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Evaluation of the physicochemical and sensory characteristics of ripening mandarins

Isabela Rótoli MICARONI[1], Simone Daniela Sartorio de MEDEIROS[2], Evandro Henrique SCHINOR[1], Marta Regina VERRUMA-BERNARDI[1*], Fernando Trevizan DEVITE[1], Thaís Lugli GONÇALES[1], Marinês BASTIANEL[3]

Abstract

The provision and expansion of the number of mandarin varieties and hybrids are of great importance for the market of fresh fruit, as Brazilian commercial orchards are based on a small number of varieties, which contributes to cultural vulnerability. The aim of this study was to verify, by univariate analyses, the possible physicochemical and sensory differences of early mandarin varieties: Ponkan IAC172, Múscia IAC607, Span IAC595, and the hybrid TP×TM11 (Ponkan IAC172×Murcott IAC221). The variety Span IAC595 presented expressive physicochemical characteristics, besides presenting sensory characteristics compatible with consumer preferences and a relation superior to the other varieties studied. The hybrid TM×TP11 obtained the lowest preference, demonstrating that attributes such as ease of peeling, skin color, and size are important in consumer's choice, indicating an importance of the studied attributes for the preference of a mandarin, that must be considered in the production of new varieties for the fresh fruit market.

Keywords: *Citrus reticulata*; consumer; fruit quality; preference; univariate analyses.

Practical Application: Brazilian citriculture is a global highlight, however, the search for new varieties of mandarinss, which excellent physical-chemical quality of the fruit, is one of the sector's main demands. Post-harvest trials and sensory tests constitute important selection stages and are essential for the selection of a new variety for fresh consumption. In general, sensory analyzes use descriptive scales and generate a large amount of data. How to evaluate, treat and interpret this collected data is of great relevance for understanding consumer perception and greatly assists in citrus breeding programs.

1 INTRODUCTION

Mandarins are mainly consumed as fresh fruit because of the ease of peeling and desirable flavor. The sweetness, acidity, and flavor of mandarins are the most important criteria for consumer preference (Hijaz et al., 2020).

Mandarins constitute one of the main groups of citrus for *in natura* consumption. In 2021, Brazil was the fifth mandarin producer, with 1.09 million tons, and China produced 25.0 million tons (Food and Agriculture Organization of the United Nations-FAOSTAT, 2023). The State of São Paulo is the main producer (Landau et al., 2020) because of the edaphoclimatic conditions that are favorable to the growth of this fruit, as well as the use of new scion and rootstock varieties, in addition to sustainable management techniques (Pio, 2006). The Southeast region accounts for 61% of the national production of mandarins, with approximately 603,000 tons, cultivated in more than 25,000 hectares in 2019. The productivity of 24 tons per hectare in the Southeast region is superior to that of any other Brazilian region (Landau et al., 2020).

The main commercially cultivated varieties in the State of São Paulo are the Ponkan (*Citrus reticulata* Blanco) mandarin and Murcott tangor [*C. reticulata* Blanco×*Citrus sinensis* (L.) Osbeck], representing around 80% of the orchards, followed by willow leaf mandarins (*Citrus deliciosa* Tenore) and the Cravo mandarin (*C. reticulata*), among others (Bastianel et al., 2014; Fundo de Defesa da Citricultura-FUNDECITRUS, 2023). The low diversification of the mandarin varieties cultivated in Brazil leaves the producer with few alternatives and a small harvest window throughout the year. Therefore, the development of new varieties can be a strategy not only to alleviate these issues but it can also mean opportunities to increase the period in which these fruits are offered and provide varieties that have desirable characteristics for both the producer and the internal and external consumers.

Sensory analysis is an important tool, as fruit quality and characteristics are paramount in their commercialization and acceptance. According to Pio (2003), consumers look for characteristics in fruits such as different flavors and sizes, attractive

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[1]*Universidade Federal de São Carlos, Center for Agricultural Sciences, Araras, SP, Brazil.*
[2]*Universidade Federal de Santa Catarina, Technological Center, Florianópolis, SC, Brazil.*
[3]*Instituto Agronômico de Campinas, Citrus Research Center "Sylvio Moreira", Cordeirópolis, SP, Brazil.*
*Corresponding author: verruma@ufscar.br

colors and shapes, absence of seeds, ease of peeling, and products with a long shelf life. Thus, the performance of sensory analyses in fruits of new mandarin varieties is essential, aiming at verifying the acceptance of the fruit by consumers.

The aim of this study was to evaluate the physicochemical and sensory characteristics, employing univariate techniques, of the early ripening varieties such as Ponkan IAC172, Múscia IAC607, and Span IAC595 mandarins and of the TM×TP11 hybrid, selected in previous studies by the Agronomic Institute of Campinas (IAC), for presenting a potential as a new variety for fresh fruit market.

2 MATERIAL AND METHODS

2.1 Material

Ponkan IAC172, Múscia IAC607, and Span IAC595 mandarins were used, with the latter two presenting physical fruit characteristics similar to Ponkan, and the pre-named hybrid 'TM×TP11', obtained from a controlled cross between tangor Murcott IAC221 tangor and Ponkan IAC172 mandarin. These varieties and the hybrid produce early-ripening fruits under the evaluated environmental conditions.

The mandarin fruits were collected in the experimental area belonging to the Citrus Breeding Program of the Citriculture Center Sylvio Moreira/IAC (CCSM/IAC), located in Cordeirópolis, São Paulo, Brazil. The fruit samples were collected in June 2018, and the plants had approximately 4 years of age, being established in the rootstock of Rangpur lime (*Citrus limonia* Osbeck). The experimental area was installed in a randomized block design, with four repetitions and two plants per plot. After collection, the fruits were transported to the laboratory, washed in running water, and stored in a dry place and at room temperature until the moment of the analyses.

2.2 Physicochemical analyses

The physicochemical analyses of the mandarins were performed at the Laboratory of Fruit Improvement and Quality of CCSM/IAC, quantifying fresh mass, by individually weighing the fruits on a precision analytical scale, with scale in milligrams; fruit height and width, by direct reading on a scale graduated in centimeters; fruit height/width ratio in centimeters; juice yield, determined by crushing the fruit in an OIC extractor, model OTTO1800, calculated by the juice mass/fruit mass ratio and expressed in percentage; acidity, obtained by the titration of 25 mL of juice, using a solution of sodium hydroxide and phenolphthalein as indicator (Reed et al., 1986); soluble solids (SS) content, determined by the direct reading in a B&S refractometer, model RFM 330, and expressed in °Brix, with the data corrected by juice temperature and acidity; and *ratio,* by the soluble solids/acidity ratio. A completely randomized design was considered, with four repetitions composed of five fruits for each variety.

The total number of seeds per fruit was also counted. A total of 20 fruits of each variety were superficially cut in the cross-section direction for the extraction of seeds viable (full and well-shaped seeds) and unviable (aborted and/or deformed seeds), considering the total number, i.e., the sum of viable and unviable seeds. For this information, a completely randomized design was adopted, with 4 treatments and 20 repetitions.

2.3 Sensory analysis

The study was approved by the Research Ethics Committee, CAAE n. 89476218.3.0000.5504. The sensory analysis of the fruit was performed 1 day after the harvest at the Laboratory of Sensory Analysis, of the Universidade Federal de São Carlos, in individual cabins with white light. The samples were served on plastic plates coded with three digits. The evaluators were asked about age, gender, and frequency of mandarin consumption.

The ranking test was described by the International Organization for Standardization (ISO, 2006), with 21 evaluators. The samples were presented simultaneously, and the evaluators were asked to rank them in ascending order for each attribute evaluated. The attributes evaluated were obtained based on the study described by Pacheco et al. (2017), with adaptations. The external characteristics of the fruit were evaluated: peel color, firmness, size, and texture of the fruit and the internal attributes such as ease of peeling, aroma, color, fibrosity, and flavor of the pulp, as well as preference for the external color (peel) and internal color (pulp).

For the acceptance test of color, 60 consumers participated in the test, evaluating the internal and external color using a 9-cm unstructured hedonic scale, anchored at the ends. Thus, a randomized block design was considered, with four treatments (samples) in 60 blocks (consumers).

2.4 Statistical analysis

The data of the physicochemical characteristics and color acceptance were evaluated by analysis of variance and, when necessary, the Scott-Knott test was used to verify the differences among the means.

The data from the ranking test were analyzed using the Friedman test (Newell & MacFarlane, 1987), considering a randomized block design with 21 evaluators and 4 samples. When necessary, the non-parametric means comparison test was performed. To count the number of seeds, the methodology of generalized linear models was used, i.e., analysis of deviance. All analyses were performed using the software R, considering a significance level of 5%.

3 RESULTS AND DISCUSSION

3.1 Physicochemical analyses

For the results of the physicochemical analyses (Table 1), it was verified that fruit mass varied among the studied varieties, with Span and Múscia mandarin not differing from each other and presenting the highest means in relation to Ponkan and the M×TP11 hybrid, and these latter two did not differ regarding this variable.

According to the results, the fruit height varied from 6.00 to 7.88 cm. The highest mean of height was observed in the variety

Span, and the lowest mean was observed in the TM×TP11, with all varieties statistically different from each other. According to the results, the fruit width varied from 7.15 to 8.38 cm. The width of the fruit of Ponkan was considered equal to that of the hybrid and different from the others. For fruit width, the highest mean was also presented by the variety Span, and the lowest mean was presented by Ponkan. These values are very satisfactory, as the Brazilian consumer prefers large fruit.

Regarding fruit height/width, the varieties Span and Ponkan presented the greatest means, being statistically equal. The smallest mean was observed in the hybrid TM×TP11, which differed statistically from the other varieties, indicating that the hybrid presents the smallest fruit in relation to the other varieties studied. The height/width ratio shows that the fruits of Múscia and the hybrid TM×TP11 are flatter when compared with Span and Ponkan.

The minimum quality requirements of the Companhia de Entrepostos e Armazéns Gerais de São Paulo (CEAGESP, 2011) for the commercialization of the Ponkan mandarin in São Paulo are 35% of juice yield, 9 °Brix of soluble solid content, and ratio of 9.5. Regarding the percentage of juice yield, the only variety that did not present the minimum standards of CEAGESP in relation to the Ponkan mandarin was the TM×TP11 hybrid. The greatest mean of juice yield was presented by the Ponkan, followed by Múscia and Span mandarin, with the latter two not presenting statistical difference. According to Oliveira et al. (2014), the main mandarin variety commercialized in Brazil, the Ponkan, presents mean mass of 168 g, juice yield of 43%, soluble solid content of 10.8 °Brix, acidity of 0.85 g/100 mL, and ratio of 12.7.

In relation to acidity, all varieties presented statistical difference from each other, with the smallest mean presented by Ponkan and the highest mean by the TM×TP11 hybrid. For the soluble solid content, the varieties that did not present statistical difference from each other were Span and the TM×TP11, being the greatest ones. On the contrary, the varieties Ponkan and Múscia were different from each other and presented soluble solids below the standards of CEAGESP, which is 9.0.

Regarding ratio, the values presented by the varieties (Table 1) are within the minimum quality standard of CEAGESP (2011), indicating that the fruits are appropriate for consumption. The ratio between soluble solids and titratable acidity is important, as it reflects the proportion between the sugars and acids in the fruit (Melo et al., 2013). It must be noted that, because of the low mean of acidity obtained, the Ponkan mandarin presented a high value of ratio.

Regarding the number of seeds per fruit (Table 2), the variety Span differed statistically from the others, presenting a smaller mean number of whole and total seeds. For the number of aborted seeds, there was no statistical difference among the mandarins. The reduced number of seeds is a factor of great importance for the acceptance of fruit for consumption *in natura*, indicating that fruits with very high number of seeds tend to be less accepted by consumers. The number of seeds can also be related to the pollen donor variety (Costa et al., 2019). In the experimental areas, dozens of other mandarin varieties are under evaluation; therefore, the difference in these values from those observed in the literature can be related to different pollen donors.

3.2 Sensory analysis: preference and difference ranking test

The evaluators of the preference and difference ranking test were composed of 71% women and 29% men, of whom 71.43% were between 17 and 28 years old, 14.29% were between 29 and 40 years old, 4.76% were between 41 and 52 years old, and 9.52% were between 53 and 64 years old.

For the results of the preference and difference ranking test, it was verified that for peel color (Table 3), Ponkan mandarin, Múscia mandarin, and the TM×TP11 hybrid did not differ from each other and obtained the lowest sums, indicating that these mandarins presented a less intense orange color in the peel. Conversely, the variety Span presented the peel more orange and with the greatest sum for external preference. The data from the acceptance test confirmed the greatest acceptance for the color of Span mandarin. Mandarins and their hybrids with orange peel coloration, in general, have a better acceptance by consumers. The orange peel color in mandarins, according to Pio (2003), makes the product attractive in the eyes of the consumer, who searches for attractive colors.

The variety considered with the greatest external firmness was the TM×TP11 hybrid, while the others did not present difference among them. According to Silva et al. (2014), there is a direct relationship between fruit firmness and the solubilization of pectic substances, which, when present in a large amount, give a soft texture to the fruit, thus reducing shelf life.

Table 1. Results of the physicochemical analyses for mass, height, width, height/width ratio, juice yield, acidity, soluble solids content, and fruit ratio of four varieties of early ripening mandarins*.

Variable	Varieties			
	Span IAC595	Ponkan IAC172	Múscia IAC607	TM×TP11
Mass (g)	196.75a	154.20b	184.00a	155.33b
Fruit height (cm)	7.88a	6.68c	6.95b	6.00d
Fruit width (cm)	8.38a	7.15c	7.85b	7.40c
Height/width (cm)	0.94a	0.93a	0.89b	0.81c
Juice yield (%)	38.8b	47.4a	42.20b	29.30c
Acidity (100 g/mL)	0.67b	0.28d	0.37c	0.73a
Soluble solids (°Brix)	10.88a	7.30c	8.08b	11.05a
Ratio	16.30c	25.65a	21.93b	15.15c

*Means followed by the same letter in the same line do not differ statistically from each other, by the Scott-Knott test at the level of 5% of significance.

Table 2. Results of the mean of viable seeds (VS), unviable seeds (US), and total number of seeds (WS+AS) of the fruit of the studied mandarins*.

Variety	VS	US	VS+US
Span IAC595	12.30b	0.75a	13.05b
Ponkan IAC172	14.75a	0.85a	15.60a
Múscia IAC607	17.20a	1.15a	18.35a
TM×TP11	16.00a	0.30a	16.30a

*Means followed by the same letter in the same column do not differ statistically from each other, by the Scott-Knott test at the level of 5% of significance.

Table 3. Results of the sums of the attributes and preferences evaluated with the sensory analysis of ranking of the studied mandarins*.

Attribute	Variable	Span IAC595	Ponkan IAC172	Múscia IAC607	TM×TP11
External	Peel color	82a	54b	36b	38b
	Fruit firmness	30b	51b	48b	81a
	Fruit size	55a	76a	58a	21b
	Fruit texture	51a	46a	51a	62a
	External preference	65a	54ab	49ab	42b
Internal	Ease of peeling	69a	57a	63a	21b
	Pulp aroma	58a	47a	50a	54a
	Pulp color	69a	50ab	53ab	38b
	Pulp fibrosity	47a	48a	52a	63a
	Pulp flavor	71a	35b	52ab	52ab
	Internal preference	67a	46a	50a	47a

*Values followed by different letters, in the same line, differ statistically by the Friedman test ($p \leq 0.05$). Critical value: 22 (4 samples and 21 evaluators). Means followed by the same letter in the same line do not differ statistically from each other, by the Scott-Knott test at the level of 5% of significance.

Regarding fruit size, it is observed that the TM×TP11 hybrid was the smallest fruit. The other varieties presented a greater score and did not differ from each other by size. Ponkan is one of the mandarins most consumed by the Brazilian market, and one of its characteristics of greatest acceptance is the fact that it has big fruit. Thus, a smaller size of the hybrid could mean a disadvantage in its acceptability by consumers. Regarding the visual texture of mandarin, there was no statistical difference among the mandarins.

For the ease of peeling, the hybridTM×TP11 presented the lowest sum, and it was the only one that differed from the others in this regard (Table 3), indicating that it is the most difficult fruit to be peeled compared with the others. According to Pio (2003), this can be a disadvantage in its acceptance, as the consumer market has a preference for varieties of easy peeling.

For the ranking test of the internal characteristics (Table 3), pulp aroma and pulp fibrosity did not present statistical difference. Regarding pulp color, Span mandarin was only different from the M×TP11. Pio et al. (2001) described that the Span presents the pulp with a strong orange color and grainy appearance, corroborating the results obtained with the variety Span for this attribute by the ranking test.

Regarding pulp flavor (Table 3), the variety Ponkan presented a lower intensity in flavor, but it did not differ from Múscia and the TM×TP11. Nevertheless, the variety Span obtained the greatest sum for pulp flavor, as well as a mean score above five for the acceptance of pulp and peel color (Table 4), but with no statistical difference from the Múscia and hybrid. Considering the total soluble solids content (Table 2), Span and the TM×TP11 obtained superior values.

For the results of acceptance, the consumers were composed of 55% women and 45% men, corresponding to 86.67% between 17 and 28 years old, 6.67% between 29 and 40 years old, 3.33% between 41 and 52 years old, and 3.33% between 53 and 64 years old. Regarding the frequency of consumption, 6.67% ingest mandarin "every day," 36.67% "at least once a week," 36.67% "at least once a month," and the other 20.00% "less than once a month."

Table 4. Results of the mean acceptance score of the studied mandarins*.

Attribute	Variable	Span IAC595	Ponkan IAC172	Múscia IAC607	TM×TP11
External	Peel color acceptance	6.7a	4.9b	4.4c	4.1c
Internal	Pulp color acceptance	5.8a	4.6b	5.4a	4.1b

*Means followed by the same letter in the same line do not differ statistically from each other, by the Scott-Knott test at the level of 5% of significance.

It was verified that the mandarin Span IAC95 obtained superior marks for both external and internal characteristics, confirming the highest sum in the preference ordering test.

4 CONCLUSION

The variety Span IAC595 presented expressive physicochemical characteristics, besides presenting sensory characteristics compatible with consumer preferences, presenting a superior relation to the other varieties studied. Conversely, the results obtained for the TM×TP11 hybrid, which, in this study, obtained the lowest preference, show that attributes such as ease of peeling, peel coloration, and size are important in consumer choice, indicating the importance of the studied attributes in the preference of a mandarin, that must be considered for the production of new varieties for the fresh fruit market.

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