Chapter 250

Active packaging and quality characteristics of grape tomatoes

https://doi.org/10.56238/devopinterscie-250

André Mesquita Rocha
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Gabriela Conceição Oliveira e Silva
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Andreia Aparecida dos Anjos Chagas
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Camila Gonçalves Rodrigues
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Washington Azevedo Silva
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Ernani Clarete da Silva
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Ana Paula Coelho Madeira Silva
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970

Lanamar de Almeida Carlos
Universidade Federal de São Joao del Rei - Campus Sete Lagoas, Rodovia MG-424- km 47, MG, Brazil, 35701-970
E-mail: lanamar@usfj.edu.br

ABSTRACT
One of the ways of preserving tomato fruits is the use of packaging that has the function of controlling or minimizing the degradation processes, allowing the fruits to maintain their quality characteristics until the consumers. This work aimed to evaluate the influence of packaging on shelf life, as well as on the preservation of quality attributes, bioactive compound content, and antioxidant activity of *grape* tomatoes. The experimental design was entirely randomized with 4 replications in a subdivided plot scheme, involving two packages (active packaging and PET packaging) and 5 storage times (0, 5, 10, 15, and 20 days). The following were evaluated: pH, total titratable acidity, total soluble solids, *Ratio*, firmness, instrumental color, fresh mass loss, lycopene, total phenolic compounds, vitamin C and antioxidant activity. The lycopene contents of the fruits packed in the active packaging increased (29.8 to 48.7 µg.100 g^{-1} in the 20-day storage period and decreased in the fruits packed in the PET packaging during this same period. There was degradation of vitamin C, whose mean contents in the stored fruits, regardless of the packaging varied from 21.4 to 15.9 mg.100 g^{-1} . The definition of the best packaging employed depends on the storage period submitted. For the preservation of lycopene mass the active packaging presented the best result.

Keywords: *Lycopersicon esculentum*, Lycopene, Cherry tomato.

1 INTRODUCTION

At the current moment there is a growing demand for functional foods, i.e., foods consumed regularly that, in addition to their nutritional content, provide health benefits to the consumer, mainly in reducing the risk of non-transmissible chronic diseases (NCDs). This demand has contributed to the

increased consumption of vegetables in Brazil and worldwide (CANELLA et al, 2018.; MENDONÇA et al., 2019).

Tomato (*Lycopersicon esculentum*) is a plant of the *Solanaceae family*, the same family as potato and bell pepper. Tomatoes are a low-calorie fruit and a recognized source of lycopene, in addition to the presence of ascorbic acid, vitamin E, vitamin K, folic acid, flavonoids, calcium, potassium, and other minerals. The relationship between regular consumption of lycopene and the prevention and fight against cancer has been studied for several years and has proven effectiveness in preventing, specifically, prostate cancer (ANTUNES, 2017).

There are several groups of tomatoes grown and sold in different regions of the country. The Brazilian tomato market can be divided basically into six groups: Santa Cruz, salad, saladinha, Italian, industrial, and cherry. The production of table tomatoes is distributed in a salad (51.5%), Italian (31.3%), Santa Cruz (12.1%), and cherry (5.1%). The *grape tomatoes* are in the cherry group, which is a variety of small fruits, perform shape, with high contents of soluble solids, very used to ornament dishes. This group of tomatoes has been showing great demand from consumers, reaching compensating prices in the market (NADAI et al., 2015; DOSSA & FUCHS, 2017).

Despite the high production obtained in medium and high-tech *grape* tomato crops, postharvest losses consume a considerable portion of the production, which leads to a continuous search for preservation methods to maintain the characteristics and extend the shelf life of the fruit, which allows the availability of tomatoes of optimal quality, even in markets far from the producing regions (DOSSA & FUCHS, 2017).

One of the ways to preserve fruits and vegetables *in nature* is the use of packages that have the function of controlling or minimizing the degradation processes, allowing the fruits to maintain the quality parameters until they reach the consumers (CHITARRA & CHITARRA, 2005). Active packages with properties related to selective permeability allow the controlled migration of volatile and non-volatile agents in the atmosphere surrounding the food. Depending on the intended application, there are several types of packaging on the market, including antimicrobial, antioxidant, oxygen scavenging, and ethylene absorbing among others (MOUSAVI et al., 2018; SUALEH, 2016). Some packaging incorporated zeolites (aluminosilicate materials that present a porous and complex structure formed by silica and alumina tetrahedrons) allowing a gas transfer and also that some molecules such as ethylene, for example, penetrate and lodge in the internal cavities thus promoting the absorption of this gas also known as the ripening hormone (MONTÉGUT et al, 2016, INGLEZAKIS, 2005, LUZ, 1995,).

Thus, considering the permanent search for increasing the shelf life of horticultural products while maintaining commercial quality through the use of active packaging, this study aimed to evaluate the influence of active packaging (incorporated ethylene absorbers - zeolites), on shelf life on the preservation of quality attributes, bioactive compound content, and antioxidant activity during storage of *grape* tomatoes.

2 MATERIAL AND METHODS

Plant material

Grape tomatoes of the cultivar Tomini, cultivated in greenhouses, in a semi-hydroponic system, harvested at the ripe stage, with bright red color, and selected manually (Figure 1) were used. The fruits were purchased from a commercial tomato farm located in Pará de Minas (Lat. 19.7816S, Long. 44.6198W).

Figure 1: Selection table and already selected fruits.

After harvest, the fruits were transported to the Bioactive Compounds and Food Preservation Laboratory of the Universidade Federal de São Joao del Rei - Sete Lagoas Campus, where they were selected according to the uniformity of size and color. Then, the fruits were separated in portions of 180 g (Figure 2) and packaged separately in 20 PET packages with a lid for opening and closing (thermoformed, favoring protection against mechanical damage, in the format that resembles a bunch of grapes, attractive to the consumer and lower cost of acquisition) and 20 packages of active LDPE plastic film containing ethylene absorbing particles (zeolites) incorporated in its structure (Trade name: VEGETALPACK, manufactured by Eletro Polímeros do Brasil Ltda).

Figure 2: *Grape* tomatoes being packed in PET containers and active packaging prepared for storage.

The fruits packed in the two different types of packaging were stored in B.O.D type greenhouses at 16 ºC ±2 (simulating the marketing conditions) for 20 days

For the laboratory analyses, samples of tomatoes stored in each of the packaging types (PET and active) were taken before storage and at 5, 10, 15, and 20 days of storage in BOD. Four packages were taken from each of the models, making 4 repetitions of each treatment. The analyses were performed in triplicate.

Evaluation of physicochemical characteristics

To determine the pH, 3 g of the homogenized fruits were weighed and added to 50 mL of distilled water. The reading was performed by direct immersion of the electrode of a digital pH meter (Tekna® T-1000).

Total titratable acidity was determined according to the methodology proposed by AOAC (2016). Titration was performed with 0.1N NaOH solution as standard and phenolphthalein assisted by a pH meter to detect the turning point since the color of the sample already hinders the subtle color changes. The results were expressed as % (g/100 g) of citric acid on a fresh basis.

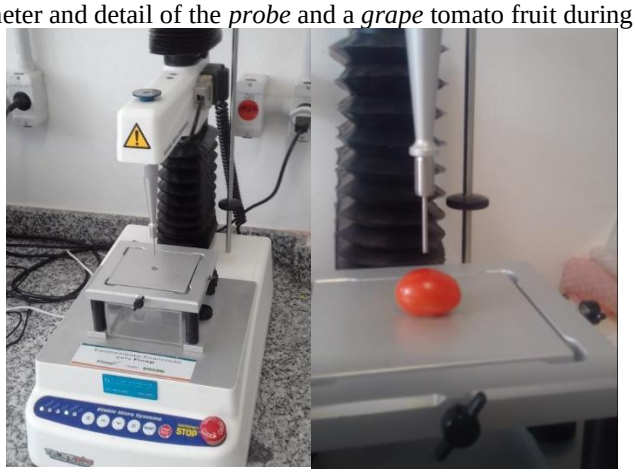
Total soluble solids (TSS) were analyzed using a Reichert® r2 Mini digital refractometer with direct reading and precision of 0.1°Brix. For the determination of the TSS content, the samples were macerated and filtered in cloth, the drops were placed directly on the prism of the refractometer (AOAC, 2016). The *Ratio* (total soluble solids/total titratable acidity ratio) was calculated using the quotient TSS/ATT.

Color determination was done using a Konica Minolta colorimeter, CR410, and was expressed in the color space L*, a*, and b*, where L* points to the brightness, a* the colors ranging from green to red, and b* defines the colors from blue to yellow. The color reading was performed at 3 distinct points in the equatorial region of each sampled fruit.

The loss of mass (g) was calculated using an analytical balance, where the packages were identified and weighed individually at the time of storage and weighed again every 5 days, at the moment before the laboratory analyses. The calculated mass loss was based on the difference between the initial (g) and final masses (g) and was later converted into a percentage.

Fruit firmness was determined using a TA XT texturometer^{Plus}, equipped with a Blade Set HDP/BS operational cell, 2 mm diameter stainless steel *probe* (Figure 3), adjusted for a penetration speed of 0.5 mm.s^{-1}. The results of the firmness analysis (the peak of the maximum force required to break the fruit peel), were expressed in Newton (N).

Figure 3: Texturometer and detail of the *probe* and a *grape* tomato fruit during firmness analysis.



Evaluation of bioactive compounds

The carotenoids present in the fruits were quantified according to the methodology proposed by Rodriguez-Amaya (2001). For the analysis, 5g of the homogenized sample was weighed, then transferred to a mortar, BHT (butyl hydroxytoluene) was added to protect the carotenoids from oxidation, celite was used to rupture the sample tissues, and acetone was added to extract the carotenoid pigments.

After the sample was finely macerated, it was vacuum filtered and acetone was added until the carotenoid pigments were completely extracted.

The extract was then transferred to a separating funnel already prepared with petroleum ether p.a. and then, using distilled water, the ether extract was washed 3 times and transferred to a conical flask, where the sample was dehydrated using sodium sulfate ($Na_2 SO_4$). The extract was immediately transferred to a 25 mL volumetric flask. The absorbance reading was performed in a spectrophotometer (FEMTO 700 S) with a wavelength of 470 nm, calibrating the equipment previously with petroleum ether. The lycopene content was calculated by applying Equation 1, with the results expressed in µg lycopene/g of fresh sample.

$$\text{Lycopene} = \left[\frac{\text{A x V x } 10^4}{\text{E1\% 1cm x M}}\right] \mu g/g \qquad \text{Equation 1}$$

Where: A = Absorbance at 470 nm, multiplied by the dilution factor; V = Volume of the sample (25 mL); E1% 1 cm = extinction coefficient of lycopene in petroleum ether = 3450, M = sample mass (5 g).

The content of total phenolic compounds was determined by the Folin- Ciocalteau method (NEVES et al., 2009) with a comparison of a calibration curve constructed with gallic acid. The analysis consists in extracting the phenolic compounds from the sample using 70% ethanol. Then, an aliquot of the extract was added to the Follin Ciocatteu solution (10%) and later the Na solution$_2$ CO_3. was added. After resting for 2 hours, it was read in a spectrophotometer at 740 nm. The results were expressed as mg of gallic acid equivalents (GAG) per 100 g of sample on a fresh basis

The quantification of vitamin C was performed by HPLC, according to the methodology described by Benlloch et al. (1993) with adaptations (Rocha et al., 2020). Weighed 1 gram of the homogenized samples and added enough 0.5% aqueous oxalic oxide solution to make up the volume to 10 mL. Then, centrifugation was performed for 5 minutes at 4500 RPM, and an aliquot of the supernatant was removed, which was then filtered on Minisart RC filters (13mm diameter, 0.45µm membrane). We proceeded to inject 20 µL into SHIMADZU Prominence chromatograph equipped with SPD-M20 DAD detector, LC20AT pump, and ThermoScientifc C-18 ODS-2 HYPERSIL 250 mm x 4.6 mm column. The mobile phase used was an aqueous solution of mono potassium phosphate 50 mmol/L and cetyltrimethylammonium bromide (BCTMA) 5 mmol/L with the pH adjusted to 4 using phosphoric acid and flow rate of 1mL.min^{-1} . The detector was set to λ = 254 nm.

The antioxidant activity was determined according to the methodology proposed by Brand-Willians et al. (1995), where after the ethane extraction, the DPPH free radical was added, and the solution was kept protected from light. When the free radical is reduced by the sample, its color changes, becoming less intense as the DPPH is reduced. After 1 hour, the absorbance was read at 572 nm in a spectrophotometer, the wavelength of maximum absorption of DPPH.

The antioxidant activity was calculated using Equation 2:

$$[\ ATA\ ] = \frac{(\Delta Abs - b) * V * D}{a * m} \qquad \text{Equation 2}$$

Where: ΔAbs=Absorbance of the blank - absorbance of the sample, B= Linear coefficient, A= Angular coefficient, V1= Total sample volume (extraction), m= Working sample mass (g), D= **Dilution** ratio

The results obtained were expressed in µmol Trolox equivalent/g sample since the total antioxidant capacity of the sample for the DPPH radical was compared to the antioxidant potential of Trolox by constructing a standard curve with increasing concentrations (straight line equation: y= 0.0009x +0.0162; R^2 = 0.9814).

Experimental design and statistical analysis

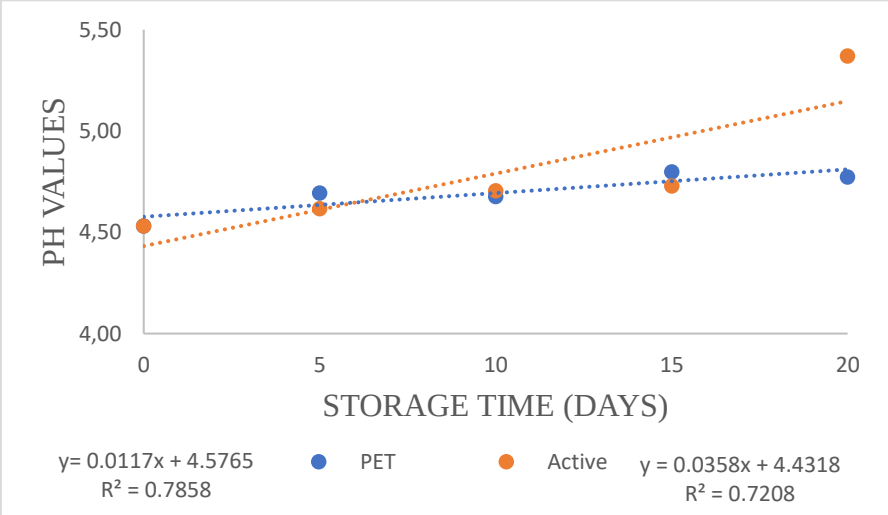
The experimental design was entirely randomized, with 4 repetitions, in a subdivided plot, with 2 levels of the packaging factor (active packaging and PET packaging) in the plot and 5 levels of the evaluation time factor (0, 5, 10, 15 and 20 days) in the subplot. The data obtained were submitted to variance analysis and the assumptions of the statistical model were verified by the Shapiro-Wilk and Levene tests, respectively. The comparisons of means for the packaging factor were done by the F test, for the time factor, regression was used, and for the variables where there was a significant interaction effect, the splitting was done. All analyses were performed in R software (R, 2020), considering a significance level of 5%.

3 RESULTS AND DISCUSSION

Physical-chemical characteristics

There was a significant effect ($p<0.05$) of the interaction between the factors type of packaging and storage time for the characteristics pH, total soluble solids (TSS), total titratable acidity (TTA), lycopene (LC) and Mass Loss (MP). For pH, an increase in the detected values was observed as the storage time progressed. The pH increased linearly, and thus, the fruits stored in both packages became less acidic throughout the studied period (Figure 4).

Figure 4: pH values in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.



From the regression model, it is observed that on each day of storage, the fruits packed in active packaging increased the average pH value by approximately 0.036 and the fruits packed in PET packaging had an average increase of only 0.012. This increase in pH possibly happened due to the biochemical processes of maturation that lead among other reactions to the degradation of organic acids during the storage of the fruits.

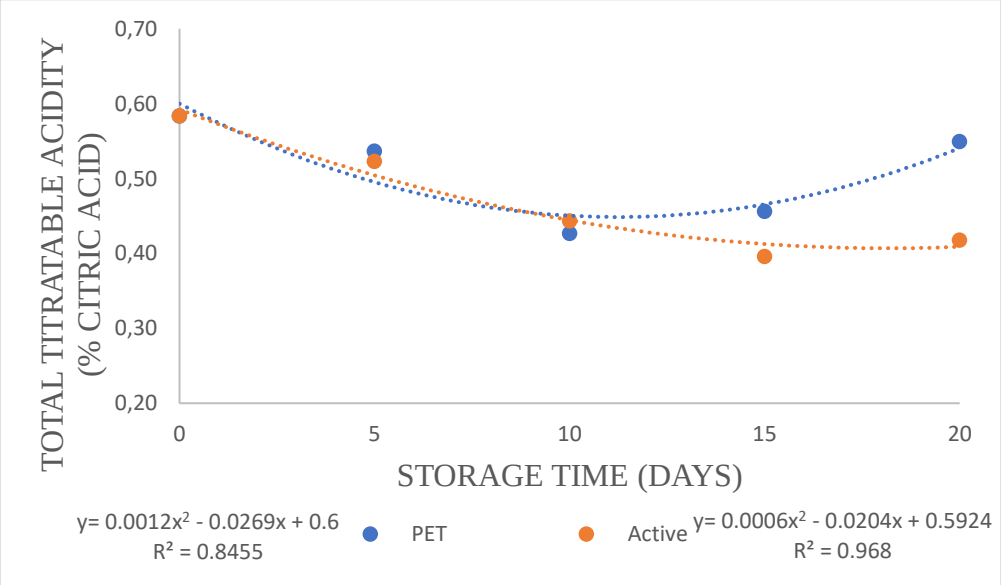
The pH curves followed the same tendency taking into account the two different types of packaging, but the fruits stored in PET packaging showed less tendency to increase the acidity during the storage period. That is, the fruits stored in PET became less acidic, starting from a pH of 4.57 at the beginning of storage and at 20 days of storage when the maximum value of 5.37 was observed. Among the fruits stored in active packaging, the highest value observed for pH was 4.77 also at 20 days of storage.

When studying fruits of the commercial hybrid *sweet grape* in different types of packaging, especially flexible plastic films of PVC (polyvinyl chloride) and LDPE (low-density polyethylene), Sandri et al. (2015) observed the maintenance of pH values in open packaging, which offered no barrier to gas exchange. In the sealed plastic film-type packages, they also observed a slight tendency for the pH to increase, although less than those observed in the present study.

The regression analysis of the mean values of ATT observed allowed the adjustment of a quadratic regression model (Figure 5). The graph shows a downward trend in the observed ATT values, with the lowest value observed at 11 days in the PET package used in this study.

At 20 days of storage, the fruits stored in the PET container showed a small increase in the observed average. This increase in ATT happened only in the fruits stored in the PET container. Other authors studying the shelf life of *sweet grape* and cherry tomatoes have reported a decrease in the ATT in the materials used (Aguiar et al., 2012). In several other studies it was observed a decrease in the ATT, in some hybrids being lower than in others, but always existing a decrease along the storage time (BECKLES, 2012; MIGUEL et al., 2007).

Figure 5: ATT values in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.



The ATT decrease happens in line with the observation of the slight increase in the pH of the fruit throughout the storage period, which probably happens due to the degradation of organic acids, which are used as a substrate for respiratory activity in the tissues, and due to the decrease of oxygen inside the package has its metabolism altered.

Fruits stored in the active packaging had an average ATT of 0.42% citric acid at 20 days of storage.

The mean values of the TSS contents of the fruits packed in the active package varied from 8.67º Brix at the time of storage to 7.35º Brix at the end of 20 days of storage. In the fruits in PET packaging, there was a more accentuated decrease, starting from 8.67 °Brix at the time of fruit storage and reaching 7.02º Brix at the end of 20 days of storage. Throughout the study period, there was an oscillation of the TSS contents in the fruits packed in both types of packaging during storage, which did not allow the adjustment of a regression equation model. However, based on the values observed at the time of storage and the end of the 20 days, it was possible to detect a clear tendency for reduction of the TSS content in both packages as the storage time increased. The reduction in TSS during storage can be influenced by the increased respiration rate of the product, which can consume the existing reserves in the cells (BECKLES, 2012).

Tolesa and Workneh (2017) when studying the quality of table tomatoes harvested, sanitized, and stored in packages without atmosphere control for up to 28 days, also observed oscillations in TSS contents throughout the storage period of the fruits.

Beckles (2012) studying the factors that influence TSS content, states that tomatoes stored at temperatures near 12.5º C show better preservation of constituent sugars, possibly due to decreased plant metabolism, as well as the use of modified and controlled atmosphere packaging also contributes to this better preservation of TSS contents.

The packaging used, as well as the storage period, exerted an independent influence on the *Ratio*. For fruits stored in PET, the *Ratio* values oscillated from 14.86 at the time of storage to 13.87 at the end of storage (20 days). However, there was a tendency for the values to decrease after 15 days of storage. In contrast, Tigist et al. (2013), when studying different varieties of tomatoes stored at room temperature, observed an increasing increase in the *Ratio* value in all varieties studied, contrary to that reported by Aguiar et al. (2012), who observed that the *Ratio* values increased at first and showed a clear decline at 17 days of storage. Similar behavior occurred in this study for the fruits packed with active packaging in which the *Ratio* values were significantly higher, reaching the final value equal to 16.92.

These results showed that the values were influenced by the type of packaging used and also by the storage time, but the statistical analysis did not indicate an interaction between them, similar to the results observed by other authors (TOLESA and WORKNEH, 2017) in their study of tomato ripening dynamics.

Color is one of the main factors related to consumer acceptance and purchase intention (VISKELIS, 2009). For the parameters L* and b*, there was a significant effect ($p<0.05$) only of the storage time, not being affected by the packaging used and the interaction between the packaging factor and the storage time.

For the* parameter, there was a significant effect of the interaction between the packaging used and the storage time.

The b* coordinate, which expresses the variation between blue and yellow, decreased as time progressed, a result similar to the observation of CARON et al. (2013), whereas storage time increased, the b* coordinate decreased.

The* coordinate, which represents the variation in the axis that goes from red to green, was maintained throughout the study period without great variations, with a small increase at 10 days of storage followed by a decrease, where it returned to values close to the initial ones (10.71 at the time of storage, 12.20 at 10 days and 10.54 at the end of the experiment). At the time of storage the fruits were at the ideal point for commercialization, that is, with the color already developed, which made the changes that happened throughout storage very subtle. This allows us to infer that both packages allowed the maintenance of the attractive color of the fruits throughout the period evaluated in this study.

This small fluctuation in the values of a* coordinate was also observed by Aguiar et al. (2012), Renna et al. (2018), and Tigist et al. (2013) when studying already ripe tomatoes with developed color at the time of storage, thus confirming the observations of this study.

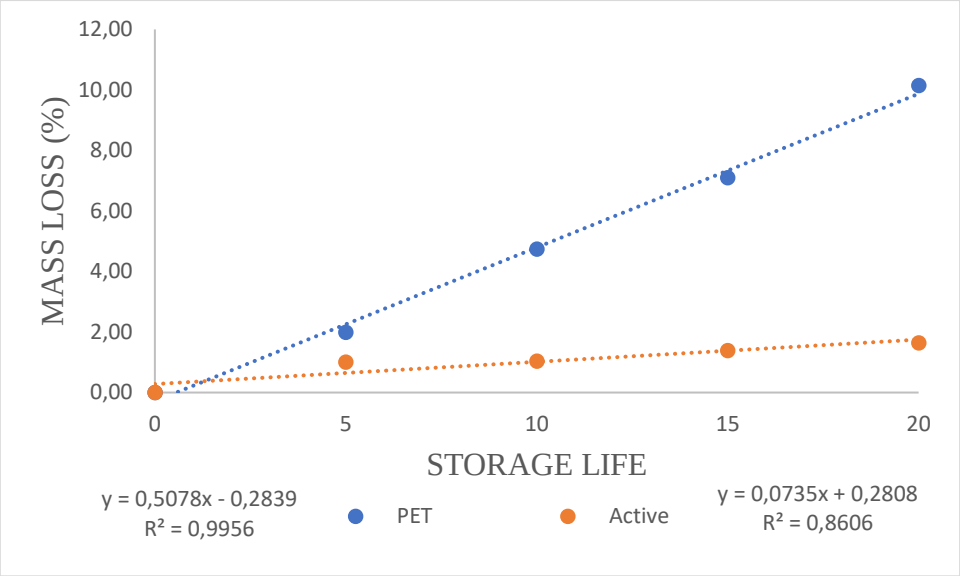
When studying the quality of tomatoes grown in Lithuania, Viskelis (2009) observed that while the lycopene content increased, the Luminance (L*) values decreased.

During storage, there was an increase in the average brightness of the fruits stored in the active packing. The lycopene levels in the fruits stored in the active package behaved similarly, i.e. the rate of lycopene biosynthesis was higher than the degradation of the pigments during the storage time, thus increasing the levels of lycopene.

The stored fruits, independently of the packaging used, lost mass during the storage time. The averages observed allowed the adjustment of a linear equation describing the interaction between the factors. As the storage time increased, the mass loss of the fruits stored in the packages also increased, and the fruits stored in the PET package presented mass loss values significantly higher than the mass losses of the fruits stored in the active package (Figure 6).

According to Chitarra & Chitarra (2005), the loss of fruit mass happens mainly due to metabolic activity and loss of moisture in the surrounding atmosphere. In the PET package, a greater mass loss was observed, since it offers little or no barrier against gas exchange in the atmosphere inside the package, due to the small opening between the lid and the body of the package, further enhancing water loss, unlike the active package, which reduces the exchange of water vapor with the external environment of the package.

Figure 6: Mass loss in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.



In PET packaging, a greater loss of mass was observed, as this offers little or no barrier against gas exchange in the atmosphere inside the packaging,

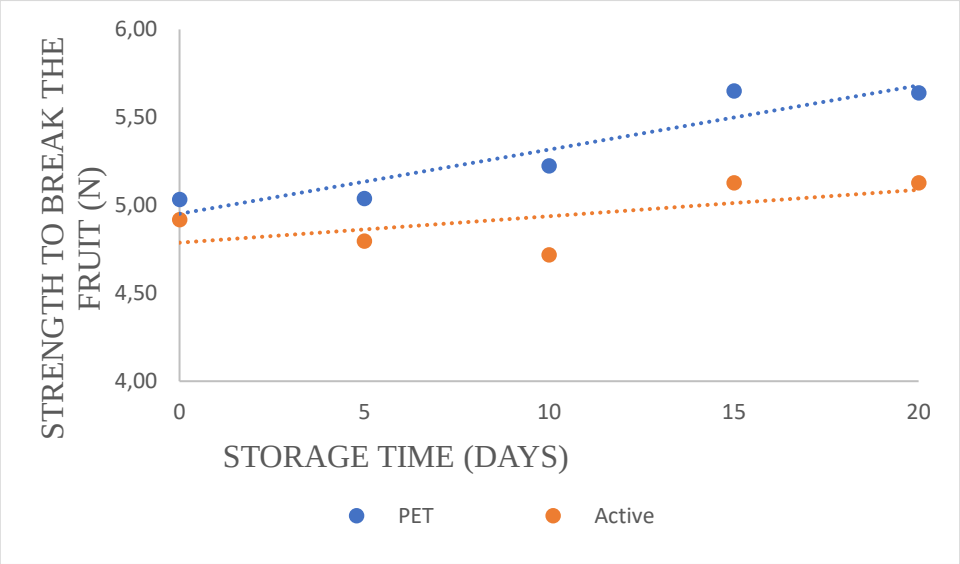
Several authors have observed fresh mass loss of tomatoes throughout storage, but there was no control of gas and water vapor exchange with the environment (TOLESA & WORKNEH, 2017).

Sandri et al. (2015), in their study of different storage conditions, observed that when fruits were packed in packages that allowed gas exchange with the environment, these also showed a greater loss of fresh mass than fruits stored in packages that did not allow or that decreased gas exchange, thus corroborating the results observed in this study.

As can be observed in Figure 7, the force to break the fruits increases along the storage period (days) and it happens in a more pronounced way in the fruits stored in the PET package. This change happened due to the loss of turgidity of the fruits during the storage time, which resulted in a greater elastic deformation of the tomato peel, and consequently, required a greater force applied to break the fruits.

It is important to emphasize that an important characteristic for consumers who appreciate *grape* tomatoes is related to the texture of the fruit, when bitten, they break in the mouth provoking pleasant sensations caused by the burst or bursting of the pericarp. The lower the force required to break the fruit peel, the better this characteristic is. In this sense, it was observed that this sensation when eating the tomatoes has an inverse relationship with the storage time.

Figure 7: Firmness of *grape* tomatoes stored under refrigeration (16 °C) in active packaging and PET for 20 days.



This increase in the force required to break the fruit peel occurs due to the ripening processes of the fruit and also the loss of turgidity. During ripening there is the hydrolysis of structural carbohydrates by the activity of the enzymes cellulases and pectinases, leading to the softening of the cell wall and loss of turgidity of the fruit, which in the case of tomatoes led to greater elasticity of the cuticle, allowing a greater elastic deformation of the tissues, thus increasing the force required to break the fruit. Importantly, this increased tissue elasticity and softening of the fruit skin is an undesirable characteristic, as a small force to break the fruit is a characteristic that consumers appreciate in *grape tomatoes* (TAIZ et al., 2017).

Saladié et al. 2007, when studying the biomechanical properties of tomato cuticles, found a direct relationship between tissue hydration and the force required to rupture these fruits, where more hydrated fruits required lower forces to be broken. Thus, it can be concluded that the active packaging showed positive results concerning the preservation of turgidity, maintaining for a longer time the firmness characteristics appreciated by consumers.

Bioactive Compounds

For the lycopene content, there was a significant effect ($p<0.05$) of the interaction, indicating a dependence between the packaging used and the storage time of the fruits. When the interactions were unfolded, it was observed that the lycopene contents differed significantly after 10 days of storage.

Several authors when studying and describing the processes and changes that take place during tomato ripening, reported that lycopene synthesis is influenced by many factors, which can act alone or together, synergistically intensifying or retarding its biosynthesis (IGLESIA et al., 2013; MONTEIRO et al., 2018; TAIZ et al., 2017; VERHEUL et al., 2018).

Taiz et al. (2017) when describing the ripening process of climacteric fruits, exposed that the chlorophyll degradation process happens concomitantly with the synthesis of carotenoids, as well as with changes in cell walls and organelle structures (mainly chromoplasts). The authors also point out that these

events are controlled by numerous environmental factors, such as the presence and intensity of light, temperature, the existence of mechanical damage, and also by endogenous factors, with ethylene being the main hormone influencing the synthesis of carotenoids.

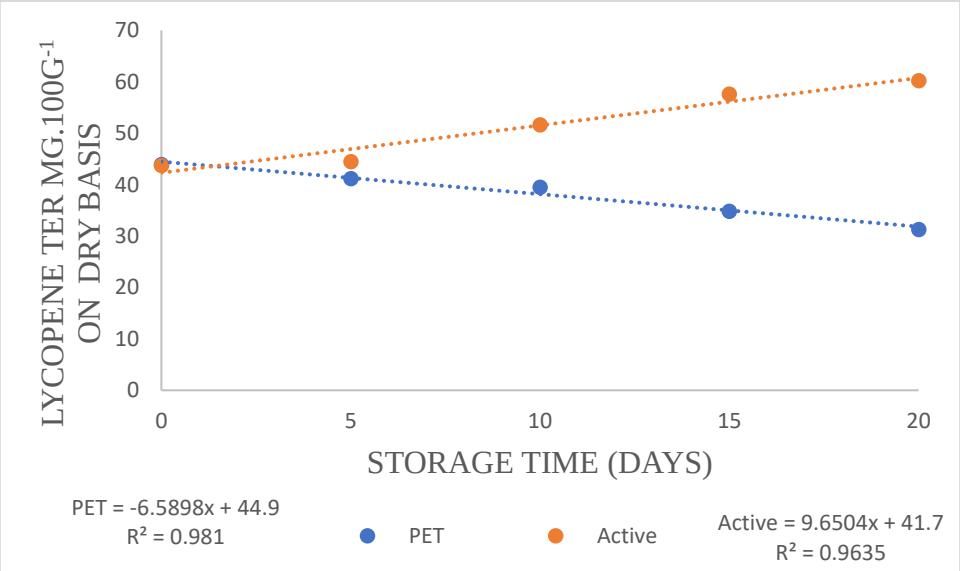
Verheul et al. (2018) and Monteiro et al. (2018) when studying the influences of tomato ripening stage on carotenoid content, show that large variations in lycopene contents can occur after harvest depending on the ripening stage at which the fruit was harvested.

Other authors when studying the dynamics of tomato ripening in various packages observed that active packaging that decreases ethylene and modifies the balance of O_2 and CO_2 causes decreased lycopene synthesis (IGLESIA et al., 2013; FAGUNDES et al., 2015; KANDASAMY et al., 2019).

Thus, when observing the behavior of lycopene content under the conditions of this study, it was detected that packaging exerted an antagonistic effect on lycopene content during fruit storage.

The lycopene content of the tomatoes stored in the PET package decreased as the storage period increased while in the fruits stored in the active package, there was a gradual increase of this carotenoid (Figure 8).

Figure 8 - Lycopene content expressed (µg. g^{-1} dry basis) in *grape* tomatoes stored under refrigeration (16 °C) in two different packages (Active and PET) for 20 days.

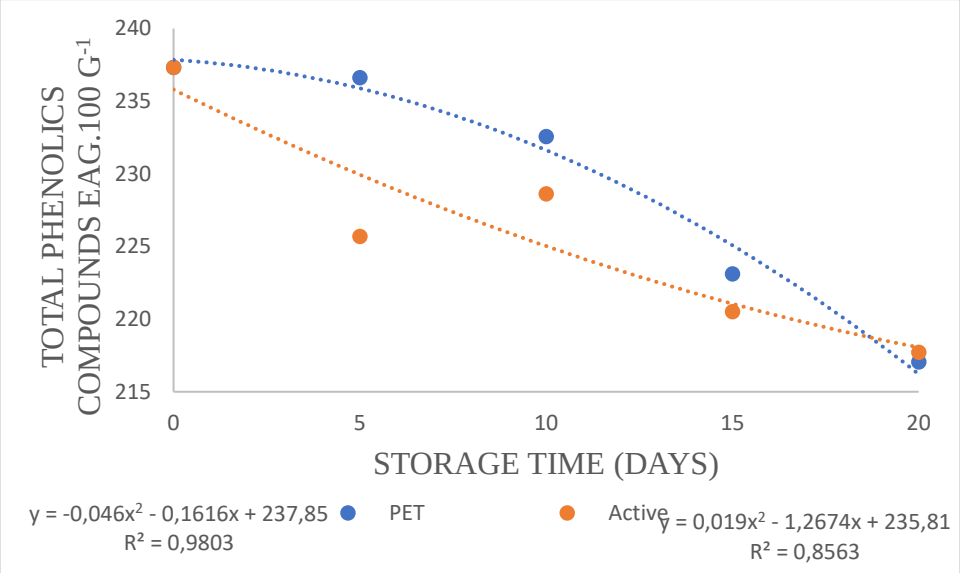


The dynamics of lycopene biosynthesis and degradation is an enzymatic process, so the dehydration of tissues influences cellular metabolism (TAIZ et al. 2017), so it is possible to assume that the decrease in lycopene levels in the fruits stored in the PET package is possibly due to the increased rate of degradation of lycopene and a decrease in the rate of biosynthesis linked to the loss of fruit mass because the fruits lost up to 10.14% mass at the end of 20 days. While in the fruits stored in the active package, it is possible to observe the increase of lycopene content, while in the same period, they lost no more than 2% of the mass.

The levels of total phenolic compounds observed in the tomatoes differed only concerning storage time. They were not influenced by the packaging used nor by the interaction between the two factors studied.

The highest levels of phenolic compounds were detected in the fruits at the time of storage (237.33 EAG/100 g) (Figure 9), and these levels gradually decreased until 20 days of storage, where the lowest average observed was 217.39 EAG/100 g.

Figure 9: Content of phenolic compounds in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.

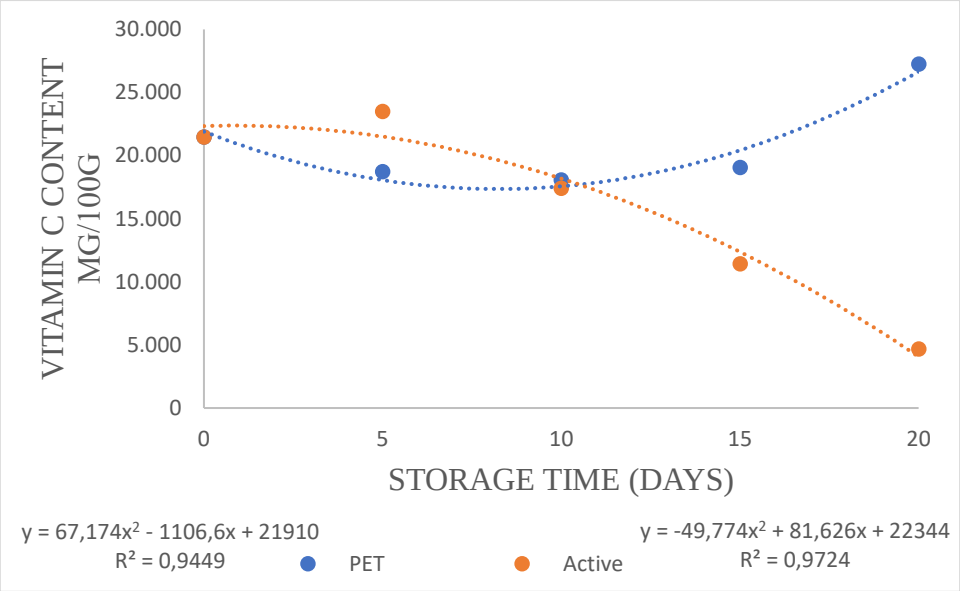


Mirdeghan & Valero (2016), on the other hand, when studying the effect of different additives for coating and surface treatment of tomatoes *in naturally* observed a reduction in the content of phenolic compounds in all the treatments used and in the witness, which matches the observations of the present study.

The vitamin C levels of the fruits stored in active packaging at the time of storage were 21.48 mg.100 g^{-1} and decreased throughout the study period, reaching the level of 4.66 mg.100 g^{-1} after 20 days, that is, they showed a loss of nearly 78% of vitamin C. The fruits stored in PET containers showed an oscillation of the average vitamin C content over time, but, at the end of the period, showed a slight increase, reaching 27.24 mg.100 g^{-1}.

As can be seen (Figure 10), the active-type packaging harmed the amount of vitamin C over the study period.

Figure 10: Vitamin C contents in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.



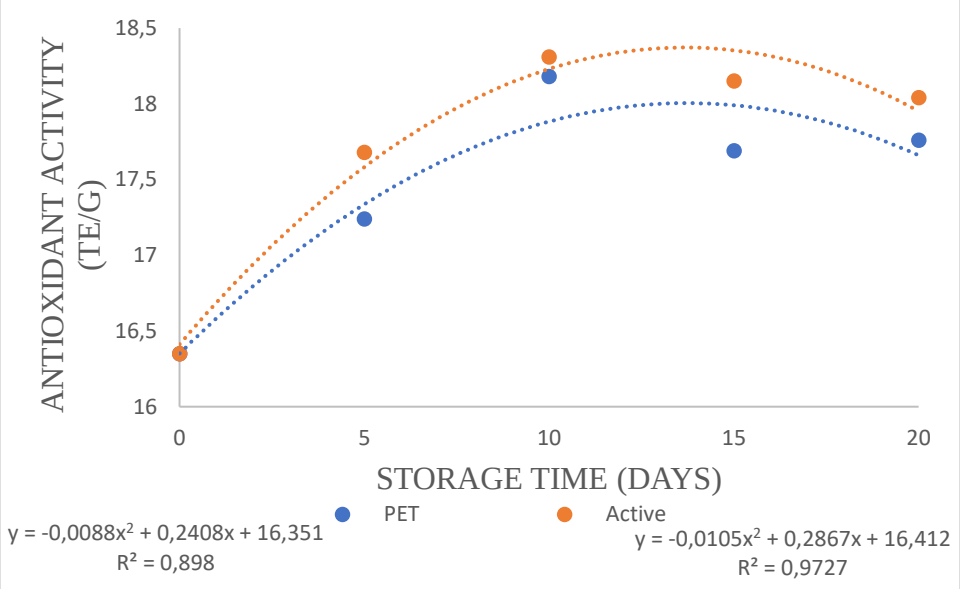
Stress situations, such as a decrease in the amount of oxygen available, lead to an increase in the production of reactive oxygen species (ROS *reactive oxygen species*), which cause progressive damage to the cells (SHARMA, 2012). The decrease in vitamin C content in fruits already harvested possibly happens due to the formation of these reactive oxygen species, which could react with vitamin C, which would be oxidized, and consequently the protection of cell organelles and other bioactive compounds would occur (TAIZ et al., 2017).

Oscillations in vitamin C content similar to what was observed in fruits stored in PET packaging were observed by Miguel et al. (2007) when studying different packages for storing minimally processed tomatoes, but in none of the treatments they observed a reduction similar to what was detected in the active packaging during the storage period.

It was observed that the storage time influenced the antioxidant activity ($p<0.05$), with no influence of the type of packaging or the interaction between these factors.

The quadratic model was fitted to the antioxidant activity data (Figure 11), with the maximum ATT value, 18 µmol TE/g, obtained with a storage time of 13.7 days for both packages, with a subsequent reduction after the optimal storage time was reached.

Figure 11: Antioxidant activity expressed as µmol Trolox equivalent (TE)/g on fresh basis in *grape* tomatoes stored under refrigeration (16 °C) in active and PET packaging for 20 days.



The initial increase in antioxidant activity in stored tomatoes was also a common observation in the studies of Mirdehghan & Valero (2016).

Mirdehghan & Valero (2016), when studying different additives for improving the quality of stored tomatoes, observed an increase in antioxidant activity between the time of storage (approximately 28 mg ascorbic acid equivalent 100 g^{-1}) and the first observation that occurred at 8 days (approximately 38.3 mg ascorbic acid equivalent 100 g^{-1}). After that, there was a retreat to levels lower than the initial one (approximately 25.7 mg ascorbic acid equivalent to 100 g^{-1}).

4 CONCLUSIONS

1. There was an influence of the type of packaging on quality attributes, bioactive compound content, and antioxidant activity of *grape* tomatoes during refrigerated storage (16 ºC) for 20 days.

2. The active packaging kept the firmness of the fruit longer and significantly reduced the loss of mass.

3. Up to 5 days of storage there was no significant difference in the quality characteristics of the tomatoes stored in the two different packages.

4. When considering 20 days of storage, the best option is the active packaging concerning the preservation of phenolic compounds, lycopene, and a lower loss of mass. The PET package, on the other hand, contributed to the maintenance of higher levels of vitamin C and total titratable acidity.

4. In general, *grape* tomatoes packed in active packaging showed better quality and greater reduction of mass loss for a longer period than the fruits packed in PET packaging, reaching satisfactory quality until 20 days of storage.

REFERENCES

AGUIAR, F. P. C.; ABRAHÃO, R. M. S.; ANJOS, V. D. A., BENATO, E. Ap. Determinação da vida útil de tomate tipo cereja e "sweet grape" CONGRESSO INTERINSTITUCIONAL DE INICIAÇÃO CIENTIFICA, 6°, 2012, Jaguariúna Anais, Jaguariúna, EMBRAPA (Vol. 66). 2012

ANTUNES, S. R. N. Propriedades fitoquímicas do licopeno: efeito preventivo no cancro da próstata. 2017. Dissertação (Mestrado em Ciências Farmacêuticas). Instituto Universitário Egas Moniz – Ciências Farmacêuticas, Almada, Portugal.

AOAC - INTERNATIONAL, LATIMER, G, W. ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTRY - Aoac. Official methods of analysis of the Association of Official Analytical Chemistry. 20th ed. 2016.

BECKLES, D. M. Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology, v. 63, p. 129–140. 2012. https://doi.org/10.1016/j.postharvbio.2011.05.016

BENLLOCH, R.; FARRÈ, R.; FRIGOLA, A. A quantitative estimate of ascorbic and isoascorbic acid by high-performance liquid chromatography: Application to citric juices. Journal of Liquid Chromatography, v. 16(14), p. 3113–3122. 1993. https://doi.org/10.1080/10826079308019637.

BRAND-WILLIAMS, W., CUVILIER, M. E., BERSET, C. L. W. T. Use of a free radical method to evaluate antioxidant activity. LWT-Food science and Technology, 28(1), 25-30. 1995.

CANELLA, D.; LOUZADA, M. L.; CLARO, R.; COSTA, J.; BANDONI, D.; LEVY, R.; MARTINS, A. P. Consumption of vegetables and their relation with ultra-processed foods in Brazil. Revista De Saúde Pública, v.52, p. 50. 2018. https://doi.org/10.11606/S1518-8787.2018052000111

CARON, V. C.; TESSMER, M. A.; MELLO, S. C.; JACOMINO, A. P. Quality of mini tomatoes harvested at two maturity stages and kept chilled in three packages. Horticultura Brasileira, Brasília. v.31(2), p. 279–286. 2013. https://doi.org/10.1590/S0102-05362013000200017

CHITARRA, M. I. F.; CHITARRA, A. B. Pós-colheita de frutas e hortaliças: fisiologia e manuseio.2. ed. rev. e ampl. Lavras: UFLA, 2005. 785 p.

DOSSA, D.; FUCHS, F. Tomate: Análise Técnico-Econômica E Os Principais Indicadores Da Produção Nos Mercados Mundial, Brasileiro E Paranaense. Ceasa, 2017.

FAGUNDES, C.; MORAES, K.; PÉREZ-GAGO, M. B.; PALOU, L.; MARASCHIN, M.; MONTEIRO, A. R. Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes. Postharvest Biology and Technology, v. 109, p.73–81. 2015. https://doi.org/10.1016/j.postharvbio.2015.05.017.

IGLESIA, N.; M. S.; QUEVEDO, M. A.; GONZAGA, Z, C. Physico-chemical Changes in Tomato (Solanum lycopersicum L.) Fruits as Influenced by Cultivation Systems and Modified Atmosphere Packaging. Annals of Tropical Research, v. 35(1), p. 74-104, 2013.

KANDASAMY, P.; MUKHERJEE, S. Enhancing shelf life of tomato under controlled atmosphere condition using diffusion channel system. Engineering in Agriculture, Environment and Food, v. 0–1. 2018. https://doi.org/10.1016/j.eaef.2018.07.001

LÓPEZ-GRESA, M. P.; MALTESE, F.; BELLÉS, J. M.; CONEJERO, V.; KIM, H. K.; CHOI, Y. H.; VERPOORTE, R. Metabolic response of tomato leaves upon different plant-pathogen interactions. Phytochemical Analysis, v. 21(1), p. 89–94. 2010. https://doi.org/10.1002/pca.1179

MENDONÇA, R., LOPES, M.; FREITAS, P.; CAMPOS, S.; MENEZES, M.; LOPES, A. Monotony in the consumption of fruits and vegetables and food environment characteristics. Revista De Saúde Pública, v. 53, p. 63. 2019. https://doi.org/10.11606/S1518-8787.2019053000705

MIGUEL, A. C. A., DIAS, J. R. P. S., SPOTO, M. H. F. e RIZZO-BENATO, R. T. Qualidade de tomate "Débora" minimamente processado armazenado em dois tipos de embalagens. Horticultura Brasileira, Brasília. v. 25(4), p. 582–585. 2007. https://doi.org/10.1590/S0102-05362007000400017

MIRDEHGHAN, S. H.; VALERO, D. Bioactive compounds in tomato fruit and its antioxidant activity as affected by incorporation of Aloe, eugenol, and thymol in fruit package during storage. International Journal of Food Properties, v. 20, p. 1–9. 2016. https://doi.org/10.1080/10942912.2016.1223128

MONTEIRO, S. S., MONTEIRO, S. S., DA SILVA, E. A. e MARTINS, L. P. Maturação fisiológica de tomate cereja. Revista Brasileira de Agrotecnologia, v. 8(3), p. 05-09, 2018.

NADAI, F. B.; MENEZES, J. B. DE C.; CATÃO, H. C. R. M.; ADVÍNCULA, T.; COSTA, C. A. Produção de mudas de tomateiro em função de diferentes formas de propagação e substratos. Revista Agro@mbiente on-line. v. 9(3), p. 261. 2015. https://doi.org/10.18227/1982-8470ragro.v9i3.2348.

NEVES L. C.; ALENCAR SM; CARPES S. T. Determination of antioxidante activity, total phenolic compounds and total flavonoids of samples of apicultural pollen from Apis melífera. Brazilian Journal of Food Technology. 2009.

R CORE TEAM. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2020. Disponível em: https://www.R-project.org/.

RENNA, M.; DURANTE, M.; GONNELLA, M.; BUTTARO, D.; D'IMPERIO, M.; MITA, G.; SERIO, F. Quality and Nutritional Evaluation of Regina Tomato, a Traditional Long-Storage Landrace of Puglia (Southern Italy). Agriculture, v. 8(6), p. 83. 2018. https://doi.org/10.3390/agriculture8060083

ROCHA, A. M.; CHAGAS, A. A. A.; SILVA, G. C. O.; SILVA, E. C.; SILVA, W. A.; ALMEIDA-CARLOS, L. A. Quality of grape tomatoes in differents cultivation systems. Research, Society and Development, v. 9, p. e7109109008-16, 2020. https://doi.org/10.33448/rsd-v9i10.9008

RODRIGUEZ-AMAYA, D.B. A guide to carotenoid analysis in food. Washington: International Life Sciences Institute, 2001. 64 p.

SALADIÉ, M.; MATAS, A. J.; ISAACSON, T.; JENKS, M. A.; GOODWIN, S. M.; NIKLAS, K. J.; ROSE, J. K. C. A reevaluation of the key factors that influence tomato fruit softening and integrity. Plant Physiology, v. 144(2), p. 1012–1028. 2007. https://doi.org/10.1104/pp.107.097477

SANDRI, D.; RINALDI, M. M.; ISHIZAWA, T. A.; CUNHA, A. H. N.; PACCO, H. C.; FERREIRA, R. B. 'Sweet grape' tomato post harvest packaging. Engenharia Agrícola, v. 35(6), p. 1093–1104. 2015. https://doi.org/10.1590/1809-4430-Eng.Agric.v35n6p1093-1104/2015

SHARMA, A. B. J.; RAMA S. D.; Mohammad P. Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions, Journal of Botany, vol. 2012, Article ID 217037, 26 pages, 2012. https://doi.org/10.1155/2012/217037

TAIZ, L.; ZEIGER, E.; MOLLER, I.; MURPHY, A. Fisiologia e Desenvolvimento Vegetal. In Artmed. 2017. https://doi.org/10.1007/978-3-642-32304-1_19

TIGIST, M.; WORKNEH, T. S.; WOLDETSADIK, K. Effects of variety on the quality of tomato stored under ambient conditions. Journal of Food Science and Technology, v. 50(3), p. 477–486. 2013. https://doi.org/10.1007/s13197-011-0378-0

TOLESA, G. N.; WORKNEH, T. S. Influence of storage environment, maturity stage and pre-storage disinfection treatments on tomato fruit quality during winter in KwaZulu-Natal, South Africa. Journal of Food Science and Technology, v. 54(10), p. 3230–3242. 2017. https://doi.org/10.1007/s13197-017-2766-6

VERHEUL, M. J.; SLIMESTAD, R.; TJØSTHEIM, I. H. From Producer to Consumer: Greenhouse Tomato Quality as Affected by Variety, Maturity Stage at Harvest, Transport Conditions, and Supermarket Storage. Journal of Agricultural and Food Chemistry, v. 63(20), p. 5026–5034. 2018. https://doi.org/10.1021/jf505450j

VISKELIS, P. Quality and physiological parameters of tomato (Lycopersicon esculentum Mill.) fruits of Lithuanian selection. Biologija, v. 54(2), p. 108-111, 2009 https://doi.org/10.2478/v10054-008-0022-8.