

# Physicochemical and sensory characterization of 'Dekopon' fruits

## Caracterización fisicoquímica y sensorial del fruto 'Dekopon'



ANA PAULA SILVA SIQUEIRA<sup>1, 6</sup>  
EDUARDO PRADI VENDRUSCOLO<sup>2</sup>  
LUÍS HENRIQUE COSTA VASCONCELOS<sup>3</sup>  
ISABELA ROSA DE ARAÚJO<sup>4</sup>  
ALEXSANDER SELEGUINI<sup>5</sup>

'Dekopon' fruits in three ripening stages

Photo: A.P.S. Siqueira

### ABSTRACT

The Dekopon is a seedless tangor of expressive size that its harvested differently than the most commercialized cultivar, Ponkan's. The aim of this study was to physico-chemically and sensorially characterize this tangor through evaluations of soluble solids, acidity, *ratio*, vitamin C, diameter, peel thickness, firmness, juice volume and sensory impressions on taste, appearance, aroma, texture, overall impression and purchase intention. High levels of vitamin C and a juice volume that represented about 50% of the fruit weight stood out for the chemical attributes. Most of the 'Dekopon' scores were above 6.0, and the purchase intention scores were above 3.0. This fruit is promising for commercialization because of its good characteristics.

**Additional keywords:** acceptance; *Citrus reticulata* 'Shiranui'; seedless fruits; tangor; ascorbic acid.

- <sup>1</sup> Instituto Federal de Educação Ciência e Tecnologia Goiano, Food Science and Technology Department, Goiás (Brazil). ORCID Siqueira, A.P.S.: 0000-0003-3292-5836
- <sup>2</sup> Universidade Estadual do Mato Grosso do Sul, Agronomy Department, Mato Grosso do Sul (Brazil). ORCID Vendruscolo, E.P.: 0000-0002-3404
- <sup>3</sup> Instituto Federal de Educação Ciência e Tecnologia de Brasília, Campus Estrutural, Engineering Department, Goiás (Brazil). ORCID Vasconcelos, L.H.: 0000-0002-6701-8710
- <sup>4</sup> Instituto Federal de Educação Ciência e Tecnologia Goiano, Food Science and Technology Department, Goiás (Brazil). ORCID Araújo, I.R.: 0000-0001-7474-529X
- <sup>5</sup> Universidade Federal do Triângulo Mineiro, Agronomy Department, Minas, Gerais (Brazil). ORCID Seleguini, A.: 0000-0002-5762-9278
- <sup>6</sup> Corresponding author. [ana.siqueira@ifgoiano.edu.br](mailto:ana.siqueira@ifgoiano.edu.br)



## RESUMEN

Dekopon es un tangor sin semillas de tamaño expresivo y su cosecha no es la misma que 'Ponkan', quien es el cultivar más comercializado. El objetivo de este estudio fue caracterizar fisicoquímica y sensorialmente este tangor, a través de evaluaciones de sólidos solubles, acidez, proporción, vitamina C, diámetro, grosor de la cáscara, firmeza, volumen de jugo e impresiones sensoriales sobre sabor, apariencia, aroma, textura, impresión general e intención de compra. Se destacaron los altos niveles de vitamina C y el volumen de jugo que corresponde a aproximadamente al 50% del peso de la fruta con respecto a los atributos químicos. La mayoría de los puntajes atribuidos a 'Dekopon' estaban por encima de 6.0 y los de intención de compra estaban superiores a 3.0. La fruta puede considerarse prometedora para ser comercializada debido a sus buenas características.

**Palabras clave adicionales:** aceptación; *Citrus reticulata* 'Shiranui'; frutas sin semillas; tangor; ácido ascórbico.

Received for publication: 20-02-2019 Accepted for publication: 11-06-2020

## INTRODUCTION

Citriculture is one of the most competitive sectors in the Brazilian agribusiness, and Brazil is the largest citrus producer, followed by the United States (USDA, 2018). Among the most important citrus fruits in the world, tangerines are tasteful, easier to peel than oranges and generally more affordable (lower cost) than other fruits; in addition, they are widely recognized for their organoleptic, nutritional and health-related properties (Lado *et al.*, 2018)

Ponkan is the most representative tangerine in the Brazilian market (58% of the commercialized volume). It has a sweet taste, seeds, accentuated color and peel that is easy to remove (Alcântara *et al.*, 2018; Belo *et al.*, 2018).

Thus, the Dekopon, which is a seedless tangor, has the potential to be a good option. This seedless tangor is a hybrid of the 'Kyomi' orange and the tangerine 'Ponkan' Nakano n.º 3 (Alcântara *et al.*, 2018). This fruit is known as a "superfruit" because its average mass is 0.4 kg but can reach 1 kg. Its juice yield is proportional to the size of the fruit (around 40% yield). When the fruit is physiologically ripe, the peel presents an intense orange-red color and attracts consumers. Besides the commercial characteristics, the good adaptability to some regions in Brazil results in a longer production period (May to October) than in 'Ponkan' (May to June).

Thus, the 'Dekopon' has characteristics that fulfill current market requirements. However, there are few

studies on its chemical and physical characterization and acceptance by consumers. Therefore, the aim of this study was to evaluate the physico-chemical and sensory characteristics of 'Dekopon' fruits harvested at three stages of ripening and to determine the market potential.

## MATERIALS AND METHODS

Fruits were harvested in a commercial orchard located in Anápolis, Goiás, Brazil (16°19'36" S, 48°57'10" W, 1,017 m a.s.l.). These fruits were harvested in three ripening stages: C3- Ripe: stage of commercially maturation, as reported by the producer, in which the fruits were physiologically mature; C2. Mature: fruits that changed from green to orange-yellow and C1. Green: fruits characterized by predominantly green coloration (CEAGESP, 2011).

The fruits were immediately taken to the Horticulture Laboratory of the Federal University of Goiás (UFG), Campus Samambaia, Goiânia, where they were homogenized. In the laboratory, the fruits were washed with water and neutral soap to remove surface dirt, followed by sanitization with 200 mg L<sup>-1</sup> of sodium hypochlorite to remove any surface microbiological contaminants. The lots had 25 fruits per stage of ripening. The experiment was carried out in a completely randomized design (CRD), with three treatments (C1, C2, C3) using five replications of five fruits.

## Quality evaluations

Quality evaluations were performed for each stage of ripening. The fresh mass, with and without peel, longitudinal and transverse diameters and peel thickness were determined. In addition, the firmness, juice volume, ascorbic acid, soluble solids (SS), titratable acidity (TA), ratio (SS/TA), and color through Hue angle, chromaticity and lightness were evaluated.

The fruit mass, with and without peel, was evaluated on an analytical balance, and the results were expressed in grams (g; Arévalo *et al.*, 2016). The peel thickness and longitudinal and transverse diameters were measured with a digital caliper, and the results were expressed in millimeters (mm).

The firmness was determined with applanation, according to Calbo and Nery (1995), calculating the pressure exerted by the plate on the fruit from the area of compression circularly visualized, and the pressure was expressed as  $F/A$ , where  $F$  is the force exerted by the plate, and the result was expressed in Newton (N).

The juice volume was expressed in milliliters (mL) and was obtained with measurements with a graduated cylinder. The ascorbic acid content was determined according to Strohecker and Henning (1967), and the results were expressed in milligrams of ascorbic acid per 100 g of juice. Finally, the soluble solids, titratable acidity and ratio were determined according to the methodologies described by AOAC (2010).

The color was determined at two distinct points of the fruits by reading the three parameters defined by the CIELAB system. The parameters  $L^*$ ,  $a^*$  and  $b^*$  were provided by the colorimeter (Hunterlab, Color-Quest II), in which  $L^*$  defines the lightness ( $L^* = 0$ : black and  $L^* = 100$ : white) and  $a^*$  and  $b^*$  define the chromaticity ( $+A^*$ : red and  $-a^*$ : green,  $+b^*$ : yellow and  $-b^*$ : blue). The chromaticity and Hue angle were determined with these data (Hunterlab, 1996).

## Sensory evaluation

Acceptance tests were performed with 30 individuals and 30 g samples. To evaluate the acceptance of aroma, taste, appearance, texture and overall impression, a nine-point structured hedonic scale was used, ranging from "very disagreeable" to "liked very much". These categories were later converted to

numerical values for the statistical treatment, with 1 = very disagreeable and 9 = I liked very much. The same was done for the purchase intention using a five-point scale, ranging from "1 = would certainly buy" to "5 = certainly would not buy." The hedonic values were evaluated with analysis of variance (ANOVA) and the sources of variation: sample (tangerine in stages C1, C2, C3), taster and Tukey test for comparison of means.

## Statistical analysis

The experiment was carried out in a completely randomized design (CRD). The data were submitted to analysis of variance (ANOVA), and a test of means was applied to the treatments (Tukey at 5% probability). Principal component analysis (PCA) was used to characterize the ripening stages, biochemical and physiological processes at each stage, and relationship with the sensory profile. The PCA technique generated orthogonal latent variables centered in the greater concentration of variability. For this, a data covariance matrix was used, from which eigenvalues that produce eigenvectors were extracted (main components, MCs). The Kaiser criterion was used considering the eigenvalues above 1 because they generate components with relevant information in the original data (Kaiser, 1958).

Hierarchical clustering was used with all stages of ripening with the Euclidian dissimilarity measurement as a coefficient of similarity and Ward's algorithm as a grouping strategy (Hair *et al.*, 2005) to find the best ripening stage for all evaluated characteristics.

## RESULTS AND DISCUSSION

The 'Dekopon' has higher fresh mass and is bigger than common tangerines usually found in markets. The peel is very thick and represents about 28% of the fresh mass in fruits. For the chemical attributes, there were high levels of vitamin C, and the juice volume corresponded to about 50% of the fruit weight (Tab. 1). After the analysis of variance and Tukey's test, no significant difference was observed at 5% probability between the maturation stages.

The fruit weight is an important factor for the commercialization chain since weight defines the price of the product. Belo *et al.* (2018) evaluated 26 tangerines varieties and noted that the weight of these fruits

**Table 1. Means per ripening stage and general mean with standard deviation of physical, physicochemical and bioactive characteristics in 'Dekopon'.**

| Variables                      | Ripening Stage |              |              |              |
|--------------------------------|----------------|--------------|--------------|--------------|
|                                | Ripe           | Mature       | Green        | General mean |
| <b>Fruit</b>                   |                |              |              |              |
| Diameter (mm)                  | 84.74±4.80     | 91.27±4.68   | 90.46±3.63   | 90.10±5.00   |
| Height (mm)                    | 94.59±4.42     | 103.64±5.79  | 94.39±10.11  | 96.83±7.95   |
| Firmness (N)                   | 0.12±0.07      | 0.15±0.02    | 0.17±0.02    | 0.15±0.03    |
| Fresh mass (g)                 | 310.73±49.64   | 405.64±44.28 | 358.28±54.43 | 363.47±61.39 |
| Peel                           |                |              |              |              |
| Mass (g)                       | 96.65±11.61    | 120.28±23.12 | 87.21±16.77  | 97.17±21.48  |
| Thickness (mm)                 | 5.34±0.66      | 5.85±1.25    | 5.14±0.55    | 5.06±0.89    |
| <b>Juice</b>                   |                |              |              |              |
| SS (°Brix)                     | 15.99±0.80     | 12.92±0.73   | 11.10±1.27   | 12.74±2.26   |
| TA (mg citric acid/100 g)      | 1.20±0.12      | 1.04±0.11    | 1.22±0.15    | 1.15±0.10    |
| Vit. C (mg citric acid/100 mL) | 102.08±0.33    | 92.01±0.30   | 93.05±0.22   | 95.71±0.18   |
| Volume (mL)                    | 163.08±52.86   | 213.33±28.75 | 182.50±43.63 | 195±45.65    |
| Ratio                          | 13.32±0.46     | 12.42±0.42   | 9.09±0.70    | 11.61± 0.50  |

ranged from 141 to 484 g, representing the highest mass score in 'Dekopon'. When comparing the minimum and maximum fresh mass data for the 'Dekopon' (Tab. 1), it was noted that the 'Ponkan' (243 g) corresponds to about 50% of the fresh 'Dekopon' mass.

The juice volume in 'Dekopon' fruits is about 50% of fruit weight. The juice volume is an important factor for fruit acceptability because it is associated with juiciness and refreshment, which are essential attributes in tropical countries with high temperature averages, such as Brazil. Juice volume is also important for the processing industries, which use this ingredient in the production of jams and nectars, etc.

The content of soluble solids in juices is very important for acceptability and for processing. In 'Ponkan' tangerines, the SS content ranges from 10% to

13% with a sweetness/acid balance (ratio) higher than 20, higher than in the Dekopon cultivar (Tab. 1) (Belo *et al.*, 2018; Cao *et al.*, 2019). The acidity of the 'Dekopon' is greater than other tangors, which, as previously stated, presents an obstacle to its commercialization.

Belo *et al.* (2018) studied tangerines of different varieties and reported ascorbic acid contents of 33 to 72 mg of ascorbic acid mL<sup>-1</sup> of juice, noting that the 'Dekopon', with its higher values, has bioactive characteristics for the citrus industry (Tab. 1).

The mature tangerines were closer to the color of green fruits. The lightness data showed that the mature or green fruits were clearer and translucent, while the chromaticity revealed that the ripe fruits had a more intense color than mature ones, which

**Table 2. Lightness, hue and chroma of ripe, mature and green 'Dekopon' fruits.**

| Color     | Color avaluation |              |              |
|-----------|------------------|--------------|--------------|
|           | Ripe             | Mature       | Green        |
| Lightness | 20,42±2,19 b     | 35,75±7,26 a | 43,22±2,23 a |
| Hue       | 75,82±2,72 b     | 84,71±3,78 a | 86,90±1,40 a |
| Chroma    | 35,51±2,83 a     | 23,93±7,32 b | 16,74±2,40 c |

Means with the same letters in the same line do not present significant differences according to the Tukey test at 5% probability.

had a more intense color than green ones. The hue angle revealed the differences in the color, demonstrating that ripening reactions are not only catabolic.

### Sensory evaluation

In the evaluation of sensory profile, most of the scores attributed to the 'Dekopon' were above 6.0, and the purchase intention values were above 3.0 (Tab. 2). The highest scores were for the ripe and mature tangerines, which did not differ in any of the evaluated attributes. Physico-chemical and bioactive characteristics are important, mainly from a nutritional and technological point of view. However, sensorial impressions contribute to the marketing of fresh fruits.

Differences in taste were mainly related to acidity. The acidity of this cultivar is higher than in common tangerines, such as 'Ponkan'. However, the tasters argued that a more acidic taste in citrus fruits pleases certain palates, so the acidity of the 'Dekopon', while sensorially perceptible, cannot be considered a disadvantage for fruits sold *in natura* or used for processing because it is possible to add sucrose to balance the flavor of the products.

### Multivariate analysis

The hierarchical clustering analysis was represented with a dendrogram, which showed three groups (ripe, mature and green tangerines) when a 3.8 Euclidean distance cut-off value was used (Fig. 1).

Well-defined groups of green and ripe tangerines and a not so defined group of mature tangerines were observed. If the cut were larger (around 4.3 or above), the mature tangerines would be grouped with ripe

mandarins, while the green ones would still be in a well-defined separate group. In the shorter cuts (2.3), smaller groupings within each stage of ripening and a less-defined representation within the mature group were noted.

When evaluating the ripe, mature and green fruits, only the green fruits differed significantly from the others for most of the attributes, mainly for taste and purchase intention. This information is important for the market chain and especially for the post-harvest period since the 'Dekopon' is a non-climacteric fruit. Many growers harvest fruits at a later stage of ripening, reducing the post-harvest period and resulting in fruits with a senesced flavor.

Therefore, the 'Dekopon' can go to market when it is physiologically mature but not completely ripen, i.e. maturity stage C2, and this will not affect commercialization but may confer benefits to the productive chain.

The principal component analysis method was applied to evaluate the characteristics in 'Dekopon', taking into account the ripening stages, where the first two factors represented 100.00% of the total variance (Fig. 2), with 51.43% explained by Factor 1, and 48.57% explained by Factor 2.

These two factors showed that green and ripe tangerines occupy opposite quadrants, highlighting the physicochemical and sensorial differences between them. Whereas, mature tangerines occupy a quadrant that may be positively correlated with ripe fruits because their characteristics are similar, confirming the observations in the sensory evaluation (Tab. 3).

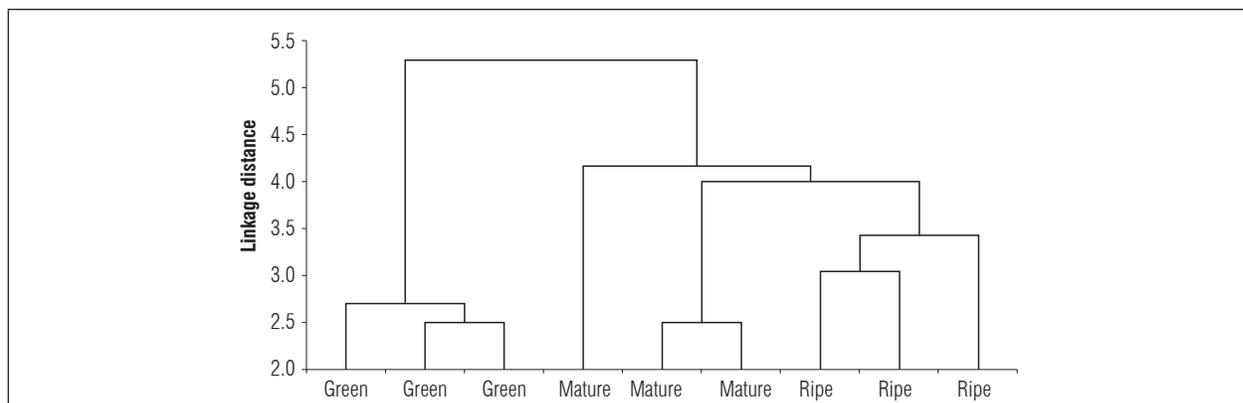
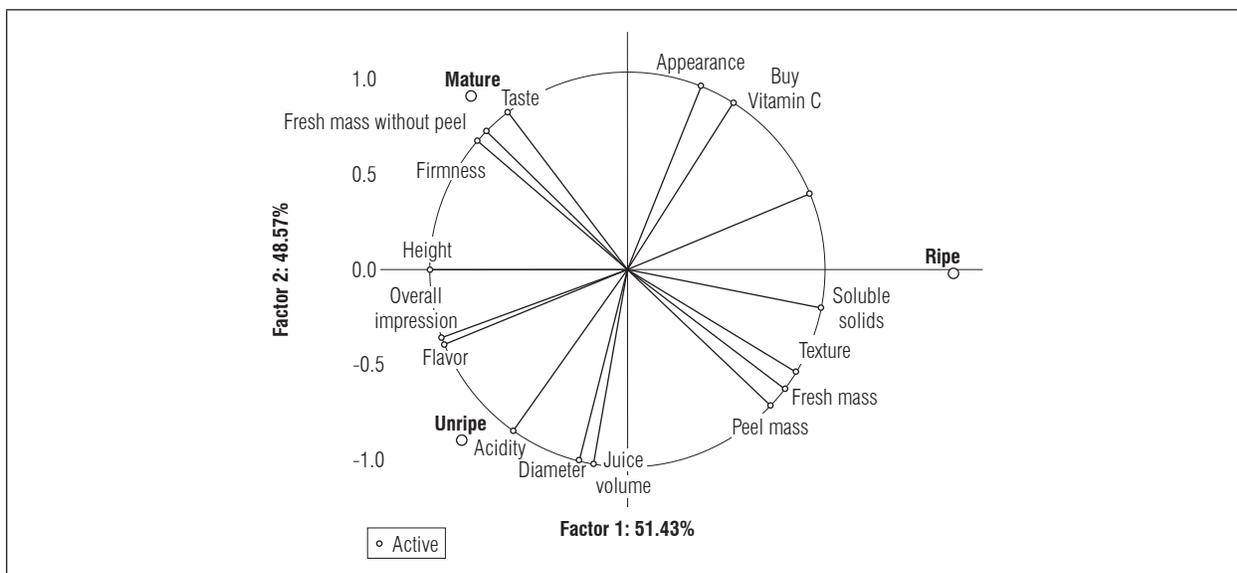


Figure 1. Tree diagram for 9 cases with single Linkage Euclidean distances for 'Dekopon' fruits.

**Table 3. Sensory profile scores for appearance, aroma, taste, texture, overall impression and purchase intention of ripe, mature and green 'Dekopon' tangerines.**

| Sensory profile |                    |                    |                    |                    |                    |                     |
|-----------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|
| Treatment       | Appearance         | Aroma              | Taste              | Texture            | Overall impression | Purchase intention  |
| Ripe            | 7.26 a             | 6.87 a             | 7.16 a             | 7.52 a             | 6.97 ab            | 4.03 a              |
| Mature          | 7.29 a             | 6.97 a             | 7.13 a             | 7.71 a             | 7.26 a             | 4.16 a              |
| Green           | 6.52 a             | 6.13 a             | 5.65 b             | 6.32 b             | 6.13 b             | 3.03 b              |
| F               | 1.95 <sup>NS</sup> | 2.48 <sup>NS</sup> | 9.14 <sup>**</sup> | 5.19 <sup>**</sup> | 4.88 <sup>**</sup> | 12.47 <sup>**</sup> |
| CV (%)          | 24.85              | 24.63              | 23.99              | 25.54              | 21.77              | 25.53               |

Means with the same letters in the same row do not present significant differences according to the Tukey test at 5% probability. <sup>\*\*</sup>Significant interaction between the treatments. <sup>NS</sup>There is no significant interaction between the treatments.

**Figure 2. Principal components analysis in 'Dekopon' tangerine.**

Firmness positively correlated in quadrant I, where the green tangerines were concentrated. The firmness of green and ripe fruits is mainly due to polymers of the cell wall. The loss of firmness during ripening and senescence occurs as the result of the activity of the hydrolytic enzyme, which promotes the solubilization of pectins in the cell wall (Faria *et al.*, 2019), mainly pectin methyl esterase (PME) and polygalacturonase (PG).

The third quadrant contained vitamin C, soluble solids, appearance and flavor, which were directly related to the ripe tangerines and correlated with the mature ones (Fig. 2). In general, less firm tangerines have already seen the enzymatic degradation of

pectins, are completing ripening and have sensorial characteristics that make the product more acceptable for consumption.

During the ripening process, besides a loss of firmness, sweetness increases, expressed through soluble solids that can be indirectly and positively correlated with an increase in sensory profile scores (flavor item). Color also contributes to the attractiveness of fruits. Ripening has a process of revealing carotenoids and a loss of chlorophyll, with fruits starting to have an intense orange color (Chitarra and Chitarra, 2005).

Quadrants II and IV had titratable acidity, peel mass and thickness, juice volume and fruit height.

Generally, these parameters are inversely proportional to fruit ripening. The maturation process and ripening use organic acids as a substrate in fruit respiration, which must generate enough energy for the metabolic processes (Chitarra and Chitarra, 2005). Thus, acidity decreases considerably with ripening, unlike the soluble solids, which increase as the result of the degradation processes of more complex molecules. These processes balance sweetness in fruits and explain the higher ratio for ripe and mature 'Dekopon' fruits. Fruit ripening also sees an increase in turgor caused by the expansion of the intercellular space and increase in vacuoles (Taiz *et al.*, 2017), which hold reserves of water and organic acids, influencing the juice volume in these fruits.

Evaluating the significant correlations between the variables with Pearson's correlation showed a mean correlation of 0.60 between the soluble solids and the hue angle and chroma, and a mean correlation of 0.69 between the soluble solids and lightness. The 0.99 correlation between the soluble solids content and flavor or purchase intention demonstrated that non-destructive SS classification can be used to classify fruits in terms of greater acceptance by consumers.

## CONCLUSION

This fruit is promising, marketable product because of its good sensory and physical-chemical characteristics. Mature fruits do not vary considerably in their sensorial and physical-chemical quality as compared to ripe but using the former is advantageous for a longer shelf-life. Analyzing these attributes showed that this fruit has a broad market, both for processing and household use.

**Conflict of interests:** The manuscript was prepared and reviewed with the participation of the authors, who declare that there exists no conflict of interest that puts at risk the validity of the presented results.

## BIBLIOGRAPHIC REFERENCES

- Alcântara, R.I., Y.M.V. Camilo, W.N. Rodrigues, and T. Ogata. 2018. Caracterização pós-colheita de variedades de tangerina com potencial de produção e comercialização no Estado de Goiás. *Rev. Agrar.* 11, 319-323. Doi: 10.30612/agrarian.v11i42.7061
- AOAC, Association Official Analytical Chemists. 2010. *Official Methods of Analysis of AOAC International*. 18<sup>th</sup> ed. Gaithersburg, MD.
- Arévalo R., A. Coronado, and J. Orduz-Rodríguez. 2017. Caracterización físico-química en poscosecha de diferentes materiales de lima ácida Tahiti (*Citrus latifolia* Tanaka) para exportación. *Rev. Colomb. Cienc. Hortic.*, 10(2), 241-251. Doi: 10.17584/rcch.2016v10i2.5749
- Belo, A.P.M., C.M. Morgado, E.R.B. Souza, T. Ogata, C.C.O. Pereira, and L.C. Cunha Junior. 2018. Comparative analysis, organic and characterization kind of Tangerine varietie. *Sci. Hortic.* 240, 102-108. Doi: 10.1016/j.scienta.2018.06.001
- Calbo, A.G. and A.A. Nery. 1995. Medida de firmeza em hortaliças pela técnica de aplanção. *Hortic. Bras.* 3, 14-18.
- Cao, J., C. Wang, S. Xu, Y. Chen, Y. Wang, X. Li, and C. Sun. 2019. The effects of transportation temperature on the decay rate and quality of postharvest Ponkan (*Citrus reticulata* Blanco) fruit in different storage periods. *Sci. Hortic.* 247, 42-48. Doi: 10.1016/j.scienta.2018.12.009
- CEAGESP, Companhia de Entrepósitos e Armazéns Gerais de São Paulo. 2011. Programa brasileiro para a melhoria dos padrões comerciais e embalagens de hortigrangeiros. Normas de classificação: Citros de mesa. Centro de Qualidade em Horticultura, Sao Paulo, Brazil.
- Chitarra, M.I.F. and A.B. Chitarra. 2005. Pós-colheita de frutos e hortaliças: fisiologia e manuseio. 2<sup>nd</sup> ed. UFLA, Lavras, Brazil.
- Faria, J.A., M.N. Lima, S.E. Araújo Neto, E.B.L. Oliveira, and R.L.F. Ferreira, 2019. Qualidade de frutos de abacate cv. Fuerte tratados com revestimento natural. *Sci. Nat.* 1, 35-44.
- Hair, J.R., R.E. Anderson, R.L. Tatham, and W.C. Black. 2005. *Análise multivariada de dados*. Buckman, Porto Alegre, Brazil.
- Hunterlab. 1996. Applications note: CIE L\* a\* b\* color scale. Reston, VA.
- Kaiser, H.F. 1958. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 23, 187-200. Doi: 10.1007/BF02289233
- Lado, J., G. Gambetta, and L. Zacaria. 2018. Key determinants of citrus fruit quality: Metabolites and main changes during maturation. *Sci. Hortic.* 233, 238-248. Doi: 10.1016/j.scienta.2018.01.055
- Strohecker, R.L. and H.M. Henning. 1967. *Análisis de vitaminas: métodos comprobados*. Paz Montalvo, Madrid.
- Taiz, L., E. Zeiger, I. Moller, and A. Murphy. 2017. *Fisiologia e desenvolvimento vegetal*. 6<sup>th</sup> ed. Artmed, Porto Alegre, Brazil.
- USDA, United States Department of Agriculture. 2018. *Citrus: world markets and trade*. Foreign Agricultural Service, Washington, DC.