Natural antioxidants and postharvest quality of grape tomatoes at different ripening stages

Antioxidantes naturais e qualidade pós-colheita de tomates tipo grape em diferentes estádios de maturação

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ABSTRACT
The objective of this work was to characterize the 5 classes of grape-type cherry tomatoes of *sweet heaven* variety based on the instrumental color. The experiment was carried out in a completely randomized design (CRD), with five stages of maturation (treatments) and five replications. The contents of the bioactive compounds (total phenolic compounds, total carotenoids, lycopene and flavonoids) and the physicochemical characteristics (pH, total soluble solids, total titratable acidity and SST/ATT ratio) were evaluated. Data were submitted to the Shapiro-Wilk normality test and the Bartlett homogeneity test, and for those that did not meet, the Kruskall Wallis nonparametric equivalent ANOVA test was used, followed by Dunn's test. The results showed a reduction in the total titratable acidity content; an increase in pH, total soluble solids and SST/ATT ratio. The samples collected in the mature stage showed the highest concentrations of bioactive compounds and antioxidant capacity. Despite presenting superior characteristics in relation to the other stages, the harvest of tomatoes at this stage becomes compromised due to their perishability to handling. Yet, the joint assessment of quality attributes can improve the identification of maturation stages, in order to ensure the delivery of a product that satisfies consumer requirements.

Keywords: *Lycopersicon esculentum* L., lycopene, greenhouse crop.

1 INTRODUCTION

In Brazil, the cultivation of tomatoes has a great relevance, both for its expression in planted area, as well as for the quantity produced. Among the numerous tomato, cultivars available on the market, the demand for cherry tomatoes (*Solanum Lycopersicum* L. var
cerasiform), of the variety *sweet heaven grape*, type has increased in recent years, and Brazil, as a major producer, has been investing in the production of this tomato, since its *in natura* consumption is growing quickly, due to the preference for a differentiated product (Vieira et al., 2014).

Because they are small and more delicate, the mini tomatoes are considered an exotic fruit, have great versatility, being incorporated into the menus of restaurants, in the elaboration of various dishes and appetizers, thus bringing new flavors. This wide approval is directly related, to the sensory and nutritional properties, of the fruit *in natura*, and also, because it is considered a food rich in vitamins (retinol, thynoxin, riboflavin, niacin, pantothenic acid and ascorbic acid), mineral salts, folic acid, calcium and fructose (Pobiega et al., 2020). In addition, its consumption has been correlated with the reduction of several types of chronic non-communicable diseases, such as cancer, cardiovascular diseases and cataracts. This positive effect is attributed to antioxidants, particularly carotenoids (lycopene and β-carotene) and phenolic compounds (Melo et al., 2014).

The classification of tomatoes, for *in natura* consumption, by current Brazilian legislation, establishes the subgroups according to their color, a characteristic that is related to the maturation stage. Therefore, tomato is classified into five subgroups: ripe green, painted, pinkish, red and ripe red (Brazil, 1995). However, in practice, most producers, and packers use the nomenclature developed by Ceasa-Minas, which differentiates the subgroups into: green, salad, colored, red and sauce (Cunha et al., 2016).

According to Aguiar et al. (2015), a quality fruit is one that, through internal and external properties, satisfies the expectations of a wide range of consumers. The internal properties are directly associated with flavor (sugar content and acidity) and juice content (yield), and these in turn, are parameters widely applied as a method for the selection of fruits by the industry, while the external properties are related to good appearance (peel color, size, weight, absence of flaws) and characterize the criteria used by the consumer in the purchase.

However, tomato quality is influenced by a variety of factors, such as cultivation conditions, cultivar characteristics, storage conditions, harvest point, transport and packaging. The tomato, being a climacteric fruit, ripens quickly, after harvest, due to transpiration and respiration. In its post-harvest period, several physiological, biochemical and molecular transformations occur, including chlorophyll degradation, and the synthesis and storage of
carotenoids, especially lycopene. These transformations induce the change of color, flavor, appearance, firmness, loss of mass, pH and acidity. In addition, other important antioxidants, such as phenolic compounds, also present changes in the contents (Paula et al., 2015).

Thus, the relationship between skin color and maturation stages, will enable the producer to establish a harvest plan, in order to increase shelf life and provide tomatoes that can satisfy consumer demands. In this context, the present work had to characterize the 5 classes of cherry tomatoes of the variety sweet heaven grape type based on the instrumental color characterize.

2 METHODOLOGY
2.1 MATERIALS AND METHODS

The experiment was conducted at the Laboratory of Bioactive Compounds and Food Conservation, Department of Food Engineering, Federal University of São João del-Rei, Campus Sete Lagoas in Sete Lagoas- MG. The sweet heaven grape tomatoes from a protected cultivation system in the Avestruz no Cerrado farm, located in the rural area of Araçai, were used for the experiment. The fruits were harvested at each maturation stage, randomly in July 2021. The samples were transported under refrigeration to the laboratory, where the minimal processing was carried out, later a division into five classes was carried out (Figure 1), according to the measurement of the instrumental color.

Figure 1- Separation of ripening classes of tomato sweet heaven grape type, according to colorimetric data.
The colorimetric parameters were evaluated with the aid of a Konica Minolta CR410, color meter in the color space L*, a* and b*, adapted to be used in a dark cabin and under light (Figure 1). The readings were standardized, and performed in 3 distinct points of the fruit in the upper, equatorial and apical regions, in a certain, position with the hand paved by a black glove. And the results were obtained from the mean. The fruits were separated according to ranges of values of the color parameters (L*, a* and b*), as shown in Table 1.

<table>
<thead>
<tr>
<th>Maturation Stages</th>
<th>Interval L</th>
<th>Interval a*</th>
<th>Interval b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54 – 65</td>
<td>(-25) – (-10)</td>
<td>27 – 30</td>
</tr>
<tr>
<td>2</td>
<td>48 – 53</td>
<td>(-9) – (1)</td>
<td>24 – 26</td>
</tr>
<tr>
<td>3</td>
<td>42 – 47</td>
<td>2 – 12</td>
<td>20 – 23</td>
</tr>
<tr>
<td>4</td>
<td>36 – 41</td>
<td>13 – 23</td>
<td>17 – 19</td>
</tr>
<tr>
<td>5</td>
<td>30 – 35</td>
<td>24 – 30</td>
<td>13 – 16</td>
</tr>
</tbody>
</table>

Source: authors.

Soon after, the fruits were submitted to physicochemical evaluations, quantification of bioactive compounds and antioxidant activity. The experiment was conducted according to a completely randomized experimental design (IHD) with five maturation stages (treatments) and five replications. All analyses were performed in triplicate.

2.2 PHYSICAL-CHEMICAL CHARACTERISTICS

To express the results on a dry basis (BS), the humidity of the respective samples was determined, in order to make the necessary corrections.

The hydrogen potential (pH) was determined with the aid of a digital pH meter (Tekna® T-1000), dipping the electrode into the homogenized sample and adding 50 mL of distilled water (AOAC, 2016).

The total titratable acidity was determined by titration, using NaOH 0.01 N solution as standard and phenolphthalein as an indicator, according to the methodology proposed by Aoac (2016), with the aid of pH measurement. The results were expressed (g citric acid.100g⁻¹ of sample on dry basis).

The content of total soluble solids (TSS) was evaluated by direct refractory reading in Brix degrees (“Brix), using a digital refractometer (REICHERT r2MINI), according to the Aoac
methodology (2016). The ratio between the total soluble solids content and the total titratable acidity (SST/AAT) was also calculated.

2.3 BIOACTIVE COMPOUNDS

2.3.1 Total content of carotenoids and lycopene

The lycopene content was determined according to the methodology proposed by Rodriguez-Amaya (2001), which consists in the extraction of carotenoid pigments with acetone p.a and quantification by spectrophotometry at 450 nm for total carotenoids and 470 nm for lycopene. The results were expressed in μg. 100g\(^{-1}\) of sample on dry basis.

2.3.2 Total phenolic compounds

The total phenolic compound content was determined by the Folin-Ciocalteau method (Neves et al., 2009) comparing a calibration curve constructed with gallic acid. Absorbance was read on a FEMTO 700 S spectrophotometer at 740 nm. The results were expressed mg EAG .100g\(^{-1}\) of sample on dry basis.

2.3.3 Total flavonoids

Flavonoids were determined according to the Francis method (1982). Absorbance was read in a FEMTO 700 S spectrophotometer at 374 nm for flavonoids and the results were expressed in mg.100g\(^{-1}\) of sample on dry basis.

2.4 ANTIOXIDANT ACTIVITY

Antioxidant activity was determined by the methods ABTS [2,2 azinobis (3-ethylbenzothiazolin-6 sulphonic acids)] and DPPH (2,2-defenil-1-picril-hydrazila), both based on free radical sequestrations by antioxidant, according to the methodology described by Brand-Williams et al. (1995) and adapted by Embrapa (2016). The method extraction methodology is similar. Approximately 0.1500 g of sample was weighed and 15 mL of acidified methanol was added with 1% HCL in each erlenmeyer of 125 mL, then agitated in the Shaker incubator (Novatécncia) at 150 rpm (rotation per minute) for 2 hours. Subsequently, 10 mL of this content was transferred to a Falcon tube and this was centrifuged at 3000 rpm (rotation per minute) for 15 min. A rate of 0.1 mL of the sobrenatant was transferred to a test all, where 2.9 mL of the
working radical was added. After the reaction of the solutions (30 minutes), a spectrophotometer was read at 734 nm for ABTS and 515 nm for DPPH. The results obtained were expressed in μmol Trolox equivalent/g sample on dry basis.

2.5 STATISTICAL ANALYSIS

The data were analyzed according to the one-way ANOVA analysis model. The assumptions of normality and homogeneity of variances were verified by the Shapiro-Wilk and Bartlett tests, respectively. Once the conditions were satisfied, the comparison of the averages of five stages of maturation was performed by the Tukey test at 5% significance. For the variables that were not observed normality and/or homoscedasticity, we opted for the use of the non-parametric equivalent Kruskall Wallis test of ANOVA, followed by Dunn. All analyses were performed using Software R (R Core Team, 2017), and adopting a significance level of 5% (p<0.05).

3 RESULT AND DISCUSSION

From the verification, the variables met the assumptions of normality and homoscedasticity, except for pH, carotenoids, lycopene and antioxidant activity (DPPH/ABTS). For these variables, the Kruskall Wallis nonparametric equivalent ANOVA test was used, followed by Dunn's test, which indicated the existence of significant differences between the stages.

3.1 PHYSICAL-CHEMICAL ANALYSIS

The results of the variance analysis revealed significant differences (p<0.05) for the characteristics evaluated as a function of fruit maturation stages. Thus, the results will be presented and discussed according to the means of maturation stages, from 1 (green) to 5 (mature), Table 2.
Table 2- Physicochemical characteristics of cherry tomatoes *sweet heaven grape* type: total soluble solids (SST, °BRIX), total titratable acidity (ATT, g ac. citrus/100g BS) and SST/ATT ratio, depending on fruit maturation stages.

<table>
<thead>
<tr>
<th>Stages of Maturation</th>
<th>SST</th>
<th>ATT</th>
<th>SST/ATT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.56 e</td>
<td>1.18 a</td>
<td>3.02 e</td>
</tr>
<tr>
<td>2</td>
<td>4.13 d</td>
<td>1.16 a</td>
<td>3.56 d</td>
</tr>
<tr>
<td>3</td>
<td>5.31 c</td>
<td>0.86 b</td>
<td>6.17 c</td>
</tr>
<tr>
<td>4</td>
<td>6.64 b</td>
<td>0.74 c</td>
<td>8.97 b</td>
</tr>
<tr>
<td>5</td>
<td>7.85 a</td>
<td>0.61 d</td>
<td>13.01 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.09</td>
<td>2.96</td>
<td>4.81</td>
</tr>
</tbody>
</table>

**Averages followed by lowercase distinct letters in the column indicate significant difference by Tukey test at the level of 5% probability (p≤0.05).**

Source: authors.

The total soluble solids contents showed an increase with the advance of maturation stages, showed significant differences between maturation stages, with mean values ranging from 3.56 °Brix (stage 1) to 7.85 °Brix (stage 5), according to Table 2.

Trindade et al. (2015) attributed this increase to greater degradation of polysaccharides and sugar accumulation. As soluble solids are composed, mainly of fructose, sucrose and glucose, in ripening, the polysaccharides of the cell wall, are broken by the hydrolases and lyases enzymes, resulting in an increase in sugar content, thus making the ripened fruits more sweet (Vinha et al., 2014). Here, the tomatoes in stage 5 of maturation, were the ones that presented the highest SST contents, being considered the most sweet.

The results, of the present work, showed similar behavior, with the Ferreira et al. (2012), who studying the quality of two hybrids, of industrial tomato, ('Mariana' and 'SM -16'), during ripening, observed that the SST content increased, with maturation (3.68 °Brix to 3.97 °Brix).

The states that high levels of soluble solids are important, both for consumption of the fruit *in natura*, as well as for the industry, as they provide better flavor and greater income in the production of products. Furthermore, this parameter is extremely important, for the acceptance of the fruits, by the consumers, since the presence of carbohydrates and, consequently, sweetness, are relevant characteristics in the choice decision of the public (dos Santos et al., 2020).

The levels of total titratable acidity presented a behavior inverse to STT, that is, decreased, according to the degree of ripening, presenting significant differences, between maturation stages, as can be observed in Table 2. The contents ranged from 1.18g citric acid/100g of BS sample (stage 1) to 0.60g citric acid/100g of sample on dry basis (stage 5).

The titratable acidity (TA), in tomato fruits, reaches the maximum, during the first yellow-colored signs, but gradually decreases, as maturation progresses. Citric acid is one of the
most abundant organic acids in tomatoes, representing about 90% of total acidity (Martins et al., 2017). Paula et al. (2015), evaluating the postharvest quality, of the tomato "saladete", harvested at different stages of maturation, detected a significant decrease in ATT, values with ripening (0.38 to 0.30 g citric acid/100g⁻¹), a behavior similar to those found in this study.

The decrease in ATT occurs as a result of the respiratory metabolism, that continues to occur after harvest, causing substrates, including acids, to be used in the Krebs cycle, as a form of energy generation, for the maintenance of vital fruit processes (Malgarim et al., 2005).

The SST/ATT ratio increased significantly between the maturation stages of tomato fruits from 3.02 (stage 1) to 13.01 (stage 5) (Table 2). This is due to the decrease in acidity, concomitantly with the increase in solids content, as the fruits have a higher degree of ripening.

According to Kader et al. (1978), the tomato fruit is considered tasty and of good quality, when it presents the SST/ATT ratio, greater than 10, thus indicating, a excellent combination between sugar and acidity. Meanwhile, low values are associated with acidity, and fruits may present unpleasant or astringent taste. Therefore, only the tomato in stage 5 presented a value above 10 (13.01), thus being considered as a fruit of mild flavor, ideal for consumers.

Freitas et al. (2016), evaluating the influence of maturation stages, on ratio (SST/ATT), of Italian tomatoes, verified averages between (7.23 to 26.38), being the highest value for extremely ripe tomatoes. These values are higher than, the means obtained in this study (3.02 to 13.01), but the variation found in STT/ATT, among the hybrids, is due to many factors, among them, the genetic factor is determinant.

For the variable pH, the Kruskall Wallis test was significant at 5%, indicating that there are differences between the maturation stages of the groups (\(\chi^2_{(4)} = 23.139; p = 0.0001\)). For the variable pH, the Kruskall Wallis test was significant at 5%, indicating that there are differences between the maturation stages of the groups, as illustrated in table 3.
Table 3- PH content in tomatoes *sweet heaven grape* type as a function of the different maturation stages. For the different maturation stages studied, their medians are presented.

<table>
<thead>
<tr>
<th>Maturation Stages</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.00 c</td>
</tr>
<tr>
<td>2</td>
<td>4.75 abc</td>
</tr>
<tr>
<td>3</td>
<td>4.87 abc</td>
</tr>
<tr>
<td>4</td>
<td>5.18 ab</td>
</tr>
<tr>
<td>5</td>
<td>5.69 a</td>
</tr>
</tbody>
</table>

**Kruskal Wallis test; Medians followed by the same letter do not differ from each other by Dunn's test at the level of 5% probability (p≤0.05).**

Source: authors.

Due to the ripening of the fruits, tomatoes, at advanced maturation stages have, higher pH and lower acidity, than tomatoes in green maturation stages, implying that these fruits are less acidic. This can be attributed to the consumption of organic acids during ripening due to the respiratory activity of the cells.

Corroborating this fact, Ferreira et al. (2012), in his work evaluating some characteristics of tomato quality, at different maturation stages, it was reported that the pH decreased until stage 3 of maturation, of the two tomato hybrids studied. However, there was an increase in pH, at the final stage of maturation, due to the reduction of the titratable acidity of the pulp.

Freitas et al. (2016), verified the influence of maturation stages on physicochemical characteristics of persimmon tomatoes, noting an increase in pH, according to the maturation process, similar behavior to that found in this study.

3.2 BIOACTIVE COMPOUNDS AND ANTIOXIDANT ACTIVITY

Table 4 shows the results of the evaluation of antioxidant compounds, carried out on *sweet heaven grape* type cherry tomatoes, depending on the different stages of maturation.

The tomato fruits analyzed showed statistically different levels of phenolic compounds depending on the maturation stages. It is observed that the contents of total phenolic compounds vary between 11.272 to 20.641 mg EAG 100g⁻¹ BS, with the tomatoes in stage 1 (green), presenting the lowest content of these compounds and the fruits in stage 5 (ripe) the highest (Table 4).
Table 4. Bioactive compounds of cherry tomatoes *sweet heaven grape* type as a function of maturation stages: phenolic compounds (mg EAG 100g⁻¹ BS), anthocyanins (mg cyanidine 3-glycoside 100g⁻¹ BS) and flavonoids (mg 100g⁻¹ BS).

<table>
<thead>
<tr>
<th>Maturation Stages</th>
<th>C. Phenolic</th>
<th>Flavonoides</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.272 e</td>
<td>0.052 e</td>
</tr>
<tr>
<td>2</td>
<td>12.201 d</td>
<td>0.071 d</td>
</tr>
<tr>
<td>3</td>
<td>14.545 c</td>
<td>0.085 c</td>
</tr>
<tr>
<td>4</td>
<td>18.171 b</td>
<td>0.091 b</td>
</tr>
<tr>
<td>5</td>
<td>20.641 a</td>
<td>0.119 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>0.86</td>
<td>5.46</td>
</tr>
</tbody>
</table>

**Averages followed by lowercase distinct letters in the column indicate significant difference by Tukey test at the level of 5% probability (p≤0.05).**

Source: authors.

The same behavior of phenolic compounds during the maturation of tomato fruits was observed in other studies. Paula et al. (2015) evaluating the physicochemical characteristics and bioactive compounds, in tomato fruits harvested, at different maturation stages, observed that fruits harvested at the most advanced stage of maturation (stage 5) presented higher content of phenolic compounds than those harvested less mature.

The increase in the levels of phenolic compounds, in fruits, can be explained mainly, due to solar radiation and temperature, in which the fruits kept in the mother plant, were exposed. Phenolic compounds are secondary metabolites, and are produced by the plant, under stress conditions, which may also, be caused by pests or climatic factors.

Regarding flavonoid content, the highest concentration was presented, at stage 5 (0.119 mg 100g⁻¹ of sample on dry basis), that is, higher content when compared with the other maturation stages (Table 4). According to Chaudhary at al. (2018), in tomatoes, the accumulation and increase of flavonoids occurs during ripening, with the decrease in chlorophyll content. In a study conducted, by Sharma et al. (2018), flavonoids, found in greater abundance in tomatoes, are quercetin and chlorogenic acid.

Souza (2017), evaluating the antioxidant capacity, of the peel and pulp of red cherry, orange and purple tomatoes, observed that the purple tomato peel showed higher concentration of flavonoids, when compared to the other fruits. The total flavonoids, of the purple tomato peel was (298.28 mg. 100g⁻¹), for the peel of the orange fruit (43.06 mg. 100g⁻¹) and red (84.39 mg. 100g⁻¹), respectively.

The properties of flavonoids, in each plant species, are determined by an internal system of genetically controlled enzymes, that regulate synthesis and distribution in plants. In addition to internal factors, flavonoid content is strongly influenced by external factors, such as the season,
Regarding the photosynthetic pigments studied as the (total carotenoids /lycopene) and antioxidant activity, the Kruskall Wallis test was significant at 5%, indicating that there are differences between the maturation stages of the groups ($\chi^2_{(4)} = 23.077; \rho = 0.0001$) for all components. Thus, multiple comparisons by Dunn’s test showed that the tomatoes, in the stages of maturation 4 and 5, differ statistically from the tomatoes of the stage of the 1, according to Table 5.

<table>
<thead>
<tr>
<th>Maturation Stadium</th>
<th>Carotenoides</th>
<th>Lycopene</th>
<th>Antioxidant Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ABTS</td>
</tr>
<tr>
<td>1</td>
<td>28237.34 c</td>
<td>8112.25 c</td>
<td>7487.66 c</td>
</tr>
<tr>
<td>2</td>
<td>48243.65 abc</td>
<td>27961.82 abc</td>
<td>1178.33 abc</td>
</tr>
<tr>
<td>3</td>
<td>59629.82 abc</td>
<td>42786.25 abc</td>
<td>1225.72 abc</td>
</tr>
<tr>
<td>4</td>
<td>61929.12 ab</td>
<td>56944.37 ab</td>
<td>1264.14 ab</td>
</tr>
<tr>
<td>5</td>
<td>68998.35 a</td>
<td>61062.31 a</td>
<td>1351.82 a</td>
</tr>
</tbody>
</table>

**Kruskal Wallis test; Medians followed by the same letter do not differ from each other by Dunn’s test at the level of 5% probability ($p \leq 0.05$).**

Source: authors.

Tomatoes at a more advanced maturation stage, have a high content of carotenoides, compared to fruits in the green stage. This process occurs due to chlorophyll degradation and the synthesis of carotenoides, especially lycopene. Chlorophyll degradation occurs due to changes in pH, release of organic acids, acceleration of oxidative processes and chlorophyllases.

These results corroborate those of Silva et al. (2017), when quantifying total carotenoides in ripe tomatoes and of times, observed that red fruits (ripe) tend to accumulate greater quantity when compared to non-red (of times). The concentration of lycopene in tomatoes is linked to a better visual perception of the products, implying that there is a great demand for increased concentration of this pigment in fruits of cultivars both for in natura consumption and for industrial processing (Carvalho et al., 2018).

The increase in lycopene concentration in ripe fruits can be considered beneficial, as it may be linked to anticarcinogenic activity in human cell tissues. Therefore, lycopene is considered a potent natural antioxidant, and its action, in disease prevention, is directly associated with this characteristic (Martí et al., 2016).
According to Alves et al. (2020), carotenoids play two important functions: as a complement to pigment in photosynthesis and photoprotection. This can be explained by the structure of conjugated polyene of carotenoides, which allows the molecule to absorb light to quell or inactivate singlet oxygen and free radicals.

These components cannot be synthesized by humans, emphasizing the importance of eating foods rich in carotenoids, such as fruits and vegetables. However, the real health-related benefits depend heavily on its bioavailability, that is, the fraction of an ingested nutrient that is released from the food matrix and made available for intestinal absorption (Palmero et al., 2014).

Tomatoes, at more advanced stages of maturation, showed higher antioxidant capability than immature tomatoes. The fact that these tomatoes have higher capacity, may be a consequence of higher levels of carotenoids (lycopene), phenolic compounds and flavonoids identified them. These compounds have the ability to act as antioxidants, which confers this property on the foods that contain them.

4 FINAL CONSIDERATIONS

The results obtained under the experimental conditions in which this work was carried out allow us to conclude that the physiological stage directly influences the characteristics of physicochemical quality, in the bioactive compounds and in the antioxidant capacity, since, there was a significant effect on all variables analyzed.

In general, the physicochemical parameters showed a reduction in the content of total titratable acidity; and an increase in pH, total soluble solids and SST/ATT ratio, for fruits harvested at more advanced stages of maturation. For the compounds bioactive substances and antioxidant capacity, the maturation stages that stood out the greatest concentrations were stages 4 and 5.

Although ripe tomatoes have sensory characteristics (color and flavor represented by the SST/ATT ratio) and nutritional characteristics that are superior to tomatoes at a previous ripening stage, their harvest at this point is compromised, due to their high perishability and sensitivity to handling and transport. However, the tomato can reach the stage of maturation 5 until its consumption.
A joint assessment of quality attributes can improve the identification of maturation stages and monitoring of the post-harvest ripening process of the fruits, in order to ensure the delivery of a quality product to consumers.

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