'.

TABLE 1. Weight, diameter, firmness, total soluble solids, titratable acidity and TSS/TA ratio. Mean values ($n = 15$) followed by the same letter in the same column do not differ in the Tukey test at $p < 0.05$.

Genotype	Weight (g)	Diameter (mm)	Firmness (kg)	Total soluble solids – TSS (°Brix)	Titratable acidity – TA (mL citric acid)	TSS/TA
Andesneccuatro	207bc	71c	5.8a	17.4a	4.7d	3.7a
Andesnecuno	162de	66e	5.5a	14.1c	7.0a	2.0c
Ruby Diamond	149e	64f	2.6c	13.5c	5.6bc	2.4bc
Magique	219b	75b	2.9c	12.1d	6.0bc	2.0c
6B168	189c	69d	2.5c	15.9b	5.1c	3.1b
24B106	252a	80a	4.9b	13.2c	4.9b	2.7bc
Andesnectres	186c	71c	5.7a	13.9c	6.2bcd	2.2c
Venus	172d	68d	5.2ab	10.6e	2.7bc	3.9a

TABLE 2. Descriptive sensory evaluation of nectarine. Mean values (test performed in duplicate by 10 trained judges using a 9-point scale) followed by the same letter in the same line do not differ in the Tukey test at $p < 0.05$.

Sensory attribute	Andes-neccuatro	Andes-necuno	Ruby Diamond	Magique	6B168	24B106	Andes-nectres	Venus
Peach odor	3.8 c	4.0 b	5.1 a	4.7 ab	4.9 a	5.0 a	5.0 a	4.9 a
Crunchiness	4.2 bc	4.9 ab	2.7 d	3.1 d	2.5 d	4.0 b	4.3 bc	5.0 a
Firmness	4.8 a	5.1 a	3.1 c	3.4 c	3.0 c	4.1 b	4.5 ab	4.7 ab
Juiciness	4.3 cd	4.0 cd	3.6 d	5.2 b	6.2 a	4.6 bc	4.1 cd	3.8 d
Melting	3.8 c	3.4 c	4.6 b	5.1 b	5.9 a	3.8 c	3.1 c	3.1 c
Fibrousness	3.7 ab	3.2 bc	3.0 c	2.7 c	2.7 c	3.7 ab	3.5 ab	3.8 a
Mealy	2.3 b	2.0 b	3.6 a	2.2 b	2.0 b	2.1 b	2.2 b	2.6 b
Sweet	4.4 b	4.1 bc	4.5 b	4.4 bc	5.7 a	4.8 b	4.7 b	3.7 c
Acid	3.2 abc	3.7 a	3.1 bcd	3.8 a	3.0 bcd	2.5 b	2.9 cd	3.6 ab
Bitter	2.9 a	2.3 bc	1.9 c	2.2 bc	1.8 c	1.7 c	2.2 bc	2.8 ab
Astringent	4.1 a	3.8 ab	3.2 bc	3.5 abc	2.9 c	2.8 c	3.0 c	3.9 ab
Peach flavor	4.2 bc	4.2 bc	4.6 ab	4.5 b	5.3 a	4.1 bc	4.1 bc	3.6 c
Floral flavor	3.1 b	2.8 bc	3.4 b	3.6 b	4.6 a	3.2 b	2.8 bc	2.1 c
Grass flavor	2.8 a	3.1 a	2.6 a	2.7 a	2.7 a	2.9 a	2.4 a	3.0 a
Freshness	4.0 b	4.8 ab	3.9 b	4.6 ab	5.2 a	4.2 b	4.1 b	4.0 b
Quality score	4.2b	4.9 b	4.5 b	4.7 b	6.2 a	4.8 b	4.5 b	4.1 b

FIGURE 1. Projection of the sensory descriptors and peach samples using Principal Component Analysis (PCA).

Consumer test

Regarding the total counts of CATA evaluation, the visual attributes used to describe nectarines are shown in Table 3. Fifteen attributes out of 18 were found to be significantly different, indicating that consumers perceived differences in the visual characteristics of the evaluated nectarine genotypes. The variety 'Magique' clearly prevailed for brightness and lightness of the skin, and selection 6B168 for its large blush. The large size of fruits of 'Andesneccuatro', 'Andesnecuno' and selection 24B106 was clearly addressed, the same was for 'Ruby Diamond' regarding its small size. Wrinkles, perhaps attributable to mild dehydration, were signaled for the selection 6B168. Fruits received quite high evaluations for visual appeal, with 'Andesnecuno', 'Andesnectres', and 'Venus' recording the highest evaluations. Eating attributes used to describe nectarines, and related frequencies of citation, are shown in Table 4. Of the 21 attributes proposed, 14 varied significantly among genotypes. The selection 6B168 clearly prevailed for peach aroma and positive flavor notes, softness, melting, juiciness and sweetness. The variety 'Andesnecuno' recorded the most frequent citations for firmness, hardness and crunchiness, together with 'Andesnectres' and selection 24B106. About half of the consumers indicated 'Venus' as mealy. 'Ruby Diamond' had the highest frequency of citation for acidity (56% consumers) and astringency (36%). The selection 6B168 recorded the highest number of citations (494, with an average of 7 per consumer), suggesting a relevant interest of consumers for this sample. When comparing visual appeal and satisfaction at eating, 7 out of 8 nectarine genotypes did not confirm the positive score of the visual evaluation, in particular 'Venus' (-2.4; 35%) and 'Ruby Diamond' (-1.6; 25%), falling below the acceptability level (5). Only the selection 6B168 recorded an increase in appreciation when tasted (+0.77; 12%). Figure 2 shows samples and term configurations from the CA performed on the frequency

table containing consumer responses to the CATA terms statistically different between the samples. The first and second dimensions of the CA accounted for 40.9 and 28.9% of the inertia, respectively.

'Ruby Diamond', 'Venus' and 'Magique' were located at positive values of the first and second dimension and were mainly described by acid, astringent and mealiness. In contrast, nectarine 6B168 at negative values on the second dimension, being mainly described by peach, floral and in general positive flavor, sweet, juiciness, softness and melting. Nectarine 24B106, 'Andesnecuno' and 'Andesneccuatro' were located at negative values of the two dimensions and were mainly described by crunchiness, hardness and firmness.

Sensory data provided by trained judges and consumers (frequency of CATA terms statistically different between the samples) were investigated through Multi Factor Analysis (MFA) (Figure 3), which indicates the relationship between variables, the correlation between variables and the dimensions and the relative position of the tested genotypes. The correlation between quantitative variables and dimensions of the MFA (Figure 3A) shows how dimension 1 (46% of the variance) set on the positive side (right) of consumers' liking. Trained judges and consumers agreed in positioning in the positive side attributes such as sweetness, peach flavor, floral flavor, juiciness, melting and freshness. Individual MFA (Figure 3B) shows how the selection 6B168 is defined by these attributes. The negative part is characterized by texture attributes (fibrousness, mealy, firmness, crunchiness) and taste-chemesthetic attributes (bitterness, astringency). 'Venus' is the variety with the most negative value in dimension 1, followed by 'Ruby Diamond', which consumers associate to mealy and peach aroma. Dimension 2 (22%) discriminates the mealy 'Ruby Diamond', from varieties having the highest impact determined by texture attributes. This dimension shows also some differences between trained judges and

TABLE 3. Frequency of mention (*n*) for the visual Check-All-That-Apply evaluation (*n* = 85). Significant difference for * *p* < 0.05; ** *p* < 0.01; *** *p* < 0.001 performed by Cochran's Q test. Consumer hedonic score was evaluated using a 9-point scale.

Attribute	Andes- neccuatro	Andes- necuno	Ruby Diamond	Magique	6B168	24B106	Andes- nectres	Venus
Brightness***	15	33	31	48	6	32	36	29
Color equilibrium***	20	40	33	30	16	28	42	35
Elongated shape***	5	8	1	5	2	5	4	15
Anomalous shape	6	9	2	5	1	8	1	4
Round shape*	31	30	41	30	42	31	33	20
Typical shape	43	39	43	39	45	37	54	45
Browning***	22	25	26	6	18	27	25	5
Lightness***	23	41	34	55	8	31	39	33
Wrinkle***	4	5	5	1	23	2	5	0
Color homogeneity**	17	18	11	17	32	14	15	20
Large size***	63	62	3	2	5	60	5	5
Small size***	2	0	42	17	16	2	11	17
Regular size***	18	12	36	52	54	11	50	47
Bumps*	8	7	2	8	5	14	4	9
Large blush***	33	27	11	16	52	5	27	36
Little blush***	3	2	17	18	3	28	2	3
Regular surface***	32	38	38	46	33	38	55	56
Turgidity	36	35	29	31	18	36	30	35
Total citations	381	431	405	426	379	409	438	414
Consumer hedonic score	6.7 ab	7.3 a	6.3 ab	6.2 ab	6.3 ab	6.0 b	7.2 a	7.0 a

TABLE 4. Frequency of mention (*n*) for the eating traits Check-All-That-Apply (CATA) evaluation (*n*=85). Significant difference for * $p<0.05$; ** $p<0.01$; *** $p<0.001$ performed by Cochran's Q test. Consumer hedonic score was evaluated using a 9-point scale.

CATA attribute	Andes-neccuatro	Andes-necuno	Ruby Diamond	Magique	6B168	24B106	Andes-nectres	Venus
<i>Odor and flavor</i>								
Aromatic	26	22	9	18	41	24	19	12
Flavor (positive)**	45	49	26	30	64	27	42	23
Flavor (negative)	8	3	16	16	2	13	4	12
Peach flavor**	11	16	13	6	25	16	19	12
Floreal flavor**	19	6	4	19	27	10	6	4
Grass flavor	8	12	10	13	7	15	7	10
<i>Texture</i>								
Crunchiness (first bite)**	33	40	9	32	8	45	46	20
Crunchiness (eating)**	22	49	3	19	3	53	51	19
Firmness**	36	48	15	24	7	32	38	16
Hardness**	27	50	8	24	4	43	44	17
Softness**	26	8	39	20	62	11	16	32
Juiciness**	30	20	20	17	64	19	13	9
Melting**	17	10	21	13	50	5	4	20
Gummy	6	7	11	7	5	8	6	10
Fibrousness	15	9	12	15	3	7	13	23
Mealiness**	13	3	32	11	6	6	9	43
<i>Taste and chemestesis</i>								
Sweet**	51	33	16	24	72	37	30	13
Acid**	6	31	48	29	4	1	5	11
Astringent**	17	22	31	18	3	4	5	6
Bitter	12	2	12	16	2	4	2	6
Fresh	33	34	19	33	35	34	36	18
Total citations	461	474	374	404	494	414	415	336
Consumer hedonic score	6.31 b	6.38 b	4.75 d	5.03 cd	7.03 a	5.37 c	5.68 c	4.56 d

FIGURE 2. Representation of the nectarine samples and CATA attributes, statistically different between the samples, in the first and second dimensions of the Correspondence Analysis (CA).

consumer as related to attributes such as acid and astringent.

Partial Least Square analysis (PLS) (Figure 4) allows the study of trained panel judgments, and consumer liking, for their interactions with instrumental analyses. Perceived and measured firmness are similar, while the ratio TSS/acidity results more correlated to perceived acidity than titratable acidity *per se*. Trained panel quality score (Panel_J) appears correlated to a number of well-known positive attributes, i.e., juiciness, sweetness, melting, floral and peach flavor, while consumer liking shows a clear correlation with TSS in fruit.

Discussion

Nectarine genotypes were deeply described through the multidimensional instrumental-sensory-hedonic integrated approach. All the tested varieties recorded positive visual evaluations, indicating how breeding is efficient in releasing varieties with visually appealing fruits, even when, as in the present research, they are subjected to long storage and a trans-hemispheric transportation. However, the observation of a consistent disconfirmation of judgment expressed on visual traits and eating satisfaction, should be taken in ac-

FIGURE 3. Representation of the projections of the CATA variables and Overall liking from consumers, DA variables from expert panel for the MFA of the peach samples (A) and projection of the peach samples on the factorial plane formed by Dim1 and Dim2 of the MFA (B).

FIGURE 4. Correlation Loadings Plot obtained by the PLS regression model of the 8 nectarine genotypes based on sensory profiles defined by expert panel, consumer liking and instrumental analyses.

count. It is often reported how consumers are not satisfied by eating quality of fresh peaches and nectarines (Crisosto et al., 2003; Ceccarelli et al., 2019). This is an issue that should be considered when a new fruit is introduced to the market. A fruit with well-looking appearance, if it is not coupled to an excellent flavor, could disappoint consumers, and compromise its performance in the market, particularly in the off-season period, when fresh nectarines are quite expensive, and consumer's expectations are high. Thus, to reach consumers' satisfaction, it appears essential to obtain sensory profiles from a trained panel, to be matched with consumer perceived and preferred quality parameters. It is known that the evaluation performed by trained assessors allows to validate the consumer response data, identifying their sensorial preference drivers (Carr et al., 2001; Dupas de Matos et al., 2018; Gatti et al., 2011). In this research, for most of the attributes evaluated, a consensus between judges and consumers was recorded. Indicating the potential of trained panel in predicting consumer perception of the products. However, for some traits important for appreciation, such as astringency and bitter, some discrepancies were found. This was expected, partly due to the complexity of astringency perception (Thomas and Lawless, 1995) and since the perception of these stimuli has genetic bases (Bartoshuk et al., 1988; Drewnowski et al., 1997; Bajec and Pickering, 2008), determining relevant differences in consumer individual sensitivity. Furthermore, when interesting traits are identified, it is possible to improve varieties to better satisfy consumers (Infante et al., 2011) for a target market.

Among the tested varieties, 'Venus' recorded the lowest quality scores from the trained panel, confirmed by consumers. 'Venus' weaknesses were evidenced by the panel as a lack of peach and floral flavor and sweetness, known to be correlated to liking, and well-known to affect quality (Infante et al., 2012; Cirilli et al., 2016; Ceccarelli et al., 2019). CATA confirmed these evaluations, and described 'Venus' flesh as soft, but dry, mealy and fibrous. Also 'Ruby Diamond' did not reach the minimum acceptance level (5), resulting similar to 'Venus' for the low sweetness, and negative texture features, recording the highest frequency of citations of meakiness. The two varieties recorded few citations for freshness. Known to be a positive hedonic meta-descriptor of consumers' common use and linked with consumer liking (Péneau et al., 2009; Dinella et al., 2014). Furthermore, consumers found 'Ruby Diamond' as the softer and the less aromatic sample, while being the most cited for acidity, astringency and bitter. These results validate the choice of including in this trial varieties belonging to different breeding programs and representative of different epochs within the history of peach breeding. In general terms, 'Venus' (1986) and 'Ruby Diamond' (1992) are two old yellow-fleshed varieties, from Italy and the US, respectively. Both of them belong to the so-called traditional flavored nectarines; these have a hard texture, and particularly high acid content, some retailers and nurseries called them euphemistically a fruit with "balanced flavor". In general terms it is well accepted that peach and nectarine varieties released before 2000 were more focused to satisfy growers, because these were high-productivity varieties, but less attention was reserved to sensory quality and consumer satisfaction. In contrast, the "low acid" varieties, which appeared in the market some years later (Crisosto and Crisosto, 2005; Infante et al., 2008a), showed to be highly accepted by consumers. The variety 'Magique' is a white-fleshed variety with less acid content, and a crunchy texture,

developed after 'Big Top', which was an iconic variety developed in California, that had a great success in Europe in the first decade of the XXI century. All the other tested genotypes were from the Chilean breeding program, which was initially focused on long postharvest potential and afterward to post-harvest potential coupled with high sensory attributes too. The two varieties 'Andesnecuno' and 'Andesnectres' are the oldest varieties of that program, which could be considered, in terms of flavor, closer to the old varieties, but with a better postharvest performance since they are not prone to chilling injury decay as the old ones (Crisosto et al., 2003). On the other hand, 'Andesneccuatro' and particularly the selection 6B168 (which is in the way to become the new 'Andesnecincinco') are different, mainly because they have white flesh and also because they were rigorously selected due their up-standing sensory quality after long conservation.

It remains evident that some attributes that are associated to high sensory quality, as for example sweetness, peach flavor, floral flavor, juiciness, melting and freshness, define the highest perception of quality by consumers. Whereas consumers reject peaches with mealy, dry or meaty textures (Olmstead et al., 2015).

A limited number of consumers cited firmness to be a relevant parameter for 'Venus', while the most cited attribute for it was mealy (48%). This should be a quite interesting result for the Chilean industry since for more than 10 years 'Venus' has been the most exported variety. This is basically because Chilean growers appreciate this variety due to its high productivity, but it is time to realize that at the present day a high-quality fresh fruit exportation business on such weak variety in terms of consumer satisfaction is not more sustainable.

In general terms, all the cultivars tested are part of the present available cultivars in the market for local growers, all of them being competitive regarding their potential productivity. The selection '6B-168' is a very new cultivar, named 'Andes Nec-5', which has been extensively planted in the last seasons, and 'Ruby Diamond', among the oldest varieties, that, even being a good cropper, is not anymore planted by growers in Chile.

Conclusions

This study aims to evaluate the market potential of new nectarine varieties from the Southern Hemisphere to be consumed in Italy, according to consumers' hedonic judgments and attitudes, regarding off-season fruit consumption. Genotypes deriving from recent breeding programs resulted well appreciated, showing that technology and breeding are able to improve the postharvest quality, supporting a successful export and global market for nectarine. Since fruit breeding programs are focusing in creating new varieties with up-standing sensory quality, the dialogue between the breeder and researchers involved in consumer science is mandatory. Moreover, CATA analysis proves to be a powerful method for assessing and interpreting consumer's perception of product, further to be capable to detect some attributes that are appreciated or rejected by consumers. This information means to be a key tool for a better understanding which sensory attributes drive consumer preference and acceptance of new cultivars for the export market.

Acknowledgments

This research was funded by the Project "CORFO 09 PMG 7240".

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Received: May 14, 2020

Accepted: Oct. 14, 2020

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SUPPLEMENTAL INFORMATION

SUPPLEMENTAL INFORMATION – TABLE S1. Firmness values measured for harvest moment. Values followed by the same letter do not differ in the Tukey test at $p < 0.05$.

Genotype	Firmness (kg)
Andesneccuatro	11.5ab
Andesnecuno	11.6ab
Ruby Diamond	12.0a
Magique	11.1b
6B168	10.7c
24B106	12.2a
Andesnectres	11.7a
Venus	11.0b