Capítulo 83

Quality characteristics of tomatoes grape type as function of packaging and storage

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ABSTRACT
One of the ways of preserving tomato fruits is the use of packages that have the function of controlling or minimizing degradation processes, enabling fruits to maintain quality characteristics even for consumers. This work aimed to evaluate the influence of active packaging (incorporated from ethylene absorbers) on the preservation of quality attributes, bioactive compound contents, and antioxidant activity *of grape* tomatoes during storage. The experimental design was completely randomized involving 2 treatments (active packaging and PET packaging), 5 storage times (0, 5, 10, 15, and 20 days), and 4 replications. The following were evaluated: pH, total titratable acidity, total soluble solids, *Ratio*, firmness, instrumental color, loss of fresh mass, lycopene, total phenolic composites, vitamin C, and antioxidant activity. The lycopene content of fruits packed in active packaging increased (29.8 to 48.7 µg.100 $^{g-1\ in}$ 20 days of storage and decreased in the fruits packed in PET packages during this same period. There was the degradation of vitamin C, whose average contents of the stored fruits, regardless of the packaging ranged from 21.4 to 15.9 mg.100 g $^{-1}$. The definition of the best packaging used depends on the storage period submitted. For the conservation of mass and lycopene content for 20 days at 16 ºC ± 2 the active packaging showed the best result.

Keywords: *Lycopersicon esculentum*, lycopene, cherry tomatoes, active packaging.

1 INTRODUCTION

At present, there is a growing demand for functional foods, that is, regularly consumed foods that, in addition to their nutritional content, provide benefits to consumer health, especially in reducing the risk of chronic non-communicable diseases (NCDs). This demand has contributed to the increase in vegetable consumption in Brazil and worldwide (CANELLA et al, 2018.; MENDONÇA et al., 2019).

Tomato (*Lycopersicon esculentum*) is a plant of the *family Solanaceae*, the same family as potatoes and peppers. Tomato is a fruit of low caloric value 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 lycopene consumption and cancer prevention and prevention has been studied for several years and has proven efficacy in the prevention, specifically, of prostate cancer (ANTUNES, 2017).

There are several groups of tomatoes grown and marketed in the most different regions of the country. The Brazilian tomato market can be divided basically into six groups: tapir cross, salad, small salad, Italian, industrial, and cherry, and the production of table tomatoes is distributed into the salad (51.5%), Italian (31.3%), Santa Cruz (12.1%) and cherry (5.1%). The *grape tomatoes* are within the cherry group, which are a variety of small fruits, perform shape, with high contents of soluble solids, widely used in the ornamentation of dishes. This tomato group has been presenting 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 crops of grape tomatoes*, postharvest losses consume a considerable part of the production, which leads to a continuous search for preservation methods to maintain the characteristics and prolong the shelf life of the fruits, which allows the availability of tomatoes of excellent quality, markets away from producing regions (DOSSA & FUCHS, 2017).

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

Thus, considering the permanent search for the increased shelf life of vegetables maintaining commercial quality through the use of active packaging, this study aimed to evaluate the influence of active

packaging (incorporated from ethylene absorbers – zeolites) on the preservation of quality attributes, bioactive compound contents, and antioxidant activity during the 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 in the mature stage, with the color bright red and manually selected (Figure 1) were used. The fruits were acquired in a commercial located in the municipality of Pará de Minas (Lat. 19.7816S, Long. 44.6198W).

Figure 1: Selection table and fruits already selected.

After harvest, the fruits were transported to the Laboratory of Bioactive Compounds and Food Conservation of the Federal University of São João del Rei - *Campus* Sete Lagoas, where they were selected according to the uniformity of size and color. Then, the fruits were separated into 180 g servings (Figure 2) and packed separately in 20 PET-type packages with lids for opening and reclosing (molded term, favoring the protection against mechanical damage, in the format reminiscent of a bunch of grapes, attractive to the consumer and of lower cost of acquisition) and 20 packages of active LDPE plastic film containing ethylene absorbing particles (zeolites) incorporated into its structure (Trade name: VEGETALPACK, manufactured by Eletro Polímeros do Brasil Ltda).

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

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

For 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 BOD storage. Four packages were removed from each of the models, making 4 replicates of each treatment. The analyses were performed in triplicate.

Evaluation of physical-chemical characteristics

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

The total titratable acidity was determined according to the methodology proposed by AOAC (2016). Titration was performed with NaOH 0.1N solution as standard and phenolphthalein was advised by pHmeter 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 (SST) were analyzed with the aid of a Reichert® r2 Mini digital refractometer with direct reading and accuracy of 0.1°Brix. To determine the SST content, the samples were macerated and filtered in tissue, the drops were placed directly into the prism of the refractometer (AOAC, 2016). The *Ratio* (ratio of total soluble solids / total titratable acidity) was calculated using the SST/ATT quotient.

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

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

Fruit firmness was determined with the aid of a TA XT *Plus tellurometer*, equipped with an operational Blade Set HDP/BS *cell*, 2 mm diameter stainless steel probe (Figure 3), adjusted for a penetration velocity of 0.5 mm.s-1. The results of the firmness analysis (the peak of the maximum force necessary to break the peel of the fruits) were expressed in Newton (N).

Figure 3: Texturometer and probe *detail* 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, added BHT (butyl hydroxytoluene), was to protect the carotenoids from oxidation, celite, was used to completely break the tissues of the sample, acetone was to extract the carotenoid pigments.

After the sample was finely macerated, it was vacuum filtered and added acetone until the complete extraction of carotenoid pigments.

The extract was then transferred to a separation funnel already prepared with p.a. petroleum ether and then, with the use of distilled water, the ethereal extract was washed 3 times, being transferred to Erlenmeyer, where the sample was dehydrated with the use of sodium sulfate (Na_2SO_4). The extract was immediately transferred to a 25 mL volumetric balloon. The absorbance reading was performed on 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, and the results were expressed in µg of lycopene/g of fresh sample.

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

Where: A = Absorbance at 470 nm, multiplied by the dilution factor; V = Volume of the sample (25 mL); E1% 1 cm = Lycopene extinction coefficient 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 the comparison of a calibration curve constructed with lalic acid. The analysis consists of the extraction of 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_2CO 3 solution was added. After a 2-hour rest, a spectrophotometer was read at 740 nm. The results were expressed in mg of paric acid (EAG) equivalents per 100 g of fresh-based sample

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). 1 gram of homogenized samples was weighed and 0.5% oxalic oxide aqueous solution was added in sufficient quantity to complete the volume to 10 mL. Then, centrifugation was performed for 5 minutes at 4500 RPM, and an aliquot was removed from the sobrenatant, which was then filtered in Minisart RC filters (13mm diameter, 0.45µm membrane). The injection of 20 µL was carried out in a SHIMADZU Prominence chromatograph equipped with DAD SPD-M20 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 pH adjusted to 4 using phosphoric acid and flow of 1mL.min $^{-1}$. The detector was set to $\lambda = 254$ nm.

The antioxidant activity was determined according to the methodology proposed by Brand-Willians et al. (1995), where after ethane extraction, the free radical DPPH was added, and the solution was maintained under the light. Free radical when reduced by the sample has its color modified, becoming less intense as the DPPH is reduced. After 1 hour, the absorbance reading was made at 572 nm in the spectrophotometer, the wavelength of maximum ABSORPTION of DPPH.

Antioxidant activity was calculated using Equation 2:

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

Where: ΔAbs=White absorbance - sample absorbance, 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 (equation of the line: y= 0.0009x +0.0162; R^2= 0.9814).

Experimental design

The plot scheme was subdivided in time 2 x 5 (2 packs and 5 evaluation periods) in a completely randomized design with 4 replications.

The data were submitted to variance analysis by the F test. Laboratory tests were performed in triplicate

3 RESULTS AND DISCUSSION

Physical-chemical characteristics

It was observed that there was an interaction of the factors studied (type of packaging and storage time) for the characteristics pH, SST, ATT, lycopene content, and mass loss (Table 1).

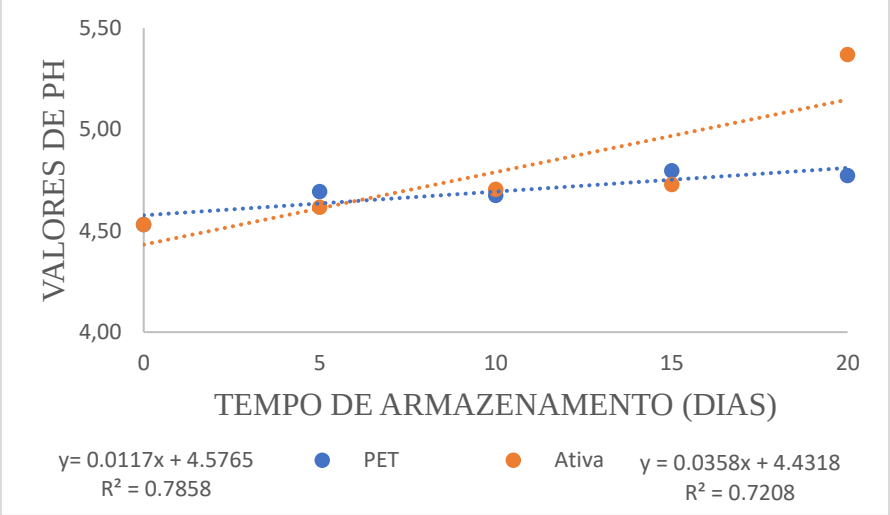
Table 1- Mean squares and significance of the variables: pH, Total Soluble Solids (SST), Titratable Total Acidity (ATT), Lycopene (LC), Mass Loss (PM), Firmness (FM), total phenolic compounds (CFT) and Antioxidant Activity (ATA).

CV	GL	QM							
		ph	SST	ATT	LC	PM	FM	CFT	MINUTES
Pk. (A)	1	0,0931*	0,2030	0,0140*	178813*	579,9567*	1,4668*	112,7952	0,6760
Has. (B)	4	0,0330*	3,8678*	0,0352*	1662.65	91,7327*	0,4592*	508,1138*	4,3918*
An x B	4	0,1621*	1,1279*	0,0070*	30859.51*	65,1217*	0,0744	42,7054	0,0796
Residue	30	0,1135	0,2734	0,0013	2461.87	0,7966	0,1548	24,8827	0,6243
CV (%)		2.248	6.94	7.34	11.06	13,76	7,67	2,19	4,50

*Significant with 5% probability by F test

In terms of pH, there was an increase in the values detected as the storage time progressed. The pH increased linearly, and thus, the fruits stored in both packages became less acidic over the period studied (Figure 4).

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



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

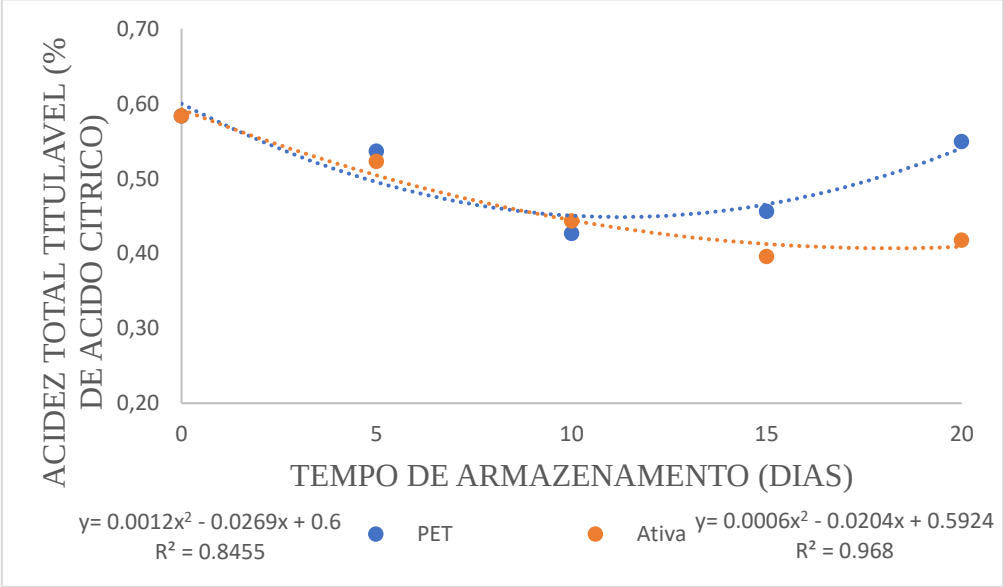
The pH curves followed the same trend taking into account the two different types of packaging, but the fruits stored in PET packaging showed a lower tendency to increase acidity during the storage period. That is, the fruits stored in the PET package became less acidic, starting from pH 4.53 at the beginning of storage and at 20 days of storage, where the maximum value of 5.37 was observed. Among the fruits stored in the active packaging, the highest value observed for pH was 4.77 also at 20 days of storage.

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

The regression analysis of the observed TA means allowed the adjustment of a quadratic regression model (Figure 5). The graph points to a trend of reduction of the observed values of TTA, and its lowest value was observed at 11 days in the PET package used in this study.

At 20 days of storage, the fruits stored in the PET package showed a small increase in the observed average. This increase in ATT happened only in the fruits stored in the PET package. Other authors in the study of the shelf life *of sweet grape tomatoes* and "Coco Cereja" reported a decrease in TA in the materials used (Aguiar et al., 2012). In several other studies, a decrease in TA was observed in some hybrids lower than in others, but there is always a decrease in storage time (BECKLES, 2012; MIGUEL et al., 2007).

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



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

In the fruits stored in the active packaging, they presented an average ATT of 0.42% citric acid at 20 days of storage.

The mean values of OSH contents of fruits packed in active packaging ranged from 8.67 Brix at storage to 7.35 brix at the end of 20 days of storage. In the fruits of pet packaging, there was a sharper decrease, starting from 8.67 °Brix at the time of fruit storage and reaching 7.02 Brix at the end of the 20 days of storage. During the study period, there was an oscillation of OSS contents in fruits packed in both types of packages 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 trend of reduction of the SST content of the fruits packed in both packages to the extent that the storage time was increased. The reduction of SST during storage may be influenced by the increase in the respiratory 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 packaging without atmosphere control for up to 28 days, also observed oscillations in THE CONTENTS contents throughout the fruit storage period.

Beckles (2012) studying the factors that influence the OSH content, states that tomatoes stored at temperatures close to 12.5 o C present a better conservation of the constituent sugars, possibly due to the decrease in plant metabolism, as well as the use of packaging with modified and controlled atmosphere also contribute to this better conservation of OSH contents.

The type of packaging used, as well as the storage period, had an independent influence on the *Ratio*. For the fruits stored in the PET package, the *Ratio values ranged* from 14.86 at the time of storage to 13.87 at the end of 20 days. However, there was a trend of reduction of values after 15 days of storage. On the other hand, 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, contrary to that reported by Aguiar et al. (2012), who observed that *ratio values increased* at first and presented a sharp decline at 17 days of storage. Similar behavior occurred in this study for fruits packed with active packaging in which *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 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 the study of tomato ripening dynamics.

Regarding color, which is one of the main factors related to consumer acceptance and purchase intention (RADZEVIČIUS et al., 2008), it was observed that the parameters L* and b* were influenced only by storage time, not being affected by the type of packaging or by the interaction between the s factory

packaging and storage time. Parameter a* was influenced by the interaction between the packaging used and storage time (Table 2).

Table 2 - Average squares and significance for instrumental color parameters L*, a*, b*.

CV	GL	QM		
		L*	the*	b*
Packaging (A)	1	0,1016	2,1903*	0,0204
Time (B)	4	77,0148*	4,4797*	71,5558*
An x B	4	0,6790	0,4376*	0,1102
Residue	30	0.4095	0,1286	0.0547
CV (%)		1,55	3,24	1,80

*Significant with 5% probability by F test

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, coordinate b* decreased.

The* coordinate, which represents the variation in the axis ranging from red to green, was maintained throughout the study period without major variations, with a small increase at 10 days of storage followed by a fall, where it returns to values close to the initial (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 the storage very subtle.

This allows us to infer that both packages allowed the maintenance of the attractive color of the fruits throughout the evaluated period.

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

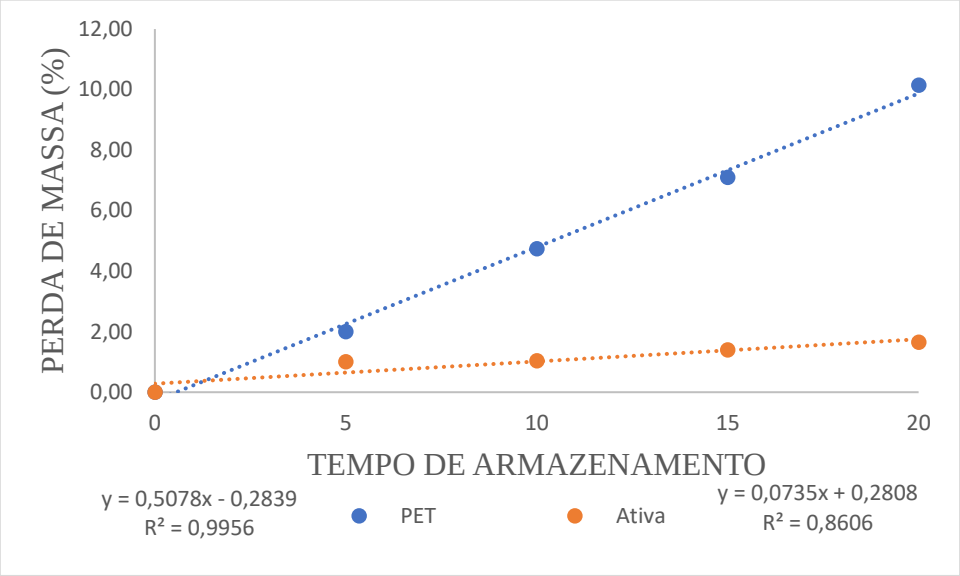
There was no influence of the packaging on the luminosity (L*) of the fruits, however, taking into account the storage, an increase in this characteristic was observed, whose mean values varied from 37.95 at the time of storage to 44.20 to 20 days.

The stored fruits, regardless of the packaging used, lost mass over the time of storage. The observed means allowed the adjustment of a linear equation describing the interaction between the factors. As storage time increased, fruit mass loss also increased, which was significantly higher in fruits stored in pet packaging (Figure 6).

According to Chitarra & Chitarra (2005), fruit mass loss occurs mainly due to metabolic activity and moisture loss to the surrounding atmosphere. In the PET package, a greater loss of mass was observed, since it offers little or no barrier against the exchange of gases in the inner atmosphere of the package, due to the small opening between the lid and the body of the package, further enhancing the loss of water,

different from the active packaging, which decreases the exchange of water vapor with the external environment of the packaging.

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



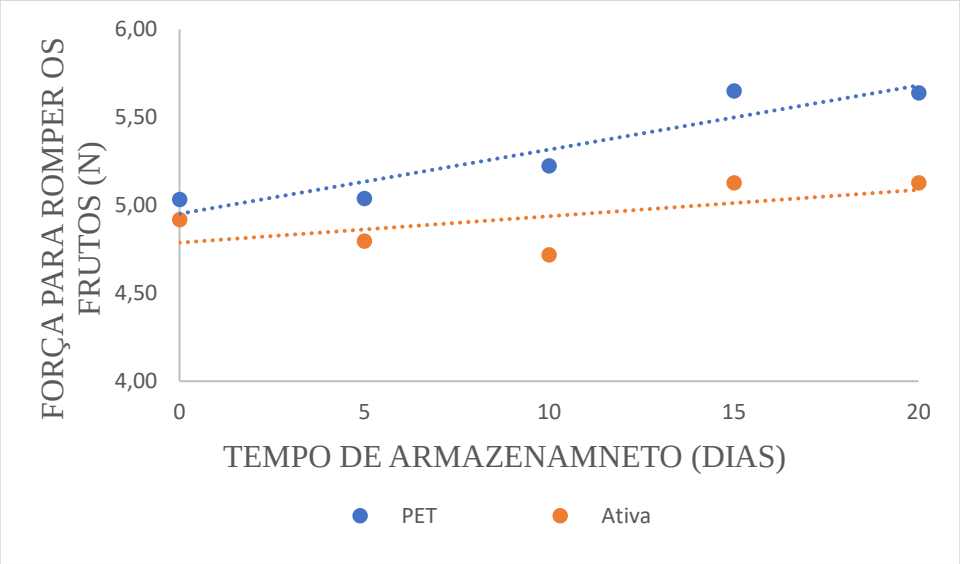
Several authors observed loss of fresh tomato mass throughout storage, but there was no control of the exchange of gases and water vapor with the environment (TOLESA & WORKNEH, 2017).

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

As can be seen in Figure 7, the strength to break the fruits increases or over the storage period is more pronouncedly in the fruits stored in the PET package. This change occurred due to the loss of turbidity during storage time, which resulted in greater elastic deformation of the pericarp of tomatoes and consequently required greater force applied in the fruit disruption.

It is important to highlight that an important feature for consumers who appreciate *grape tomatoes is related to the texture* of fruits when bitten, these break in the mouth causing pleasant sensations caused by bursting or bursting of the pericarp. The lower the force required to break the peel of the fruits, the better this characteristic. In this sense, it was observed that the parameter responsible for this sensation in the consumption of tomatoes has an inverse relationship with storage time. The increase in tissue elasticity and softening of fruit peel is an unwanted characteristic because a small force for fruit disruption is a characteristic that consumers appreciate in *grape tomatoes* (TAIZ et al., 2017).

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



Saladié et al. 2007, when studying the biomechanical properties of tomato cuticles, found a direct relationship between tissue hydration and the strength necessary for rupture, where the most hydrated fruits needed smaller forces to be ruptured. Thus, it can be concluded that the active packaging showed positive results concerning the preservation of turgide, maintaining for longer the firmness characteristics assessed by consumers.

Bioactive Compounds

The type of packaging influenced the lycopene contents, as well as the interaction between the packaging used and the storage time of the fruits. When the interactions were unfolded, it was observed that lycopene contents differed significantly ($p<0.05$) from the 10 days of storage.

Several authors studying and describing the processes and changes that occur during the maturation of tomatoes, reported that the synthesis of lycopene is influenced by many factors, which can act alone or together, synergistically intensifying or delaying 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 maturation process of climacteric fruits, exposed that the chlorophyll degradation process occurs concomitantly with the synthesis of carotenoids, as well as with changes in cell walls and organelle structures, especially chromoplasts. The authors also point out that these events are controlled by numerous environmental factors, such as light intensity, temperature, and mechanical damage, and also by endogenous factors, ethylene being the main influencing hormone in the synthesis of carotenoids.

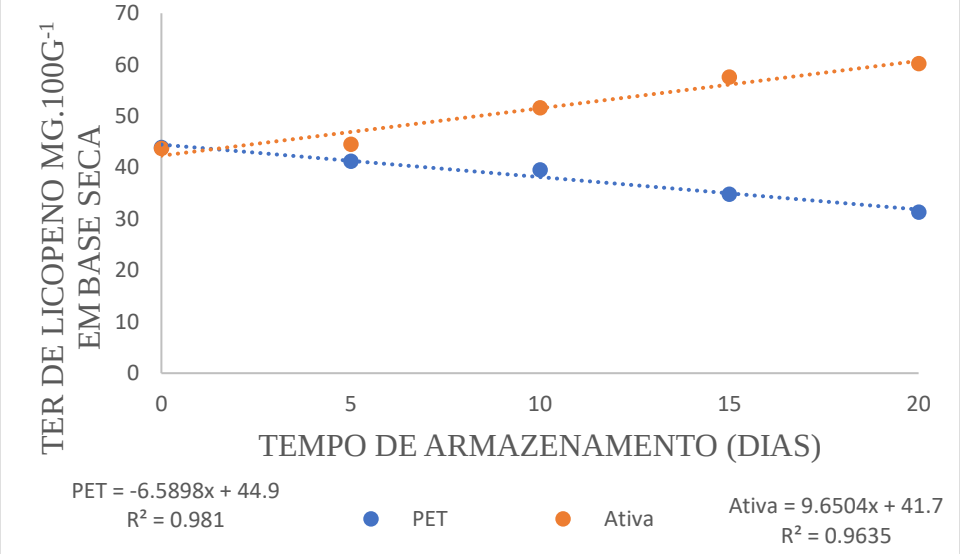
Verheul et al. (2018) and Monteiro et al. (2018) when studying the influences of the maturation stage of tomatoes on the content of carotenoids show that large variations in lycopene contents can occur after harvest depending on the maturation stage in which the fruit was harvested.

Other authors studying the dynamics of tomato ripening in several packages observed that active packages that absorb ethylene and modify the balance of O_2 and CO_2 cause a decrease in 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 the packages had an antagonistic effect on the content of this pigment during fruit storage, as can be observed in Figure 8.

The lycopene contents of tomatoes stored in pet packaging decreased throughout storage, reaching the minimum value at 20 days, while in the fruits stored in the active packaging, there was a gradual increase of this carotenoid and the maximum concentration was reached also at 20 days (Figure 8).

Figure 8 - Expressed lycopene contents (µg. $^{g-1}$ dry basis) in *grape tomatoes stored* under refrigeration (16 °C) in two different packages (Ativa and PET) for 20 days.

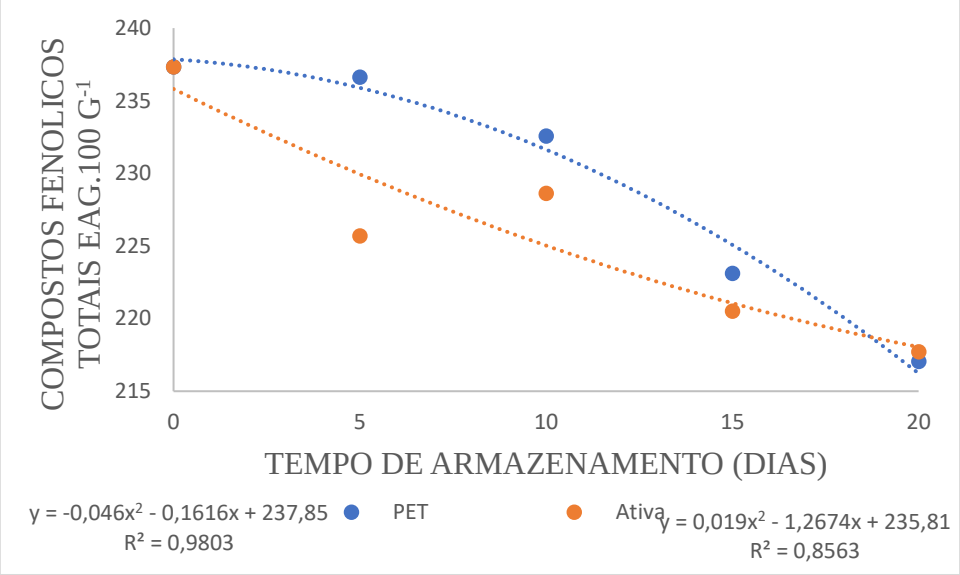


The dynamics of biosynthesis and degradation of lycopene is an enzycopene process, so tissue dehydration influences cell metabolism (TAIZ et al. 2017), thus it is possible to assume that the decrease in lycopene contents in fruits stored in the PET pack is possibly due to the increased rate of degradation of lycopene and a decrease in the rate of biosynthesis linked to fruit mass loss because the fruits lost up to 10.14% of mass at the end of 20 days. The fruits stored in the active packaging showed an increase in lycopene content in their constitution, while in the same period, they lost no more than 2% of the mass.

The total phenolic compound content observed in tomatoes differed only in the storage time. They were not influenced by the packaging used or by the interaction between the two factors studied.

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

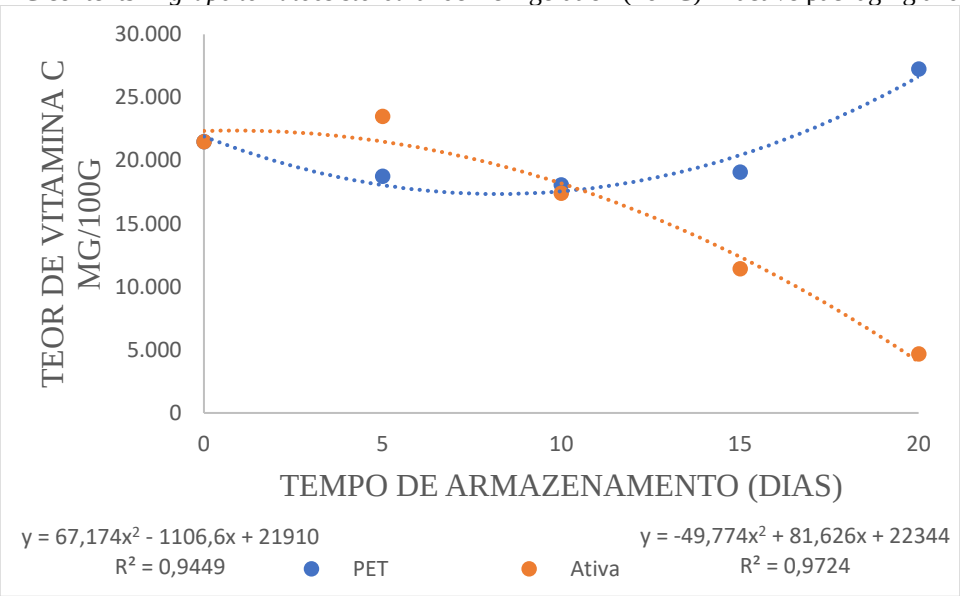
Figure 9: Phenolic compound contents in *grape tomatoes stored* under refrigeration (16 °C) in active packaging and PET for 20 days.



The average vitamin C content of the fruits stored in the active packaging was 21.48 mg.100 $^{g-1}$ at the time of storage and decreased over the study period, reaching the content of 4.66 mg.100 $^{g-1}$ at the end of 20 days, i.e., they presented a loss close to 78% While the fruits stored in the PET package presented oscillation of the average vitamin C contents over time, but at the end of the period, they showed a slight increase reaching 27.24 mg.100 $^{g-1}$.

As can be observed (Figure 10), the active 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 packaging and PET for 20 days.



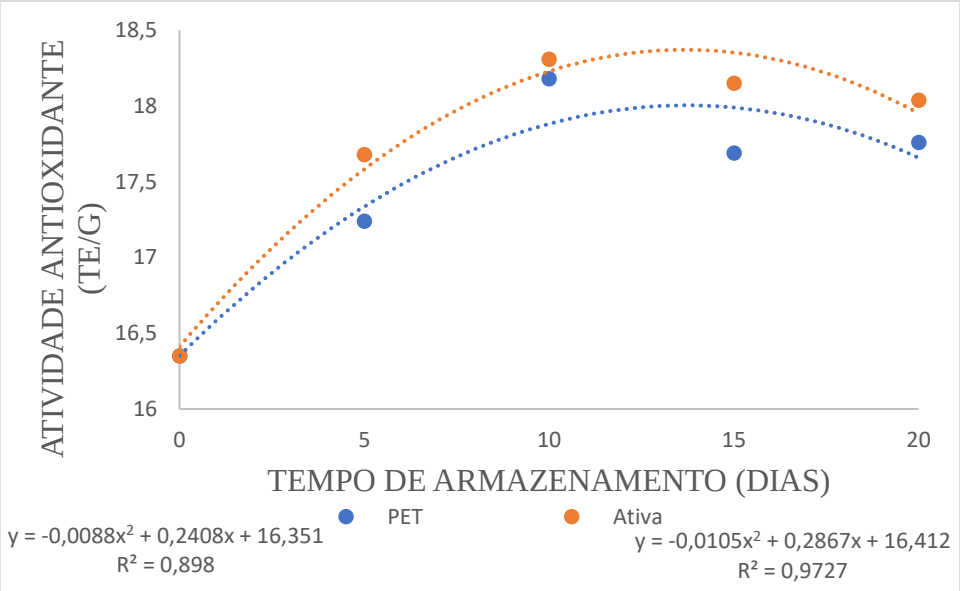
Stress situations, such as a decrease in the available oxygen content, lead to an increase in the production of reactive oxygen species (ROS), which cause progressive cell damage (SHARMA, 2012). The presence of these reactive oxygen species could be related to decreased vitamin C content, which would act as it could exert antioxidant action, consequently leading to the protection of cellular organelles (T AIZ et al., 2017).

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

It was observed that only storage time influenced antioxidant activity. No influence of the type of packaging was observed, nor was the interaction between the packaging and storage time.

The mean antioxidant activity ranged from 16.35 µmol TE/g at the time of storage, with the highest value observed at 10 days (18.24 µmol TE/g) and then, regressing to 17.9 µmol TE/g on average at 20 days of storage (Figure 11).

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



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

Mirdehghan & Valero (2016), when studying different additives to improve 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 $^{g-1}$). Then there was a retreat to levels lower than the initial (approximately 25.7 mg ascorbic acid equivalent 100 $^{g-1}$).

4 CONCLUSIONS

1. There was an influence of the type of packaging on the attributes of quality, the content of bioactive compounds, and the antioxidant *activity of grape tomatoes during* refrigerated storage (16 ºC) for 20 days.
2. The active packaging has longer conserved the firmness of the fruits 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 a storage period of 20 days, the best option is active packaging concerning the preservation of phenolic compounds, lycopene, and a lower mass loss. Pet packaging, on the other, contributed to the maintenance of higher levels of vitamin C and total titratable acidity.
4. De, grape tomatoes *packed in active packages showed better quality* and a greater reduction in the mass loss for a longer period than fruits packed in PET packages, reaching satisfactory quality up to 20 days of storage at 16 ºC ± 2.

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