Unraveling factors affecting consumers' liking of novel Uruguayan mandarins

Descifrando los factores que afectan la aceptabilidad de nuevas mandarinas Uruguayas

Descifrando os fatores que afetam a aceitabilidade de novas tangerinas uruguaias

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Abstract

Mandarin cultivars show a great diversity of fruit-quality and sensory characteristics, together with an extended harvest season. Citrus breeding is focused on exploiting season niches for higher prices as well as nutritional and sensory aspects, among others. In this context, the sensory characterization of new hybrids and the identification of key characteristics of consumers´ liking provide valuable information towards breeding efforts and marketing strategies. Previous works showed that sensory characteristics, and specially flavor, play a key role in consumer acceptance of mandarins. Two studies were carried out during mandarin harvest season (mid and late) applying "check all that apply" (CATA) questions with at least 100 consumers. Overall liking scores of the most liked hybrids and cultivars ranged between 6.5 to 7.7 in the 9-point hedonic scale, evidencing a positive hedonic reaction. Local hybrids showed similar or higher values than the reference cultivars Tango, Gold Nugget, Murcott and Ortanique. Results showed that orange color, regular shape, smoothness, sweetness, juiciness, intense and typical flavor are the key drivers of consumer's liking of mandarins, and that external appearance is not a good predictor of mandarin tasting experience. Hybrids F3P8, F5P8 and F2P3 were described using terms related to positive sensory characteristics and received liking scores similar or higher to reference cultivars such as Tango, stressing the importance of sensory and consumer science as an integral part of breeding strategies.

Keywords: breeding, CATA, citrus, flavor, fruit quality

Resumen

Las mandarinas presentan una gran diversidad en características sensoriales y de calidad de fruta, así como una cosecha extendida. El mejoramiento genético de cítricos se focaliza en la búsqueda de nichos de cosecha para la obtención de mayores precios, así como en aspectos nutricionales y sensoriales, entre otras características. En este contexto, la caracterización sensorial de nuevos híbridos y la identificación de las características sensoriales claves que influyen en la aceptabilidad de los consumidores proveen de una valiosa información para el mejoramiento y las estrategias de *marketing*. Estudios previos mostraron que las características sensoriales, especialmente el sabor, son claves en la aceptación de las mandarinas por los consumidores. Se llevaron a cabo dos estudios durante la estación de cosecha de mandarinas (media y tardía) aplicando la metodología «marque todo lo que corresponda» (CATA) y con la participación de al menos 100 consumidores. La aceptabilidad de los cultivares que fueron más aceptados se situó entre 6,5 y 7,7 en una escala hedónica de 9 puntos, evidenciando una reacción hedónica positiva. Los nuevos híbridos presentaron puntajes de aceptabilidad similares o superiores a los cultivares de referencia Tango, Gold Nugget, Murcott y Ortanique. A su vez, los resultados mostraron que el color naranja, la forma regular, la piel lisa, el dulzor, la jugosidad, el sabor intenso y el sabor típico a mandarina son características claves que determinan la aceptabilidad de las mandarinas, y que la apariencia externa no es un buen predictor del sabor. Los híbridos F3P8, F5P8 y F2P3 fueron descritos por los consumidores con términos sensoriales positivos, recibiendo valores de aceptabilidad similares o mayores que los cultivares de referencia como tango, reafirmando la importancia de la incorporación de estudios sensoriales en el contexto del mejoramiento genético.

Palabras clave: mejoramiento genético, CATA, citrus, sabor, calidad de fruta

Resumo

As cultivares de tangerina apresentam grande diversidade na qualidade dos frutos e nas características sensoriais, juntamente com uma época de colheita prolongada. O melhoramento cítrico tem como foco a exploração de nichos sazonais por preços mais elevados, além de aspectos nutricionais e sensoriais, entre outros. Nesse contexto, a caracterização sensorial de diferentes híbridos e a identificação das características-chave do gosto

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do consumidor fornecem informações valiosas para os esforços de melhoramento e estratégias de marketing. Trabalhos anteriores mostraram que as características sensoriais e principalmente o sabor desempenham um papel fundamental na aceitação das tangerinas pelo consumidor. Dois estudos foram realizados durante a safra de tangerina (meio e final) aplicando perguntas do tipo cheque todos que se aplicam (CATA) com pelo menos 100 consumidores. As pontuações de aceitação geral dos híbridos e cultivares mais apreciados variaram entre 6,5 a 7,7 na escala hedônica de 9 pontos, evidenciando uma reação hedônica positiva. Os híbridos locais apresentaram valores semelhantes ou superiores aos cultivares de referência Tango, Gold Nugget, Murcott e Ortanique. Os resultados mostraram que a cor laranja, formato regular, maciez, doçura, sabor intenso y sabor tangerina e suculência típicos são os principais motivadores do gosto do consumidor por tangerinas e que a aparência externa não é um bom indicador da experiência de degustação da tangerina. Os híbridos F3P8, F5P8 e F2P3 foram descritos usando termos relacionados a características sensoriais positivas e receberam pontuações de gosto semelhantes ou superiores a cultivares de referência como o Tango, enfatizando a importância da ciência sensorial e do consumidor como parte integrante das estratégias de melhoramento.

Palavras-chave: melhoramento, CATA, citros, sabor, qualidade do fruto

1. Introduction

Mandarins are among the most consumed citrus worldwide, being a rich source of different antioxidant and health-promoting compounds[1][2][3]. An extraordinary genetic diversity regarding fruit-quality traits and harvest periods has been described within this citrus group[4]. Mandarin harvest season in the Southern Hemisphere starts in March with Satsumas and Clementines, and ends in October with Murcott and Ortanique cultivars, offering a great diversity of fruit quality and sensory experiences during the whole period. Mandarins stand out among citrus for their intense coloration and appreciated balance between soluble solids and acidity, showing a specially high accumulation of soluble sugars (compared to other citrus) ranging between 9 and 16 °Brix, while acidity at harvest usually oscillates between 0.6 and 2.0%[1][4][5][6]. Soluble solids and acids concentration change as fruit ripens in the tree, increasing sugars content while reducing acids until reaching a desired balance that determines harvest time[3][7]. If the fruit does not reach its desired external coloration, a degreening process is carried out after harvest in order to promote chlorophyll breakdown and orange peel color[8]. Genetic background, rootstock selection, harvest time during the season, commercial postharvest operation treatments such as degreening and waxing and storage time were described to impact on sensory quality of mandarins[9][10][11].

Mandarin typical flavor is highly appreciated by citrus consumers[12][13]. Additionally, mandarins' easy peeling, absence of seeds and its whole market window are among the factors favoring a rise of mandarin consumption and its higher prices as fresh product compared to oranges[2][14]. Development of different trademarks such as Cuties®, Halos® (Clementines, as an example of an early-season cultivar by Sun Pacific and Wonderful Citrus companies, respectively), Dimples® and Suki® (Gold Nugget mandarin, as an example of late-season cultivar by Cecelia and Suntreat companies, respectively) have notably improved mandarin success in the United States of America (USA). Both products exalt sensory, convenience-related aspects or external fruit characteristics such as 'bumpy and sweet' or 'sweet, seedless, easy peel' in their packages. This represent a new product segment with higher prices for new cultivars with valued sensory characteristics, most of them being easily recognizable by fruit external appearance[14].

Sensory characteristics play a key role in consumer acceptance of mandarins[6][13][14]. In this sense, large differences among cultivars have been reported. A study including 46 different mandarin cultivars revealed large differences in consumer liking: cultivars ranged from high scores (7.5 on a 1-9 scale) for several common mandarin cultivars down to scores below 5.0 (indifference score) for satsumas[4]. Regarding the purchase intention, some

authors reported that consumer purchase decision mainly rely on external appearance[14][15]. In particular, rind color has been shown to be an important factor for early purchase intention[8]. However, repeated purchase decisions are more influenced by internal sensory characteristics of mandarins[13][16]. Flavor has been identified as the most relevant factors underlying consumer willingness to try and purchase intention of mandarins[12][14][16]. A recent study with Spanish consumers has shown that the main drivers of mandarin liking in this market are aroma intensity, color intensity, flavor intensity, sweetness and juiciness[6]. Similarly, a sensory study carried out in Israel revealed that the most preferred mandarin cultivars show high sweetness, strong mandarin and fruity flavor, moderate or low acidity levels and high juiciness[17].

Information about consumer sensory and hedonic perception of new mandarin cultivars provides valuable insights for breeders[4][16][17], informing potential production and marketing strategies for increasing mandarin consumption[6][18]. However, studies on consumer perception of mandarins are still scarce.

In this context, the objectives of this work were: a) to obtain a sensory characterization of novel hybrids from Uruguay compared to commercial cultivars based on consumers' perception; and b) to identify key sensory characteristics defining consumer liking of Uruguayan mandarins. This knowledge will feedback breeding decisions towards the sensory improvement of Uruguayan citrus and provide valuable information for the development of marketing strategies.

2. Materials and methods

2.1 Mandarin samples

Six promising mandarin hybrids (B475, A218, F3P8, F5P8, F2P3 and M19) registered by the National Institute of Agricultural Research (INIA) and the Faculty of Agronomy (Udelar), and four reference cultivars (Gold Nugget, Tango, Murcott and Ortanique) were included in the present study. Hybrids and commercial cultivars evaluated were grown under the same climatic conditions and agricultural practices in an experimental field located at INIA Salto

Grande (Southern Hemisphere: 31º 16'S; 57º 41'W, 46 m height, Salto, Uruguay). All varieties were grafted in Trifolia, the most widespread rootstock in Uruguay.

Two studies were carried out in different moments of the harvest season: mid-season and late season. Due to the wide ripening window of mandarins, the hybrids and cultivars that were fully ripe for consumption were included in each study (Figure 1). F2P3 was included in both studies (mid-season and late-season harvests) due to its extended harvest period (from June to October). In the late season harvest, F2P3 was included in two different rootstocks (Trifolia-T and Flying Dragon-FD) to obtain insights on the potential impact of agronomical decisions on the sensory characteristics and consumer liking of this hybrid.

All cultivars were harvested at commercial maturity, the day before the study grouping. A ten-fruit sample was taken to the laboratory for physicochemical analyses. The rest of the fruit were stored in a cold chamber (5ºC) until the sensory evaluation.

2.2 Physicochemical characterization

Peel and pulp color were determined with a colorimeter (CR-400, D65 illuminant, Konika Minolta, Tokyo, Japan), taking three measures per fruit. L, a and b means from Hunter space color were calculated and expressed as a color index (CI=1000 a / L b). Juice was extracted with a commercial juice squeezer (APOL.N.M., Sirman, Marsango, Italy), and expressed as a percentage of the sample weight. Total soluble solids were measured with a refractometer (DBX-55, Atago Co. Ltd., Tokyo, Japan) at 20°C and expressed as °Brix. Titratable acidity was determined by titration with 0.1 N NaOH solution, using phenolphthalein as an indicator. Results were expressed as g of citric acid in 100 mL of juice (%).

2.3 Consumer studies

Two consumer studies were carried out in a supermarket in Montevideo (Uruguay). Consumers were intercepted by researchers while doing their purchases at the fruit and vegetables section and invited to participate in the study. All participants consumed mandarins, at least occasionally. A total of 106 consumers participated in the first study (mid-

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season): 58% female, aged 18-75 years old (M=47.0 years old, SD=14.1). The second study (late-season) involved 102 consumers: 57% female, aged 18-78 years old (M=48.0 years old, SD=15.9).

Participants completed the study in a quiet and well illuminated area of the supermarket. After seating, they were presented with one fruit from each hybrid/cultivar on a white plastic tray, coded with random 3-digit number, following a Williams' Latin square experimental design. Participants were asked to rate their liking of the mandarin appearance using a 9-point hedonic scale (1 = 'dislike very much', 9 = 'like very much'). They were also asked to describe external appearance using a check-all-that-apply (CATA) question composed of 8 terms: small, regular shape, smooth, big, orange color, green color, rough and irregular shape.

Then, participants were presented with one mandarin segment per hybrid/cultivar on white plastic plates, coded with 3-digit random numbers. They could ask for more sample if needed, but almost none did. Samples were presented following a Williams' Latin square experimental design. Consumers were asked to taste each of the samples and to score their overall liking using a 9-point hedonic scale (1= 'dislike very much', 9 = 'like very much'). They also had to describe their sensory characteristics using a CATA comprised of 18 terms related color, texture and flavor: sweet, typical mandarin flavor, juicy, intense flavor, firm, intense color, orange flavor, soft, barely sour, gummy, pale color, not much typical mandarin flavor, sour, barely sweet, dry, off-flavor, tasteless, bitter.
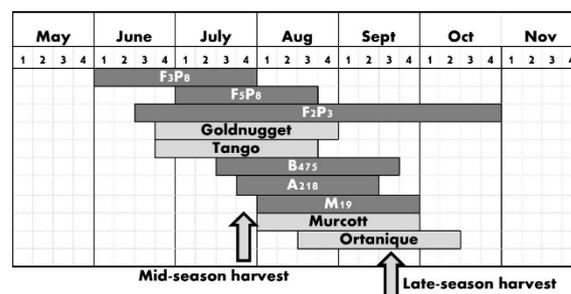
2.4 Data analysis

All statistical analyses were performed using R software[19]. Analysis of variance (ANOVA) was performed on overall liking scores considering sample as fixed effect and consumer as random effect. Mean ratings were calculated and Tukey's test was used for post-hoc comparisons (p ≤ 0.05).

Frequency of mention for each term of the CATA question was determined by counting the number of consumers who used that word to describe each cultivar. Cochran's Q test was used to evaluate the existence of significant differences among samples. When differences were significant, the sign test was

used for post-hoc comparisons. Correspondence analysis was used to obtain a graphical representation of samples and terms based on the frequency table.

Penalty-lift analysis was used to estimate the effect of each term of the CATA question on consumers' liking of mandarins. The penalty lift was calculated as the average liking score (across consumers and samples) when a term was selected minus the average liking score (across consumers and samples) when the term was not selected[20].

Figure 1. Graphic representation of the ripening period of the novel hybrids and commercial cultivars included in the present work. Month and weeks (1-4) are presented to limit the beginning and the end of the harvest period for each cultivar. Dark grey bars represent the harvest period of the novel hybrids. Light grey bars represent the harvest period of commercial cultivars. Arrows indicate the harvest time for each of the two studies

3. Results

3.1 Physicochemical characteristics

External coloration varied between 9.8 for Gold Nugget to 19.1 in A218 for midseason harvest. Among late-season cultivars, M19, F2P3-FD and Ortanique showed the highest external coloration values, whereas Murcott, B475 and F2P3-T showed the lowest (Table 1). Regarding juice content, A218 showed the lowest value (36%), F5P8 and F3P8 showed the highest values (55.7% and 52.3%, respectively) in mid-season, whereas in the late season harvest, Murcott and Ortanique showed the highest values (53.6% and 50.5%, respectively). Regarding soluble solids, F2P3 stood out with the highest values in both harvests, registering

13.8 °Brix in the mid-season harvest and 14.7 and 16.5 °Brix for F2P3-T and F2P3-FD, respectively, in the late season harvest (Table 1). The acidity was higher for A218 and B475 in the mid and late-season harvest, respectively, while the lowest values were found for Gold Nugget, M19 and F2P3-T.

Table 1. Physicochemical characterization of the hybrids and commercial cultivars of mandarins included in the mid-season and late-season harvest

Harvest	Hybrid/Cultivar	External color (CI)	% Juice	TSS (°Brix)	TA (%)
Mid-season	A218	19.1_a	36.0_c	10.5_b	1.17_a
	F3P8	16.9_{ab}	52.3_a	12.0_{ab}	1.04_b
	F5P8	13.2_{bc}	55.7_a	13.2_a	1.07_{ab}
	F2P3	10.2_c	43.8_b	13.8_a	0.93_{bc}
	Gold Nugget	9.8_c	41.2_b	11.8_{ab}	0.82_c
	Tango	16.4_b	47.7_{ab}	11.5_{ab}	0.89_{bc}
Late-season	F2P3-T	9.9_b	44.1_b	14.7_b	0.94_{bc}
	F2P3-FD	12.6_a	43.5_b	16.5_a	1.12_b
	B475	10.5_b	42.7_b	$15.2a_b$	1.86_a
	M19	13.6_a	46.7_b	11.9_b	0.92_c
	Murcott	8.9_b	53.6_a	11.4_b	1.08_b
	Ortanique	14.2_a	50.5_a	12.5_b	1.03_b

Mean values with different letters within a column and season are significantly different according to Tukey's test (p<0.05).
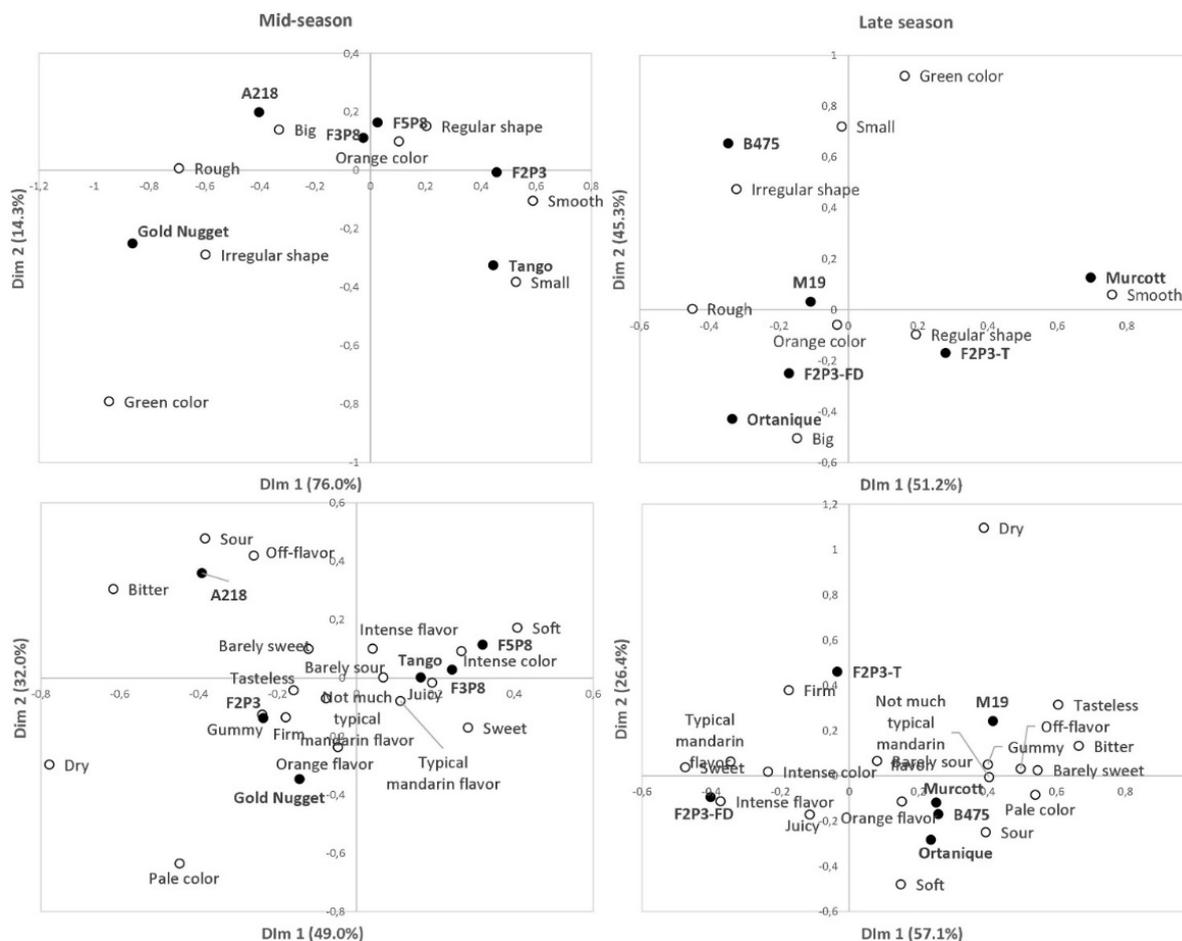
3.2 Sensory characterization

In the mid-season study, significant differences in the frequency of use of all the terms of the CATA question for describing the external appearance of the mandarin samples were found. As shown in Figure 2, in the mid-season study Gold Nugget was characterized by its roughness, irregular shape and green color, whereas A218 was characterized by its large size and external roughness. Tango was characterized by external smoothness and small size. F3P8 and P5P8 were characterized by their regular shape, smoothness and orange color. F2P3 was described as having a smooth skin.

Regarding the evaluation of mandarin segments, significant differences among samples were found for all terms except for tasteless (p=0.916), gummy (p=0.170), barely sour (p=0.445) and not much typical mandarin flavor (p=0.848). Samples were sorted into three main groups in the first two dimensions of the correspondence analysis. As shown in Figure 2, hybrid A218 was characterized by bitterness, sourness and off-flavor. Pale color, dryness and orange flavor differentiated Gold Nugget and F2P3 from the rest of the samples. Finally, Tango and hybrids F3P8 and F5P8 were located at positive values of the first dimension of the correspondence analysis, and were characterized by softness, sweetness, intense color, typical mandarin flavor and juiciness (Figure 2).

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Figure 2. Representation of mandarin samples and terms in the first two dimensions of the correspondence analysis performed on the frequency table obtained from consumer responses to the check-all-that-apply (CATA) question for the evaluation of external appearance (top) and tasting (bottom) in the studies conducted in the mid-season (left) and late season (right)

In the late season study samples largely differed in their appearance: significant differences among samples were found for all the terms of the CATA question. As shown in Figure 2, B475 was described using the terms small, green color and irregular shape. Murcott was clearly differentiated from the rest of the materials by its smoothness and regular shape. Ortanique was more frequently described as big than the rest of the materials. Finally, F2P3-F, F2P3-T and M19 were mainly described by the terms *orange color* and *regular shape*. Cultivation of F2P3 on two rootstocks led to significant differences in size and smoothness: F2P3-FD was more frequently described as bigger and rougher than F2P3-T (62% vs. 45%, and 49% vs. 22%, respectively).

Regarding the characteristics of the segments, significant differences among samples were found for all terms except for gummy (p=0.066) and barely sour (p=0.387). The first two dimensions of the correspondence analysis showed that samples were sorted into four main groups. F2P3-FD was clearly differentiated from the rest and was characterized by its intense flavor, typical mandarin flavor, sweetness, intense color and juiciness. F2P3-T showed lower juiciness, sweetness, total flavor intensity and typical mandarin flavor, and higher dryness and firmness than F2P3-FD. Meanwhile, Murcott, B475 and Ortanique were characterized by the terms *sourness*, *orange flavor* and *softness*. In particular, hybrid B475 received the highest frequency of use of the term sour. Finally, Hybrid M19 was

characterized by its firmness and low sweetness intensity, being described as tasteless, bitter, barely sweet, and having off-flavor.

3.3. Consumer overall liking

Table 2 shows the mean liking scores for external appearance and segment tasting of the hybrids and commercial cultivars in the studies conducted in the mid-season and late-season harvest. Most samples showed an external acceptance liking close to or higher than 6, the first score of the scale denoting a positive hedonic reaction. The only exception was Gold Nugget, which received an external appearance score in the disliking region of the scale (4.4). In the mid-season harvest, three hybrids and one commercial cultivar showed the highest external appearance scores: F2P3, F3P8, P5P8 and Tango (Table 2). In the late-season harvest, all the hybrids and the commercial cultivar Murcott showed the highest liking scores (close to 6).

Liking scores after segment tasting showed a different ranking of samples. In the mid-season harvest two novel hybrids (F3P8 and F5P8) and the reference cultivar Gold Nugget showed high liking scores, achieving mean values close to 7 in the 9-point hedonic score. On the contrary, hybrid A218 showed the lowest score (4.4), denoting disliking. Interestingly, Gold Nugget was better appreciated by consumers in segment tasting than in the external appearance evaluation (increasing its liking score from 4.4. to 6.7), whereas the opposite trend was observed for A218 (decreasing its liking score from 6.1 to 4.4).

In the late-season harvest, liking scores tended to be lower than in the mid-season harvest. F2P3-FD showed the highest liking score (7.7) and Murcott the lowest (5.3), whereas all other hybrids and cultivars did not largely differ in their liking score, which ranged between 5.3 to 6.3 (Table 2). It is worth highlighting that F2P3 cultivated on different rootstocks during the late season study showed different liking scores after tasting and obtained higher liking scores compared to Murcott reference cultivar. Besides, F2P3-FD showed a higher liking score than F2P3-T (Table 2). In this study differences between the evaluation of external appearance and segment tasting were not large.

Table 2. Mean consumer overall liking scores of different mandarin hybrids (codes) and commercial cultivars (Gold-Nugget, Tango, Murcott, Ortanique) in two studies conducted in different moments of the harvest season

Season	Hybrid/Cultivar	Liking (9-point hedonic scale)	
		External appearance	Segment tasting
Mid-season (n=106)	A218	6.1_b	4.4_c
	F3P8	6.9_a	6.8_{ab}
	F5P8	6.5_{ab}	7.2_a
	F2P3	7.1_a	6.1_b
	Gold Nugget	4.4_c	6.7_{ab}
	Tango	6.7_{ab}	6.3_b
Late-season (n=102)	F2P3-T	6.1_{ab}	6.3_b
	F2P3-FD	6.5_a	7.7_a
	B475	5.9_{ab}	5.4_{bc}
	M19	6.4_{ab}	5.6_{bc}
	Murcott	5.9_{ab}	5.3_c
	Ortanique	5.5_b	5.4_{bc}

Mean values with different letters within a column and season are significantly different according to Tukey's test (p<0.05).
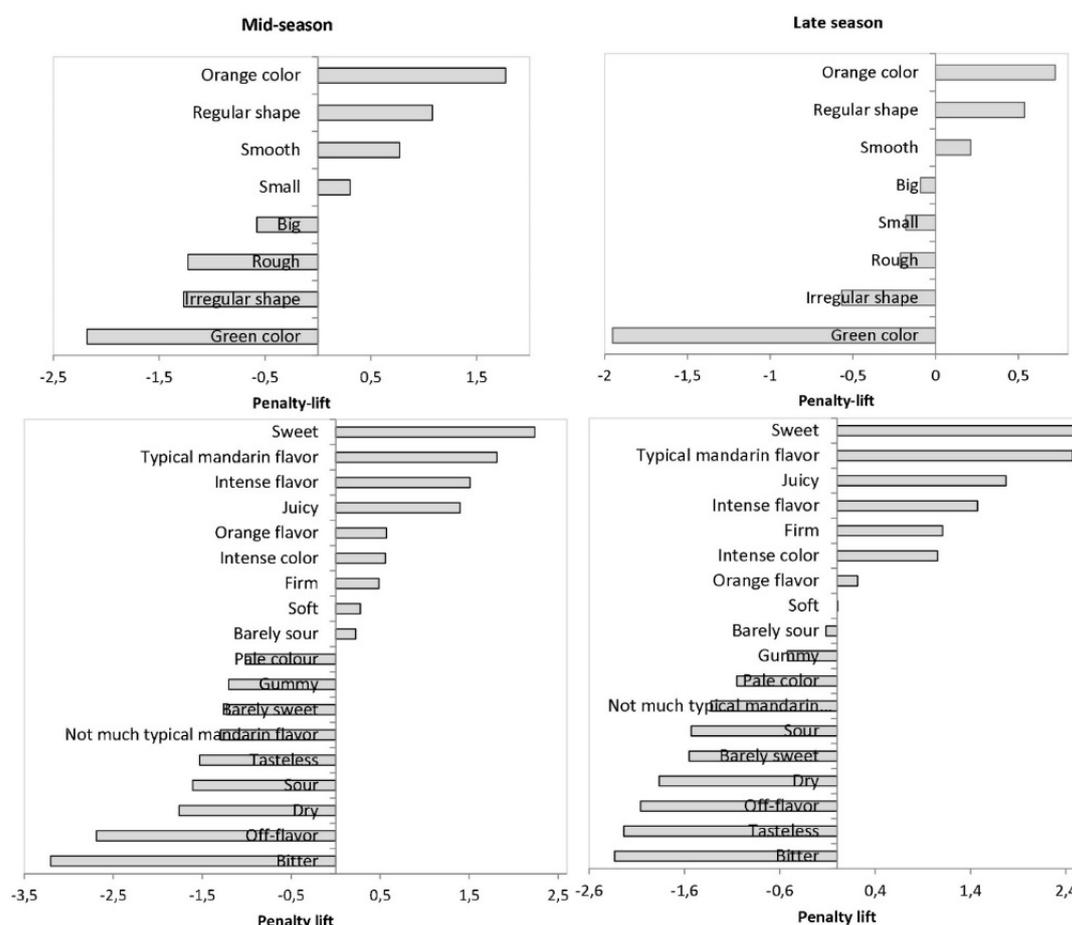
3.4. Penalty-lift analysis

Penalty lift analysis was used to estimate the relative impact of the sensory characteristics included in the CATA question on consumer liking. As shown in Figure 3, orange color, regular shape and smoothness positively influenced consumer liking of the external appearance of mandarins, regardless of the harvest season. On the contrary, green color and irregular shape negatively influenced consumer appearance liking.

After tasting, sweetness, typical mandarin flavor, total flavor intensity and juiciness were the main attributes driving consumer liking, whereas bitterness, off-flavor, dryness and low flavor intensity were negative attributes for consumer liking when tasting the segments (Figure 3).

Figure 3. Penalty lift showing the positive and negative influence of the terms included in the CATA question on liking scores for external appearance (top) and tasting (bottom) in the studies conducted in the mid-season (left) and late season (right)

4. Discussion

The present study evaluated consumer sensory and hedonic perception of different hybrids and commercial cultivars of mandarins in two moments of the harvest season. The hybrids and reference cultivars largely differ in their internal fruit quality according to physicochemical measurements of external coloration, soluble solids and juice content. Results also revealed large differences in the sensory characteristics of the different genotypes, in agreement with previous studies[2,4,6,21]. Cultivars largely differed in their external appearance, internal color, flavor and texture. Interestingly, several novel hybrids showed similar sensory characteristics compared to international reference cultivars. In particular, consumers perceived the sensory characteristics of segments from F3P8 and F5P8 similar to those from Tango in the mid-season study, whereas segments of B475 were perceived similarly to Murcott and Ortanique. Consumers described as juicy genotypes with higher juice content (Tango, F3P8 and F5P8) and as sour the hybrids with lower soluble solids and higher acidity (A218). Similarly, F2P3-FD, the genotype with the highest soluble solid content (16.5°Brix), was described as sweeter by consumers than F2P3-T, despite its higher acidity.

More importantly, consumer liking of local hybrids was similar or even higher to international reference standards. In the mid-season study, F3P8 and F5P8 were similarly perceived to Tango and Gold Nugget, whereas in the late season study F2P3-FD showed a higher overall liking score than Murcott and Ortanique, typical late-season options. Overall liking

scores of the most liked hybrids and cultivars ranged between 6.5 to 7.7 in the 9-point hedonic scale, evidencing a positive hedonic reaction. These values are similar or even higher than those reported by other studies[4][6].

The results discussed above confirm the potential of local hybrids and provide key information for breeding decisions. A similar approach has been recently applied to study Spanish local cultivars from a breeding program and compare them with commercial cultivars[6]. It is important to highlight that F2P3 an F3P8 local hybrids reached high overall liking scores and were described similarly compared to commercial reference cultivars. In the late-season, F2P3 appeared as a unique and novel option that is commercially available at the same time as Murcott and Ortanique. Results showed that the sensory characteristics of F2P3 were influenced by its harvest date and rootstock (FD vs. T). Late season is a preferred harvest time for this hybrid due to its higher soluble solid accumulation and lower acidity. Scion/rootstock combination has been reported to influence the sensory characteristics of mandarins; however, its effect seems to be dependent on the mandarin cultivar[10][11]. For example, three different rootstocks (SO, Volkameriana and US-812) exerted an effect on the sensory characteristics of Odem but not the characteristics of Orri[10]. Similarly, in Tango fruit, sugars and acids concentration were reported to be influenced by the rootstock although these differences did not affect consumer liking scores nor purchase intention[11]. In the present study fruit from plants grafted in FD were described as sweeter and juicier with more typical mandarin flavor and intense flavor, less firm and softer compared to fruit from T rootstock, leading to higher consumer liking.

The existence of differences in sensory characteristics as well as internal fruit composition associated with harvest date or scion-rootstock combinations, especially in extended-harvest cultivars such as F2P3, should be considered when planning to build up a consistent brand image, which must offer a similar sensory experience of consumption[14]. The identification of the main agronomic, ambient or storage-conditions factors that differentially affect sensory experience when consuming a new mandarin is among future challenges for further research, which will help to select the most sensory stable genotypes in a breeding context.

Results from the present study enable the identification of the main sensory characteristics that drive Uruguayan consumer liking of mandarins. Orange color, regular shape and smoothness were the main drivers of consumer liking of external appearance, whereas sweetness, flavor intensity, typical mandarin flavor and juiciness were consistently identified as the main drivers of liking when tasting the segments. These results are similar to those reported by other authors in different countries[2][14][16], highlighting the relevance of sensory studies in breeding process.

Results revealed that external appearance is not a good predictor of the sensory characteristics of the segments. The magnitude of the difference between liking scores for appearance and the tasted segments largely depended on the cultivar. This indicates that the sensory characteristics perceived after tasting would change consumer preliminary opinion (based merely on fruit appearance). In the same line, studies with consumers in USA revealed that after peeling the fruit, ease of peeling became more important than appearance to consumers. However, after tasting, consumers attached more importance to acidity and seeds compared to ease of peeling or appearance[14]. In this sense, tasting trials inside local marketing stores might be a successful strategy to introduce new mandarin cultivars, especially if they do not exhibit the most desired external characteristics (orange color, regular shape and smooth skin). In the present study, this was the case of Gold Nugget.

5. Conclusions

The present study explored Uruguayan consumers' sensory and hedonic perception of local hybrids and reference cultivars of mandarins. Orange color, regular shape, smoothness, sweetness, intense flavor, typical mandarin and juiciness are the key drivers of consumer liking of mandarins. External appearance was not a good predictor of consumer liking after tasting. Hybrids F3P8, F5P8 and F2P3 (specially in FD rootstock and late season harvest) were described using terms related to positive sensory

characteristics and received liking scores similar or higher to reference cultivars, such as Tango. It is important to highlight that most new international varieties are limited and subjected to royalties, while national varieties are available. In this line, having a new Uruguayan variety with good sensory characteristics (as good as Tango) is a big advantage for all Uruguayan growers. These results stress the importance of sensory and consumer science as an integral part of the breeding process in order to understand consumer preferences and underpin marketing strategies.

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Author contribution statement

JL, GA and FR conceived and designed the analysis. All authors collected the data. AIM and FA contributed to initial data analysis; GA and FA performed the analysis; GA and JL wrote the manuscript; FA, FR and AIM revised the manuscript.

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