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EFFECT OF PVC AND HDPE PACKAGING FILMS ON THE QUALITY MAINTENANCE OF GRAPE TOMATOES DURING STORAGE

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ABSTRACT

Packaging films can present a replacement for developing fresh vegetables and fruits postharvest life. The impact of polyvinyl chloride (PVC) and high-density polyethylene (HDPE) packaging films on some qualitative such as, mechanical, physical and chemical properties of grape tomatoes were examined. Packaging films were used as protective packaging on the grape tomatoes and stored at 4°C and 20°C for 40 days. The results didn't show any significant effects from statistical points in pH and total soluble solid compared with the packaging and without packaging. The packaging films significantly prevent moisture content and weight loss, preserve maximum work for break, maximum strain and also, maintain the firmness of the grape tomatoes, improve storage characteristics and its quality. The PVC and HDPE films had remarkable effects on color parameters. On the other hand the color of the packaged grape tomatoes had less brightness and products at 4°C had less redness during storage.

1. Introduction

Grape tomato (Lycopersicon esculentum Mill. `Santa') is one of the cultivars of tomato that because of its flavour, sweetness, the potential health benefits and ease of use, has gained popularity among consumers. Its substantial popularity is due at least in part to its higher sugar content compared to tomatoes, and its smaller, bite-sized shape (Simonne *et al*., 2007). Harvest maturity and postharvest conditions are a number of factors that lead to changes in sensory and nutritional quality of grape tomatoes. Grape tomatoes are harvested at level of specific (Reddish orange) color, In order to prevent postharvest losses due to softening. Maintaining the best quality of fresh product is still the biggest challenge for the food industry. The most impressive features of products include flavor, nutritional value, appearance, texture, color and microbial safety (Cantwell *et al*., 2009). Agricultural products with high durability have high commercial value, given that fruits and vegetables spoil quickly after harvest, and are degrading in the quality, so finding a solution to enhance the shelf life and quality of these products is considered. Temperature control has a positive impact on the storage of tomatoes, equally, low temperatures have a significant impact on increasing shelf life as well (Bourne, 1982). Apart from controlling the temperature of the environment, there are other influential factors, the most important of which can be packaging films (Hotchkiss, 1997).

Less processed fruits and vegetables are highly nutritious, but very perishable. Removing the skin and resize lead to change color, leakage of nutrients, weight loss, change the texture and the rapid growth of microbial and thus reduce the quality of fruits and vegetables. Various methods have been investigated to overcome these problems and increase durability and storage time of fresh fruits and vegetables (Sehat, 2012). For example, high relative humidity, low temperatures and packaging (Nadim *et al*., 2015; Sehat, 2012).

Packaging film is one of the most reliable methods that many studies are currently done about it. Storage using the packaging films leads to maintain quality and increase the shelf life of products, which slows down the chemical reactions and also reduces the growth of pathogenic microorganisms (Ozturk *et al*., 2016). Losing water in fruits and vegetables is one of the most important problems, however, losing water can be controlled using packaging films. Packaging film reduces the amount of water vapor transmission, form a physical protection around the products, and prevent water loss and decay of tissue (Debeaufort *et al*., 1998). The packaging film has many advantages compared with other methods. When the product is inside the packaging with the appropriate temperature, the film acts as a barrier to gasses, and controls microbial growth, preserves color, texture and moisture and effectively extends the shelf life of the product (Mistriotis *et al*., 2016). In the last decade, the growth conditions of temperature controlled food industries, has encouraged research groups to work on improving existing methods and the development of new innovations, mainly to the performance of high quality products, textures, flavors, with original color and nutritional value (Galetto *et al*., 2010).

The controlled atmosphere and temperature are useful in delaying softening and decay of the product (Gil *et al*., 1997).

D'Aquino et al (2016) examined the effects of oriented polypropylene (OPP) packaging film on acidity, water loss, firmness, total soluble solids, vitamin C and postharvest quality of cherry tomatoes. Geeson et al (1985) examined the effect of PVC packaging film on stored tomatoes quality. Modified atmosphere packaging have been studied as an alternative method to reduce postharvest deterioration and lifetime storage of cherry tomatoes (Das, 2006). Bhowmik (1992) examined the effect of controlled atmosphere and relative humidity on quality, weight loss, titratable acidity, pH, color and firmness of green tomato. Pila (2010) studied the physicochemical changes related to the quality of tomatoes during storage. Mechanical properties, including Young's modulus and firmness and physical properties were evaluated by kabas and Ozmerzi (2008) in cherry tomatoes. Although studies on the impact of packaging and temperature on grape tomatoes have been reported in the literature, this approach has not yet been pursued for the characterization of quality and mechanical properties of grape tomato inside the PVC and HDPE packaging, in temperature controlled conditions.

The objectives of this work are studying the ability of PVC and HDPE packaging films to extend the shelf life of grape tomatoes stored at room temperature and refrigerated, compared to non-packaged product, and assessing the effects of packaging films on the quality attributes of grape tomatoes, such as surface color, weight loss, some mechanical properties, size characteristics and some chemical properties, such as total soluble solids (TSS) and titratable acidity.

2. Materials and methods

Grape tomatoes were harvested from greenhouse at Hamadan, Iran. Grape tomatoes of uniform color, shape, size and without any damage were selected to the tests. The grape tomatoes were cleaned with hand to eliminate external matters and then transferred to the laboratory and were divided into three categories: without packaging, PVC packaging, and HDPE packaging. Then these three, were stored at 4°C and 20°C. The physical, mechanical and chemical characteristics of products were analyzed every five days until the fortieth day of storage.

2.1. Color

The color of Grape tomatoes surface was determined by a colorimeter (portable colorimetric, HP-200, Guangdong, China) which presented CIE a*, b*, and L* values for each replication. b* (yellowness, b* > 0, blueness < 0), a* (redness > 0, greenness < 0), L* (lightness, black = 0, white = 100), Hue° (Hue angel, H° = tan ((b*)/(a*)), red = 0°, yellow = 90°, green = 180°, blue = 270°) and c (Chroma, $c=\sqrt{(a^*)^2+(b^*)^2}$, 0 at the center of the color sphere) were quantified on each samples using a 10 degree position of the standard observer (CIE, 1978).

Total color difference was measured by equation 1, where L_0, a_0 and b_0 are control values for fresh grape tomatoes.

$$\Delta E=\sqrt{(a^*-a_0)^2+(b^*-b_0)^2+(L^*-L_0)^2}$$

2.2. Weight loss

Grape tomatoes were weighed at harvest time at first, then after that weight loss during postharvest storage was measured by subtracting sample weights from their previous recorded weights and presented as percentage of weight loss compared to initial weight.

2.3. Chemical tests

2.3.1. PH

The pH measurement was made using a digital pH meter (Eco Tester PH 2 Water proof Pocket Tester, Singapore) calibrated with pH 4.0 and 7.0 buffers.

2.3.2. TSS

TSS was determined by portable digital refractometer (Model: PAL-1; Atago, Japan) with a scale of 0-53brix at room temperature (~25°c).

2.3.3. TA

For this experiment, titratable acidity (TA) was measured by solving each 5 milliliter juice of grape tomatoes in 25 ml distilled water and after that titrated to PH 8.1, according to the AOAC official method 942.15 (AOAC, 2000) using 0.1 N NAOH.

$$\% \text{ citric acid} = (\text{Titre value (ml)} \times 0.1 \times 0.064 \times 100)/(5 \text{ g of juice})$$

2.4. Physical properties

Digital calipers with a sensitivity of 0.01 mm was applied for determine the axial dimension of products; length, width and thickness, geometric mean diameter (Dg), sphericity (ø) and surface area (S) were calculated following equations. (3), (4) and (5) (Mohsenin, 1986):

$$Dg = (LWT)^{1/3}$$

$$\Phi = Dg/L$$

$$S = \pi . Dg^2$$

Where T is the thickness, W is the width and L is the length and of the fruit (Figure 1).

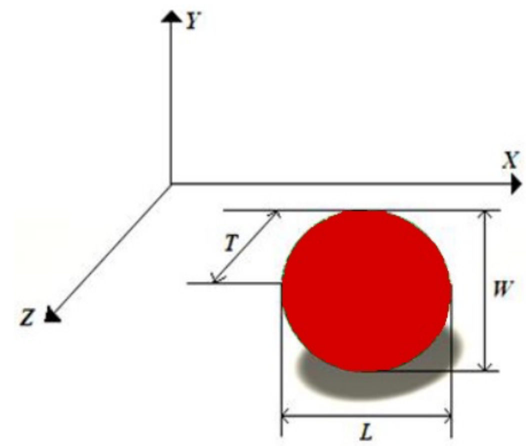

Figure 1. Three major dimensions of grape tomato

2.5. Moisture content measurement

To determine the moisture content, grape tomatoes were kept in the oven for 24 h at 70 ℃ (AOAC, 1990). These experiments were replicated thrice to obtain a reasonable average.

$$M.C = (M_0-M)/M_0$$

Where: M0 and M are initial and last (before placed in the oven) mass of product.

2.6. Determination of density and volume

Grape tomatoes volume has been determined by water displacement method (WDM) and using a graduated cylinder. The WDM is one of the most popular and simple means of measuring the volume of large objects such as fruits and vegetables (Mohsenin, 1986).

$$\text{Volume (ml)} = (\text{weight of displaced water (g)})/(\text{water density (g/ml)})$$

Product density is obtained by dividing the mass of the product to its volume.

2.7. Mechanical tests

For this experiment, mechanical features were examined using a puncture test and the grape tomatoes were pierced with a texture analyzer device (Zwick/Roell Model

BT1_FR0.5TH.D14, using Xforce HP model of load cell with capacity of 500 N, Germany) with a probe of 3.15 mm diameter (Magness–Taylor probe). Penetration speed was set at 50 mm/min and the test was finished after force fell by 30% compared to the Fmax. Five parameters were studied: firmness as the maximum puncture force Which is expressed in the form of N (Fmax), and surface area under the force diagram, As a work done to reach the maximum force which is expressed as N.mm (W), strain as the amount of maximum deformation that happen on maximum stress (ε max), modulus of elasticity was that of obtained by boussinesq techniques expressed in N/mm2 (E) (Galetto et al., 2010; Mehinagic et al., 2003).

2.8. Statistical analysis

Factors of these experiments were temperature, packaging film and storage time and these tests were described under a factorial design. ANOVA (Analysis of variance) was done on data using SPSS software (IBM SPSS Statistics 23, IBM, NY) by means of PC. The significance levels were applied as $P < 0.01$ (**) and $P < 0.05$ (*).

Duncan's multi-domain test was applied for compare the averages in this experiment. Data analysis was conducted in two groups, until twentieth day for products without packaging films and until fortieth day, for products within the packaging. The reason for this is that products without packaging film had the capability to test until the twentieth day, while products in the packaging film had the capability to do the test until the fortieth day.

3. Results and discussions

3.1. Results

3.1.1. Effect of PVC and HDPE on weight loss and moisture content

As seen from Figure 2, weight loss in grape tomatoes increased during maintenance however, the packaging films decreased rate of weight loss during maintenance. Grapes tomatoes stored without packaging increase weight loss on day 5 but reached 24.40% weight loss on day 20 along the storage at 20°C after 40 days storage. The percentages of weight loss for PVC and HDPE packaging grape tomatoes in 4°C and 20°C were 2.04%, 5.97% and 1.31%, 2.24%, respectively. Moisture content percentage in without packaging products decreased significantly during storage (Figure 2). PVC and HDPE packaging ($P < 0.05$) inhibited the decrease at storage time effectively.

At the end of the storage period, the values of without packaging moisture content in 20°C and 4°C were 66.58%, 83.71%, respectively, while the PVC and HDPE packaging After 40 days storage in 20°C and 4°C were 85.06%, 89.30% and 89.46%, 89.68%, respectively.

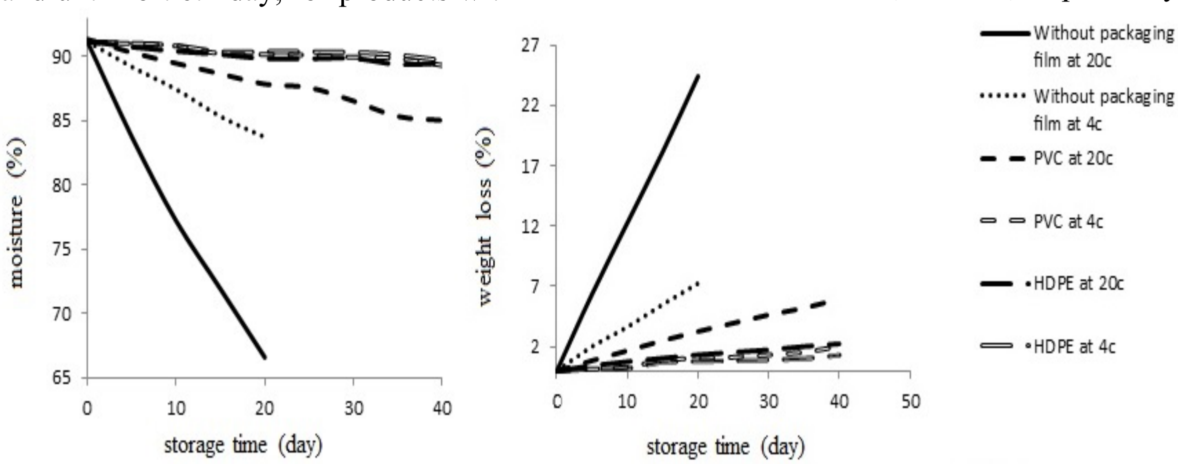

Figure 2. Effect of packaging on weight loss and moisture content in grape tomatoes during storage

3.1.2. TA, TSS and pH

Figure 3 shows the effect of packaging films and temperature on soluble solids. The results didn't show any significant differences in total soluble solid compared with the packaging and without packaging, while the results showed significant ($P < 0.05$) differences in temperature of the grape tomatoes. The levels of TA for PVC and HDPE packaging films products and without packaging film at 20°C and 4°C were 43.31%, 18.43% and 39.79%, 29.94% and 36.3%, 21.59% decrease respectively, at the end of storage time (Figure 3). This parameter for the temperatures, 4°C and 20°C had a different behavior; that is, for packaged products, reducing of TA at 20°C was 41.78% more than products that were at 20°C. For products that were inside the package until the fortieth day, significant relation ($P < 0.05$) in TA parameter between PVC and HDPE films was observed, so that, acidity of the products inside the HDPE packaging during storage was 4% less than the products in PVC films. As well temperature, storage duration and packaging significantly ($P < 0.05$) affected the TA during the experiment (Table 1 and Table 2). Also, the results showed that pH value of grape tomatoes in PVC and HDPE films at 20°C and 4°C were 7.30%, 5.63% and 9.26%, 7.37% increased, respectively during storage, while no significant differences between packaging films for pH value were observed during storage (Table 1, Table 2 and Figure 3).

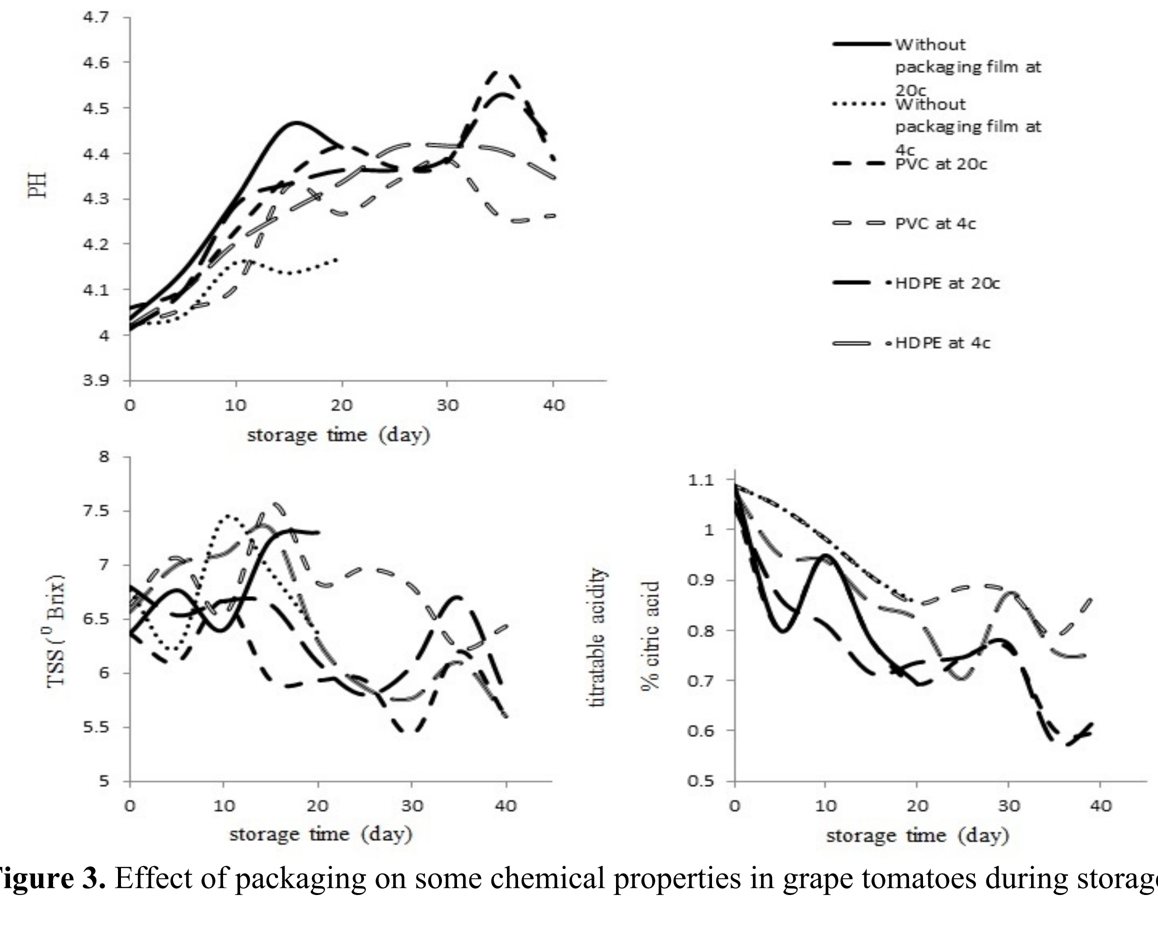

Figure 3. Effect of packaging on some chemical properties in grape tomatoes during storage

Table 1. Summary analysis of variance (mean squares) of some chemical parameters evaluated in a factorial experiment (until the day 20)

Sources of change	Degrees of freedom	PH	TSS	TA
Packaging films	2	$0.001^{n.s}$	$0.477^{n.s}$	0.013*
Temperature	1	0.185**	2.178*	0.266**
Period	4	0.320**	$0.833^{n.s}$	0.238**
Pack × Temperature	2	0.034**	1.391*	$0.001^{n.s}$
Pack × Period	8	$0.005^{n.s}$	$0.220^{n.s}$	$0.003^{n.s}$
Temperature × Period	4	0.014*	$0.231^{n.s}$	0.020**
Pack × Period × Temperature	8	$0.008^{n.s}$	0.860*	$0.005^{n.s}$
Test error	60	$0.005^{n.s}$	$0.346^{n.s}$	$0.004^{n.s}$
CV (%)		3.57	10.94	14.941

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

Table 2. Summary analysis of variance (mean squares) of some chemical parameters evaluated in a factorial experiment (until the day 40)

Sources of change	Degrees of freedom	PH	TSS	TA
Packaging films	1	$0.014^{n.s}$	$0.009^{n.s}$	0.038**
Temperature	1	0.108**	4.813**	0.389**
Period	8	0.249**	1.521**	0.169**
Pack × Temperature	1	$0.027^{n.s}$	3.203**	0.021*
Pack × Period	8	$0.004^{n.s}$	$0.312^{n.s}$	$0.004^{n.s}$
Temperature × Period	8	0.017*	0.587*	0.011**
Pack × Period × Temperature	8	$0.003^{n.s}$	$0.263^{n.s}$	$0.007^{n.s}$
Test error	72	0.008	0.276	0.004
CV (%)		3.83	11.47	17.43

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

3.1.3. Effect of PVC and HDPE films on color

Figure 4 and table 3, table 4 shows that grape tomatoes color changed significantly ($P < 0.05$) during storage. Products at 4°C and without packaging film were brighter than other products up to the twentieth day, while the products at 20°C and without film, were darker than others products up to the twentieth day. There was an effective ($P < 0.05$) reduce in L*, with increasing maintenance period until the fortieth day for other products (Table 3, 4). Packed and unpacked samples showed a significant ($P < 0.05$) decrease in a* value during storage. Application of PVC and HDPE packaging led to significantly ($P < 0.05$) low levels of a* compared with the without packaging products during the testing period. Also in the experiment, the value of a* for packaging and non-packaging at 4°C was lower than 20°C. Similarly, significant ($P < 0.05$) reduce took place in b* along the testing period (Figure 4). Based on the results, products at

20°C had lower levels of b* values compared with the others, and products in PVC packaging and without packaging, showed decrease in b* value during storage (Figure 4). The H° (Hue angle) as a function of maintenance period for PVC and HDPE, were increased 23.47%, 15.76% respectively during storage at 4°C, and for products at 20°C, were decreased 12.29% and 11.07% along the maintenance. However, the lower H° indicated more redness. Figure 4 shows an increase in the total color variation (ΔE) for every three treatments along the maintenance. The results for PVC and HDPE packaging films didn't show any effective differences in ΔE after 20 days and no significant differences were statistically observed after 40 days between PVC and HDPE films. The rate of L* of the without packaging samples were 40.47 at 20°C on the first day of storage, that decreased 12.84% and reached till 35.27% on the 20th day of maintenance, however, the rate of L* of the without packaging samples at 4°C on the first day, did not differ in the twentieth day of storage. The rate of L* for the HDPE and PVC packaging samples at 20°C and 4°C were decreased 11.87%, 11.98%, 10.68% and 9.03% respectively. The a* parameter for without packaging at 20°C and 4°C reached from 30.87 to 30.2 and 32.49 to 25.79, which has decreased 2.17%, 20.62% respectively.

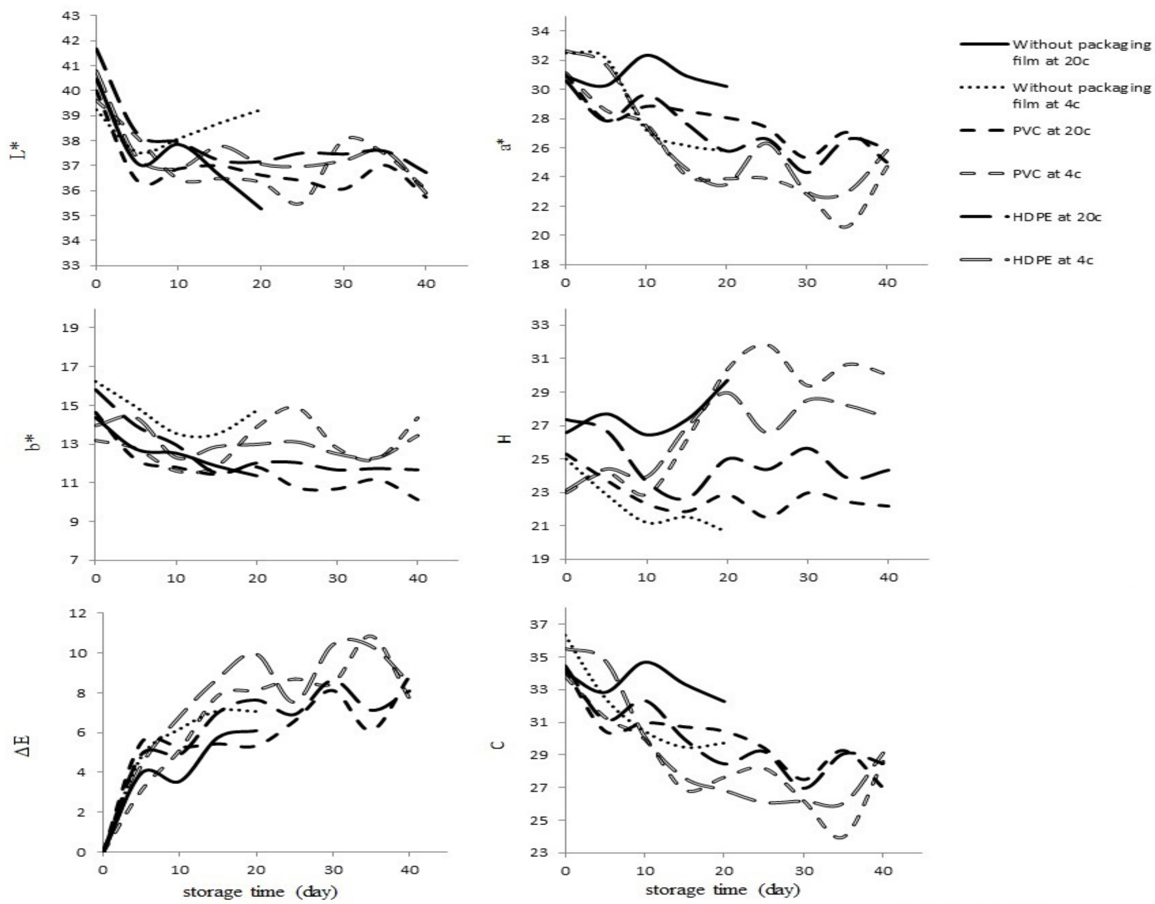

Figure 4. Effect of packaging on color in grape tomatoes during storage

Whereas this parameter is decreased about 20.61% and 19.39% respectively for the PVC packaging samples at 4°C and 20°C and decreased 15.16%, and 20.87% respectively for the HDPE packaging samples at 4°C and 20°C during storage (Figure 4 and Table 3, Table 4).

Table 3. Summary analysis of variance (mean squares) of color parameters evaluated in a factorial experiment (until the day 20)

Sources of change	Degrees of freedom	L	a*	b*	c	H	ΔE
Packaging films	2	5.515**	32.147**	8.968**	29.987**	7.754$^{n.s}$	8.530$^{n.s}$
Temperature	1	1.035$^{n.s}$	45.753**	13.642**	30.625*	152.751**	19.125**
Period	4	33.863**	80.398**	18.328**	87.873**	19.342**	156.644**
Pack × Temperature	2	4.920**	7.077$^{n.s}$	8.725**	4.368$^{n.s}$	46.706**	0.877$^{n.s}$
Pack × Period	8	1.003$^{n.s}$	3.452$^{n.s}$	0.922$^{n.s}$	4.374$^{n.s}$	2.548$^{n.s}$	1.482$^{n.s}$
Temperature × Period	4	3.095**	38.061**	4.643**	21.304**	49.323**	6.586$^{n.s}$
Pack × Period × Temperature	8	2.478**	1.914$^{n.s}$	0.725$^{n.s}$	2.608$^{n.s}$	2.225$^{n.s}$	2.008$^{n.s}$
Test error	60	0.6	4.042	1.039	4.583	3.558	2.731
CV (%)		4.27	10.99	11.88	9.92	11.99	27.29

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

Table 4. Summary analysis of variance (mean squares) of color parameters evaluated in a factorial experiment (until the day 40)

Sources of change	Degrees of freedom	L	a*	b*	c	H	ΔE
Packaging films	1	13.918**	3.579$^{n.s}$	6.770*	2.8$^{n.s}$	5.307$^{n.s}$	9.571$^{n.s}$
Temperature	1	0.357$^{n.s}$	68.513**	25.114**	37.890**	278.853**	34.039**
Period	8	19.080**	71.870**	8.248**	77.154**	17.804**	95.711**
Pack × Temperature	1	3.003*	18.089$^{n.s}$	6.011*	2.749$^{n.s}$	68.928**	0.601$^{n.s}$
Pack × Period	8	0.476$^{n.s}$	2.345$^{n.s}$	1.170$^{n.s}$	3.820$^{n.s}$	2.515$^{n.s}$	1.808$^{n.s}$
Temperature × Period	8	0.889$^{n.s}$	16.314**	6.155**	12.848*	37.576**	8.052*
Pack × Period × Temperature	8	1.091$^{n.s}$	1.449$^{n.s}$	1.108$^{n.s}$	2.026$^{n.s}$	4.475$^{n.s}$	1.556$^{n.s}$
Test error	72	0.603	4.687	1.038	5.469	2.380	3.279
CV (%)		3.94	12.37	12.03	11.4	12.16	21.34

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

3.1.4 Physical properties changes

The dimensional size features of packaged and unpackaged grape tomatoes are given in Figure 5. Based on the results, surface area, geometric mean diameter, axial dimensions, volume and sphericity were reduced along the maintenance. The thickness, length, width, geometric mean diameter, volume and surface area of product were effectively ($P < 0.05$) upper in packaging products than that of without films, while sphericity were measured effectively ($P < 0.05$) lower in without packaging than packaged ones. As well, the density of the products in the packaging decreased, and in the without packaging increased, during storage. Effective differences were seen due to packaging in the thickness, width, length, density, volume, surface area and geometric mean diameter (Table 5, Table 6).

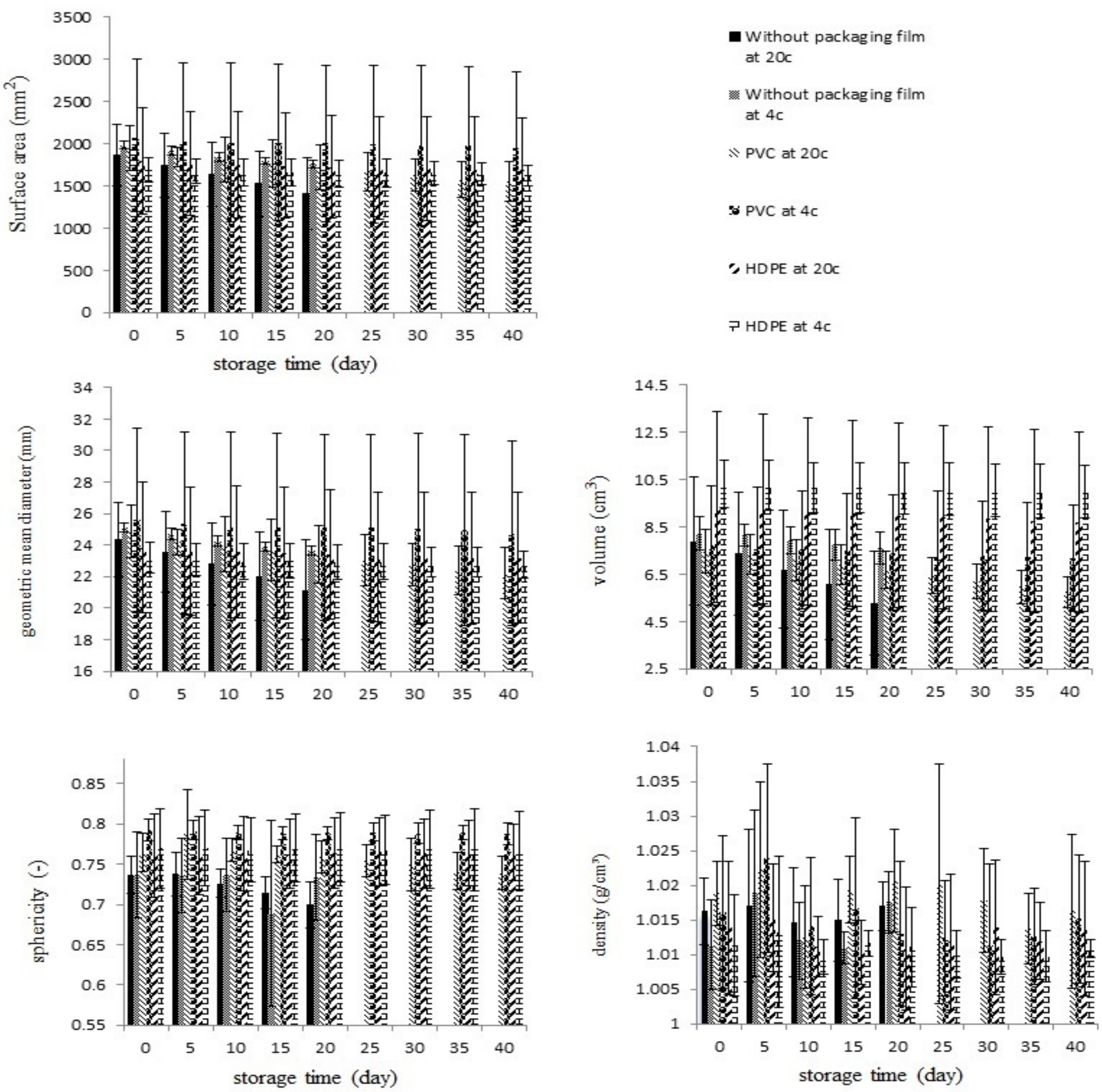

Figure 5. Effect of packaging on some physical properties in grape tomatoes during storage: Values are the means ±SE of triplicate assays. Vertical bars represent the standard errors of the means

Table 5. Summary analysis of variance (mean squares) of some physical traits evaluated in a factorial experiment (until the day 20)

Sources of change	Degrees of freedom	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Density	Surface areas (mm^2)	Sphericity	Volume (ml)
Packaging films	2	26.826*	0.055**	22.074**	15.851**	0.000**	394804.457**	0.024**	55.941**
Temperature	1	4.515$^{n.s}$	0.004$^{n.s}$	41.779**	12.766*	5.714E-5$^{n.s}$	279979.632*	0.003*	19.173**
Period	4	4.536$^{n.s}$	0.008$^{n.s}$	4.484$^{n.s}$	4.090$^{n.s}$	9.085E-5**	82310.259$^{n.s}$	0.001$^{n.s}$	1.886$^{n.s}$
Pack × Temperature	2	13.798$^{n.s}$	0.015*	10.628**	9.828*	2.411E-6$^{n.s}$	253045.254*	0.001$^{n.s}$	1.279$^{n.s}$
Pack × Period	8	0.940$^{n.s}$	0.002$^{n.s}$	1.041$^{n.s}$	0.999$^{n.s}$	1.615E-5$^{n.s}$	23650.143$^{n.s}$	0.000$^{n.s}$	0.475$^{n.s}$
Temperature × Period	4	0.571$^{n.s}$	0.001$^{n.s}$	1.287$^{n.s}$	0.655$^{n.s}$	9.702E-6$^{n.s}$	15551.110$^{n.s}$	0.000$^{n.s}$	0.544$^{n.s}$
Pack × Period × Temperature	8	0.133$^{n.s}$	0.000$^{n.s}$	0.253$^{n.s}$	0.151$^{n.s}$	1.446E-5$^{n.s}$	1841.576$^{n.s}$	0.000$^{n.s}$	0.224$^{n.s}$
Test error	60	6.363	0.004	2.032	2.714	1.814E-5	64098.348	0.000	1.471
CV (%)		7.5	7.36	8.39	7.09	0.5	14.49	4.22	20.12

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

Table 6. Summary analysis of variance (mean squares) of some physical traits evaluated in a factorial experiment (until the day 40)

Sources of change	Degrees of freedom	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Density	Surface areas (mm^2)	Sphericity	Volume (ml)
Packaging films	1	$29.778^{n.s}$	47.098**	19.270*	31.863**	0.001**	779437.149**	0.002*	173.533**
Temperature	1	$0.188^{n.s}$	$1.952^{n.s}$	47.760**	$11.344^{n.s}$	0.000**	$288899.334^{n.s}$	0.009**	24.387**
Period	8	$1.601^{n.s}$	$1.304^{n.s}$	$2.142^{n.s}$	$1.629^{n.s}$	4.901E-5*	$36083.315^{n.s}$	$0.000^{n.s}$	$0.945^{n.s}$
Pack × Temperature	1	$22.313^{n.s}$	28.541**	43.675**	32.723**	9.071E-$6^{n.s}$	860156.340**	0.005**	$0.904^{n.s}$
Pack × Period	8	$0.237^{n.s}$	$0.246^{n.s}$	$0.867^{n.s}$	$0.450^{n.s}$	1.41E-$5^{n.s}$	$10200.433^{n.s}$	0.000**	$0.177^{n.s}$
Temperature × Period	8	$0.417^{n.s}$	$0.233^{n.s}$	$0.838^{n.s}$	$0.460^{n.s}$	1.137E-$5^{n.s}$	$9675.280^{n.s}$	$0.000^{n.s}$	$0.221^{n.s}$
Pack × Period × Temperature	8	$0.122^{n.s}$	$0.116^{n.s}$	$0.586^{n.s}$	$0.208^{n.s}$	1.254E-$5^{n.s}$	$4237.044^{n.s}$	$0.000^{n.s}$	$0.065^{n.s}$
Test error	72	7.959	2.407	2.824	3.587	2.020E-5	85476.351	0.000	1.747
CV (%)		7.95	7.44	8.81	7.68	0.51	15.89	2.69	21.33

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

3.1.5. Mechanical properties changes

The standard errors and means of maximum work, maximum strain, modulus of elasticity and firmness of grape tomatoes as a function of maintenance period are provided in Figure 6. W max, E, ε max and Firmness were significantly different in packaged products from unpackaged ones (Table 7, Table 8 and Figure 6). In this study, the firmness of unpackaged fruits decreased in 20°C and 4°C from 2.21 to 1.52 N and 2.16 to 1.53 N, respectively, along the maintenance and for products inside the PVC and HDPE packaging in 20°C and 4°C from 2.20 to 1.56 N, 2.14 to 0.93 N and 2.16 to 1.85 N, 2.17 to 1.10 N, respectively, along the maintenance. As the figure 6 show the rate of W_{max} and E value were decreased during storage. As well the results showed that significant differences ($P < 0.05$) were statistically observed between packaging in W_{max} and E values. According to the results, ε_{max}, were increased during storage. The results showed that significant differences ($P < 0.05$) were statistically observed between packaging in ε_{max} during 20 day of storage (Figure 6).

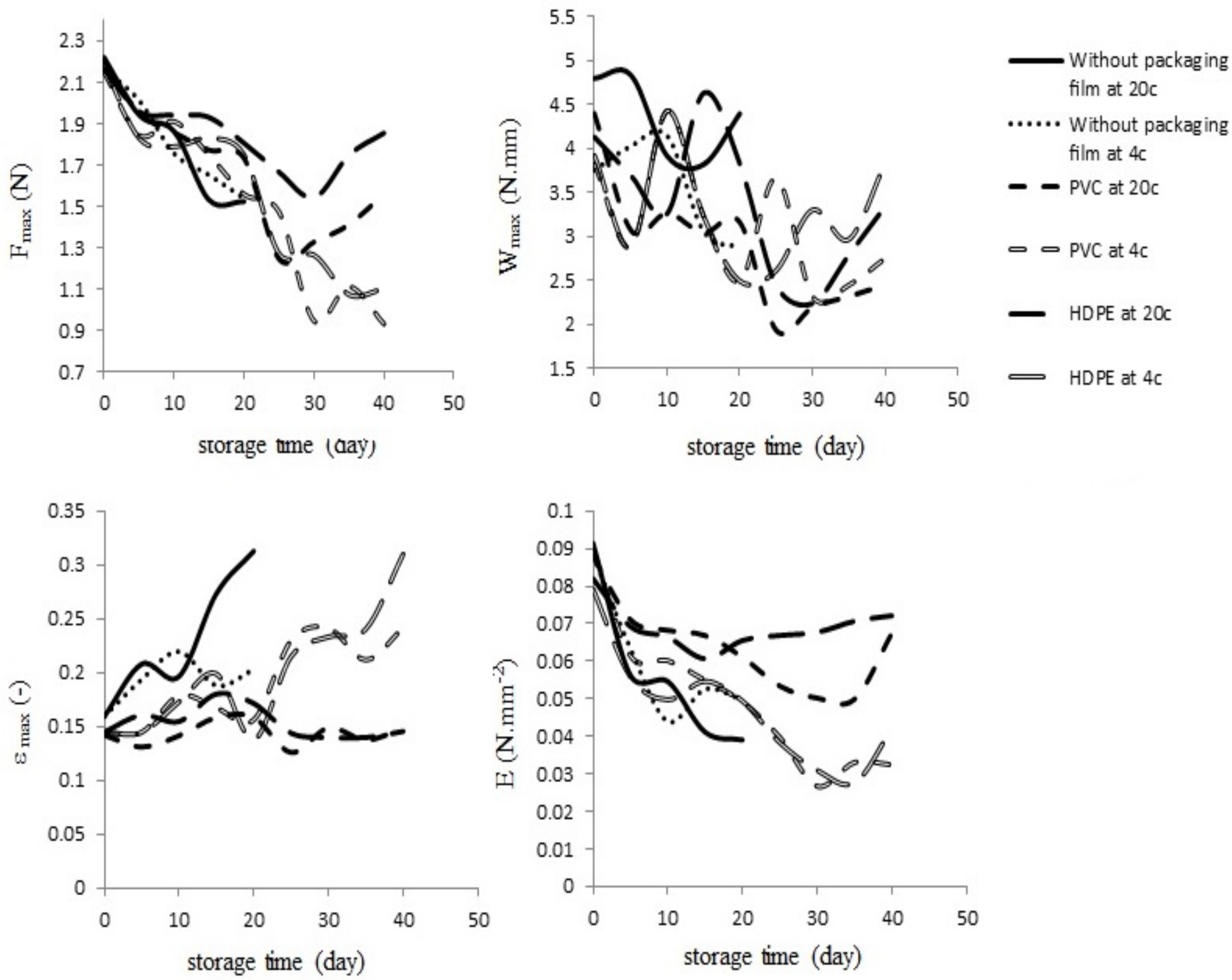

Figure 6. Effect of packaging on some mechanical properties in grape tomatoes during storage

Table 7. Summary analysis of variance (mean squares) of mechanical parameters evaluated in a factorial experiment (until the day 20)

Sources of change	Degrees of freedom	F_{max}	E	W	ε_{max}
Packaging films	2	0.78*	0.002**	1.694*	0.826**
Temperature	1	$0.35^{n.s}$	$4.946E\text{-}9^{n.s}$	2.195*	$0.25^{n.s}$
Period	4	0.850**	0.003**	1.595*	0.178**
Pack × Temperature	2	$0.022^{n.s}$	0.000**	$1.401^{n.s}$	0.099**
Pack × Period	8	0.040*	0.000**	1.533**	0.046**
Temperature × Period	4	$0.006^{n.s}$	0.000**	$0.777^{n.s}$	0.083**
Pack× Period × Temperature	8	$0.011^{n.s}$	$4.379E\text{-}5^{n.s}$	$0.179^{n.s}$	$0.024^{n.s}$
Test error	60	0.018	4.838E-5	0.539	0.013
CV (%)		12.78	23.78	22.87	24.43

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$

Table 8. Summary analysis of variance (mean squares) of mechanical parameters evaluated in a factorial experiment (until the day 40)

Sources of change	Degrees of freedom	F_{max}	E	W	ε_{max}
Packaging films	1	0.324**	$0.000^{n.s}$	6.226**	$0.067^{n.s}$
Temperature	1	1.249**	0.005**	$1.585^{n.s}$	1.606**
Period	8	1.274**	0.002**	3.860**	0.141**
Pack × Temperature	1	$0.120^{n.s}$	$0.000^{n.s}$	$0.008^{n.s}$	$0.007^{n.s}$
Pack × Period	8	$0.031^{n.s}$	$0.000^{n.s}$	$1.461^{n.s}$	$0.011^{n.s}$
Temperature × Period	8	0.168**	0.001**	$0.981^{n.s}$	0.220**
Pack× Period × Temperature	8	$0.43^{n.s}$	$9.165E\text{-}5^{n.s}$	$0.530^{n.s}$	$0.021^{n.s}$
Test error	72	0.37	8.24E-5	0.881	0.019
CV (%)		23.7	24.19	23.19	27.97

"ns" means there was no significant relationship here.
* Significant relationship between two parameters at $P < 0.05$.
** Significant relationship between two parameters at $P < 0.01$.

3.2. Discussions

Grape tomato is a climacteric product and storage time of that is often very short for the sake of high respiration. In this research, the use of PVC and HDPE packaging films significantly protected fresh grape tomatoes. Kader (1989) expressed that film packaging could delay the process of decay. Evelo (1996) expressed that packaged tomatoes had a significantly lower decay rate than unpackaged ones. According to the results, at the end of the maintenance period, for each treatment, weight loss slowly and linearly increased during storage. Packaging films are the useful physical protection around the products to drop humidity in packaged products for the sake of the film packaging Properties (Robertson, 2012). PVC and HDPE packaging films are as a barrier for O2, CO2, H2O, and moisture transfer, but this films have a very slight permeability to O2, CO2, H2O (Awoyale, 2016). Polypropylene packaging has been used to cherry tomatoes for providing physical protection to gas and humidity transfer, and these findings are consistent with our results (D'Aquino et al., 2016). Choi et al. (2015) reported that modified atmosphere provided by the packaging films effectively decreased the weight loss of cherry tomatoes along the storage compared with the without packaging. Fagundes et al. (2015) expressed that bi-oriented polypropylene and low density polyethylene decreased the respiration rate while reducing weight loss and the formation of red color and use of it maintained firmness and delayed changes in sugar and organic acid contents. Tomato color is prominent feature for acceptance by Buyers; however, packaging films couldn't alter the base color of the product (kader, 2002), that in during maintenance, the product was darker and redness was less. The reduction was due to a decrease in some chemical processes (Cantwell et al., 2009).

These findings were consistent with the results of Khairi et al. (2015), that their research showed that the color of tomatoes at the end of storage was darker. based on the results, the product that are stored at different temperatures showed a significant difference in H° (hue angle) along the maintenance and samples at 4°C had more amount of H° (hue angle) degree (Khairi et al., 2015). saad et al. (2015) also observed that tomatoes showed increase in H° degree during storage as an indicator of color during 12 days of storage. kantola and helen. (2001) stated that the tomatoes packed with LDPE film initially showed an increase in a*, that is inconsistent with our research, which may be due to differences in packaging. In the present study, PVC and HDPE packaging films showed a beneficial result on controlling maintaining product size and humidity. The products inside packaging have longer shelf life than non-packaged products. According to the results, PVC and HDPE films showed a beneficial result on firmness along the maintenance, which is due to the reduction of chemical activity and thus the survival of the product (Tanada-Palmu and Grosso, 2005). Batu (1998) findings were consistent with the results of the study, according to Batu results, packaging films improve the firmness of the product during storage, also reported that the most amount of firmness obtained from packaged foods with modified atmosphere packaging Compared with the control treatment at the end of the maintenance period.

4. Conclusions

The results of this study showed that packaging films, PVC and HDPE, are effective to increase the storage time of grape tomatoes and retarded the senescence process compared to without packaging. The PVC and HDPE packaging showed useful results on moisture content, weight loss and color changes of the grape tomatoes. The packaging films have been as a physical protection around the products for humidity and gas exchange. Up to the end of the fortieth day, HDPE packaging could keep product quality better than PVC film. It was showed that the packaging delayed the softening of grape tomatoes and texture change and decreased the loss of firmness.

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