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Effect of Fumaric Acid, β-aminobutyric Acid and Packaging Materials Treatments on Quality and Storability of Cherry Tomatoes

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ABSTRACT

This study was carried out on cherry tomato cv. Katalina 522 (*Lycopersicon esculentum* Mill) harvested at turning stage (25% red color) obtained from a private farm at Wadi Natrun, Elbehira Governorate, Egypt. during two successive seasons of 2015 and 2016 to study the effect of dipping the fruits in solution of fumaric acid at 10%, β-aminobutyric acid at 250 ppm and distillate water (untreated control) and two types of films non perforated polyolefin or non perforated polypropylene beside unpacked fruits on maintaining quality and storability of cherry tomato fruits during storage at 10°C and 90-95% relative humidity for 35 days. Results showed that all postharvest treatments (fumaric acid at 10% and β-aminobutyric acid at 250 ppm) reduced the loss in weight percentage and decay score and maintained fruit quality compared to untreated control during storage; however, β-aminobutyric acid at 250 ppm was the most effective in this concern. Fruits packed in polyolefin was more effective in maintaining quality compared to fruits packed in polypropylene.

Cherry tomatoes dipped in solution β-aminobutyric acid 250 ppm and then packed in polyolefin bags reduced the weight loss percentage and decay. Also maintained general appearance, fruit firmness, external surface color, titreatable acidity content, lycopene content, total soluble solids (TSS), total sugars and ascorbic acid content and gave good appearance after 35 days of storage.

Keywords: Cherry tomatoes, Fumaric acid, β-aminobutyri cacid, Polyolefin, Polypropylene.

Introduction

Tomatoes, one of the most vegetable crops in the world, consumed for its rich of antioxidants and have a nutritive value. Recently, ‘cherry tomatoes’ type tomato fruits but its small fruits. Cherry tomatoes became popular in Europe. Also it's a climacteric fruit during physical and chemical changes in the process of ripening by ethylene production Gharezi *et al*. (2012).

β-aminobutyric, a non-protein amino acid, and important play for delay carnation wilting, inducing resistance against disease and extend shelf life (Zhang *et al.* 2011, EL-Metwally *et al*. 2014 and Soleimani *et al.* 2015)cleared that β-aminobutyric acid inhibited blue mold keeps the appearance by effect on cell wall modification and fruit during storage in apple and sweet pepper fruits.

Fumaric acid is one of the sanitization, which has been used to control pathogens growth and efficient factor for inhibiting pathogens on fruits and vegetables (Wu and Kim, 2007, Gomez-Lopez *et al*., 2009, and Bin *et al.* 2011).

Modified atmosphere packaging used to prevent the development of keeping quality of cherry tomato fruits. Wrapping fruits in sealed polyolefin film reduced weight loss, maintained fruit firmness during storage. Wrapping fruits in polyolefin and polypropylene film is very important to protect the marketability of the fruits (Nazmy *et al.* 2012 and Bakry *et al*. 2015). Also; modified atmospheres can serve in extending fresh produce postharvest -life. Optimum oxygen and carbon dioxide concentrations lower respiration and ethylene production rates, reduce ethylene action, delay ripening and senescence, retard the growth of decay-causing pathogens, and control insects. Gas compositions which are not suited to a given commodity can, however, induce physiological disorders and enhance susceptibility to decay (Miller *et al.,* 1986, Kader 2002, Annalisa *et al.,* 2011).

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The aim of study extend the storage period of cherry tomato fruits by using different environmentally safe treatments and packaging materials at 10°C + 90% RH and compared to control fruits.

Material and Methods

Cherry tomatoes (*Lycopersicon esculentum* Mill) cv. Katalina 522 was grown under greenhouses conditions of Wadi Natrun, Elbehira Governorate, Egypt, during two successive seasons of 2015 and 2016. Fruits were harvested at turning stage on 4^{th} and 6^{th} of February in the first and second seasons respectively then transported to the laboratory of Post harvest and Handling of Vegetable Crops department at Giza governorate within 2.5 hours after harvesting.

Fruits of the same size (15-25mm in diameter), shape and free from visual damage or defects, washed initially with water, then air dried. Fruits were divided into three groups for the following treatments:

1. Dipping in the solution of β-aminobutyric acid 250 ppm for 5 minutes.
2. Dipping in the solution of 10% fumaric acid for 5 minutes.
3. Dipping in tap water for 5 minutes which served as untreated control.

After that fruits from every previous treatment were air dried and packaged in different packaging materials as follow:

1. Packed in non perforated polyolefin bags, and then placed inside corrugated carton box.
2. Packed in non perforated polypropylene bags non perforated and placed inside corrugated carton box.
3. Un packed fruits was served as control.

Eighteen replicates were prepared for each treatment; each replicate consist of a bag containing 500gm fruits. The samples were taken at random in three replicates and arranged in a factorial complete randomized design and stored at 10˚C and 90-95% relative humidity for 35 days. The treatments were examined immediately after harvest and every seven days intervals for the following parameter.

Weight loss percentage: it was estimated according to the following equation: Weight loss% = [(Initial weight - weight of fruits at sampling date)/Initial weight of fruits] x 100.

Decay: it was determined as score system of 1= none, 2= slight, 3= moderate, 4= moderately severe, 5= severe. This depends on decay percentage on fruits.

General appearance: it was determined as score system of excellent> 9, good> 7 to 8.9, fair> 5 to 6.9, poor> 3 to 4.9, and unassailable> 2.9. The scale depends on morphological defects such as shriveling, fresh appearance, color change of fruits and decay. Fruits rating (5) or below considered unmarketable.

Firmness: the average firmness of the fruits was measured in kg/cm^2 by digital force Gauge model FGV 50 A, Shimpo Instrument Co, Japan, with total capacity of $20kg/cm^2$ and resolution of $0.01kg/cm^2$ using cone pointed head.

Total soluble solids percentage (TSS) was determined as a composite juice sample by digital refractometer of model Abbe Leica according to (A.O.A.C., 2000).

Titratable acidity: This is content was determined by titration of blended flesh against NHOH 0.01 N using phenolphthalein indicator (A.O.A.C., 2000). The results were calculated as mg. citric acid per 100 g fresh weight.

Total sugars: using Nelson (1974) - Somogyi (1952) Method, were determined colormetrically using spectrophotometer model 6305 UV/visible range with 520 nm wavelength (Sadasivam and Manickam, 2004).

Lycopene content: The lycopene content was measured using Ito and Horie (2009) method. This method contains of two main steps, extraction of juiced tomato to get lycopene extract and standard, then measured the absorbance value of the solution (purity check) at 505 nm (U-1900 spectrophotometer, Hitachi, Japan) using a solvent blank, acetone, and absorbance value used to get the lycopene content of the samples and calculated lycopene content using equation: lycopene content = 10× absorbance value ÷ 0.315 × sample value (g).

Ascorbic acid content: was determined using the dye 2, 6-dichloro-phenol indophenols method (A.O.A.C., 2000).

External surface color: was evaluated by a color difference meter (Minolta CR200) to measure the *L** describes lightness (*L**=0 for black, *L**=100 for white) and *a** describes intensity in red-green (*a**>0 for red, *a**<0 for green).

Statistical analysis:

Data of the two seasons were arranged and statistically analyzed using Mstatic. The comparison among means of the different treatments was determined by using Duncan's test. The data were tabulated and statistically analyzed according to a factorial complete randomized design (Snedecor and Cochran 1982).

Results and Discussion

Weight loss percentage:-

The results in Table (1) indicate that weight loss percentage was significantly affected by the treatments, packaging materials and storage period in both seasons.

Concerning the effect of the treatments on weight loss percentage during storage, data indicate that fruits dipped in β-aminobutyric acid at 250 ppm gave the lowest value of weight loss percent followed dipped in fumaric acid 10% with significant differences between them in the two seasons, while untreated control gave the highest values of weight loss percentage. In this concern, EL-Metwally *et al*. (2014) mentioned that β-aminobutyric acid reduce the weight loss of crimson seedless grapes during storage time. The reduction of weight loss rate may be attributed to reducing the respiration process rates during postharvest storage, the obtained results of fruit weight loss are in agreement with Ngcobo *et al*. (2012) and Wang *et al*. (2015).

Data also reveal that, packaging materials were significantly affect weight loss percent of cherry tomato fruits during storage where fruits packed in polyolefin bags gave the lowest value of weight loss percent comparing with using polypropylene bags, however, the highest values of weight loss percent was recorded with unpacked fruit. This result was true in both seasons. Similar results were reported by wrapping provides excellent protection from weight loss. Packaging in non-perforated polyolefin bags effectively retarded evaporative water loss, thus enabling the fruits to maintain high water content during storage (Bakry *et al*., 2015). Also, modification of the atmosphere around the fruits, in other words, decreasing O_2 and increasing CO_2 in the storage atmosphere of fruit, resulted in more than 10 fold declines in the rate respiration and reduce sensitivity of ethylene of sweet pepper fruits which diminished the weight loss of fruit during storage (Wang and Qi, 1997).

As for, storage period, data clear that increasing storage period from 0, 7, 14, 21 up to 35 days were significantly increase weight loss percent of cherry tomato fruits. This trend was true under all using the treatments and packaging materials as shown in both seasons.

This continuous loss in weight during storage results from the loss of water by transpiration and dry matter due to respiration. These results are in harmony with results obtained by Kader *et al.* (1989).

With respect to the effect of the interaction among treatments, packaging materials and storage period on the loss in weight, data show that after 35 days of storage, cherry tomato fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin compared to all other tested treatments during both seasons.

Decay:-

As to the tested the treatments, data in Table (1) indicate clearly that examined both treatments used had lower decay score in comparison to untreated. Dipping of fruits in β-aminobutyric acid at 250 ppm was the most effective treatment for reducing decay score. Fumaric acid 10% was less effective than β-aminobutyric acid at 250 ppm in reducing fruit decay in both seasons. These results are in agreement with Zhang *et al.* (2011), who found that β-aminobutyric acid provided an effective control and strongly inhibited spore germination and tube elongation of *Penicillium expansum* populations in apple fruits.

Dipping the fruits in fumaric acid resulted in some decrease in fungal development may be related to washing off some the natural pathogenic spore population from the surface of the fruits (Cohen, 2002 and Bin *et al.,* 2011).

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Table 1: Effect of fumaric acid, β-aminobutyric acid and packaging materials treatments on weight loss %, decay and general appearance of cherry tomato fruits during storage at 10ºC in 2015 and 2016 seasons.

Treatments			First season (2015)			Second season (2016)		
Dipping	**Packaging**	**Days after storage**	**Weight loss %**	**Decay**	**General appearance**	**Weight loss %**	**Decay**	**General appearance**
Fumaric acid 10%	**Polyolefin bags**	0		1.00 J	9.00 a		1.00 j	9.00 a
		7	1.73 y	1.00 J	9.00 a	1.88 x	1.00 j	9.00 a
		14	2.45 v	1.33 Ij	7.67 abc	2.55 t	1.67 hij	7.00 abcd
		21	3.27 rs	1.67 Hij	7.00 abcd	3.41 p	1.67 hij	5.67 bcdef
		28	4.27 mn	2.33 fghi	6.33 bcde	4.41 m	2.67 efgh	5.00 cdefg
		35	5.83 hi	3.33 cdef	3.67 fghi	5.98 i	3.33 cdef	3.67 efghi
	Polypropylene bags	0		1.00 J	9.00 a		1.00 j	9.00 a
		7	1.96 wx	1.00 J	9.00 a	2.11 v	1.00 j	9.00 a
		14	2.98 t	2.00 ghij	7.67 abc	3.17 q	2.33 fghi	6.33 abcde
		21	4.05 op	2.33 fghi	6.33 bcde	4.20 n	2.67 efgh	5.00 cdefg
		28	5.01 k	3.00 defg	5.00 defg	5.19 jk	3.33 cdef	4.33 defgh
		35	6.15 g	3.67 bcde	3.00 ghij	6.30 h	3.67 bcde	3.00 fghi
	Control	0		1.00 J	9.00 a		1.00 j	9.00 a
		7	2.46 v	1.00 J	7.00 abcd	2.70 s	1.00 j	7.00 abcd
		14	3.55 q	2.00 ghij	5.00 defg	3.70 o	2.33 fghi	5.00 cdefg
		21	4.71 l	3.00 defg	3.67 fghi	4.85 kl	3.33 cdef	3.00 fghi
		28	5.48 j	3.67 bcde	3.00 ghij	5.61 j	4.00 abcd	2.33 ghi
		35	6.93 f	4.00 abcd	1.00 j	7.11 f	4.33 abc	1.67 hi
β-aminobutyric acid 250 ppm	**Polyolefin bags**	0		1.00 J	9.00 a		1.00 j	9.00 a
		7	1.13 z	1.00 J	9.00 a	1.31 y	1.00 j	9.00 a
		14	1.93 x	1.00 J	9.00 a	2.08 v	1.00 j	9.00 a
		21	2.75 u	1.00 J	9.00 a	2.91 r	1.33 ij	8.33 ab
		28	3.44 qr	1.33 ij	8.33 ab	3.62 o	1.67 hij	7.67 abc
		35	4.95 k	2.00 ghij	7.00 abcd	6.71 g	2.33 fghi	7.00 abcd
	Polypropylene bags	0		1.00 j	9.00 a		1.00 j	9.00 a
		7	1.21 z	1.00 j	9.00 a	1.39 y	1.00 j	9.00 a
		14	2.14 w	1.00 j	9.00 a	2.30 u	1.33 ij	8.33 ab
		21	3.18 s	1.33 ij	8.33 ab	3.36 p	2.00 ghij	7.00 abcd
		28	4.17 no	2.00 ghij	7.00 abcd	4.33 m	2.33 fghi	6.33 abcde
		35	5.66 ij	3.33 cdef	5.67 cdef	5.81 i	3.00 defg	3.67 efghi

Table 1: Continued

		0		1.00 j	9.00 a		1.00 j	9.00 a
	Control	7	1.93 x	1.00 j	9.00 a	2.07 v	1.00 j	8.33 ab
		14	2.85 tu	1.00 j	7.00 abcd	2.99 q	1.67 hij	7.00 abcd
		21	3.96 p	1.67 hij	5.00 defg	4.11 n	2.33 fghi	4.33 defgh
		28	4.82 kl	2.67 efgh	3.67 fghi	5.02 k	3.00 defg	3.00 fghi
		35	6.21 g	4.00 abcd	3.00 ghij	6.38 h	4.00 abcd	2.33 ghi
Control	**Polyolefin bags**	0		1.00 j	9.00 a		1.00 j	9.00 a
		7	2.13 w	1.00 j	8.33 ab	2.30 u	1.00 j	8.33 ab
		14	4.03 op	2.00 ghij	7.00 abcd	4.29 mn	2.33 fghi	7.00 abcd
		21	5.94 h	2.00 ghij	5.67 cdef	6.11 hi	3.00 defg	5.67 bcdef
		28	7.03 f	2.33 fghi	3.67 fghi	7.21 f	3.33 cdef	5.00 cdefg
		35	9.81 d	4.00 abcd	2.33 hij	9.99 d	4.00 abcd	3.67 efghi
	Polypropylene bags	0		1.00 j	9.00 a		1.00 j	9.00 a
		7	2.50 v	1.00 j	7.67 abc	2.69 s	1.00 j	7.67 abc
		14	4.43 m	2.00 ghij	6.33 bcde	4.61 l	2.67 efgh	5.67 bcdef
		21	6.21 g	3.00 defg	5.00 defg	6.39 h	3.67 bcde	4.33 defgh
		28	7.52 e	3.00 defg	3.00 ghij	7.68 e	4.00 abcd	3.00 fghi
		35	10.30 c	4.67 ab	1.67 ij	10.48 c	4.33 abc	2.33 ghi
	Control	0		1.00 j	9.00 a		1.00 j	9.00 a
		7	3.44 qr	1.00 j	7.00 abcd	3.60 o	1.00 j	6.33 abcde
		14	5.62 j	3.00 defg	4.33 efgh	5.78 i	4.00 abcd	4.33 defgh
		21	9.81 d	3.67 bcde	3.00 ghij	10.03 d	4.00 abcd	2.33 ghi
		28	12.62 b	4.33 abc	1.00 j	12.77 b	4.67 ab	1.00 i
		35	15.34 a	5.00 a	1.00 j	15.38 a	5.00 a	1.00 i
Fumaric acid 10 %			4.05 B	2.13 B	6.19 B	4.21 B	2.30 B	5.78 B
β-aminobutyric acid 250 ppm			3.35 C	1.57 C	7.56 A	3.63 C	1.78 C	7.07 A
Control			7.12 A	2.50 A	5.22 C	7.29 A	2.83 A	5.26 C
	Polyolefin		4.05 C	1.69 C	7.22 A	4.32 C	1.91 C	7.11 A
	Polypropylene		4.50 B	2.07 B	6.70 B	4.67 B	2.30 B	6.22 B
	Control		5.98 A	2.44 A	5.04 C	6.14 A	2.70 A	4.78 C
		0		1.00 E	9.00 A		1.00 E	9.00 A
		7	2.05 E	1.00 E	8.33 B	2.23 E	1.00 E	8.19 B
		14	3.33 D	1.70 D	7.00 C	3.50 D	2.15 D	6.63 C
		21	4.87 C	2.19 C	5.89 D	5.04 C	2.67 C	5.07 D
		28	6.04 B	2.74 B	4.56 E	6.21 B	3.22 B	4.19 E
		35	7.91 A	3.78 A	3.15 F	8.24 A	3.78 A	3.15 F

Values followed by the same letter (s) are not significantly different at 5%

It is clear from data presented that the decay of cherry tomatoes packed in polyolefin bags gave the lowest value comparing with using polypropylene bags, however, the highest values of decay was recorded with unpacked in both seasons. Similar results were reported by Rodov *et al.* (2000) and Bakry *et al*. (2015).

Data also clear that significant increased with prolongation of the storage period in both seasons. The decay started slowly and successively increased till the end of storage. This was a result of the changes which occurred in fruits during storage, which caused an increase of moisture condensation of external surface of fruits, which decreases fruit firmness, as well as, the transformation of complex compounds to simple forms with more liability to fungus infection. These results are in agreement with Trail *et al.* (1992).

With respect to the effect of the interaction among treatments, packaging materials and storage period on the decay score, data show that no decay was noticed in fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin till 21 days of storage and gave slight score or moderate score at the end of storage period (35 days) during both seasons.

General appearance:-

Data in Table (1) show that fruits treated for 5 minutes in β-aminobutyric acid at 250 ppm gave the best appearance followed by fumaric acid 10%treatments compared with untreated in both seasons. The keeping quality of general appearance was improved by using β-aminobutyric acid attributed to the effect of β-aminobutyric acid on the reduction of weight loss and rot rate of cherry tomato fruits. β-aminobutyric acid treatment have beneficial effects on fruit physiology such as delaying ripening of fruits by the increasing antioxidants content in fruits Soleimani *et al.* (2015). In the same time, ethylene production by fruits can be reduced by β-aminobutyric acid and this reduction keeps the appearance of fruits in the best state. In this concern, Kuang *et al.* (2012) stated that ethylene can be removed or reduced by both of ozone and β-aminobutyric acid treatments on long an fruit.

Data also reveal that, cherry tomatoes packed in polyolefin bags gave the best appearance followed by polypropylene bags compared with unpacked in both seasons; similar results were reported by Nazmy *et al.* (2012).

With respect to storage period, general appearance of cherry tomato fruits declined with the prolonging of storage period in both seasons. The decrease of general appearance during storage period might be due to shriveling, color change and decay (Gonzalez-Aguilar *et al*., 1997).

The interaction among treatments, packaging materials and storage period on general appearance showed that cherry tomato fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin did not exhibit any changes in their appearance till 28 days, of storage and gave good appearance after 35 days, of storage, in both seasons. While fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polypropylene bags rated good appearance after 28 days of storage in the second season.

Fruit firmness (kg/cm^2):-

Data in Table (2) indicated that firmness of cherry tomato fruits was significantly affected by the treatments, packaging materials and storage period in both seasons.

Concerning the effect of postharvest treatments of fruit firmness during storage, data revealed that various applied treatments had significantly greater fruit firmness as compared with untreated. However, the highest values of fruit firmness were obtained from fruits dipped in the solution of β-aminobutyric acid at 250 ppm followed by fumaric acid at 10% treatment with significant differences between them, while the lowest values were found in untreated control.

The postharvest storage of fruit is accompanied by loss of cell wall integrity due to breakdown of peptic substances, which led to an increase in soluble pectin and decrease in fruit firmness (Mirdehghan *et al*., 2007).

The differences among packaging materials treatments were significant. However, cherry tomato fruits packed in polyolefin bags or polypropylene bags were firmer than unpacked fruits. These results agree with reports where film packaging was effective in reducing quality loss (Meir *et al*., 1995; Gonzalez-Aguilar *et al*., 2000 and Ilic *et al*., 2012).

Table 2: Effect of fumaric acid, β-aminobutyric acid and packaging materials treatments on firmness (kg/cm^2), total soluble solids % and Titratable acidity of cherry tomato fruit during storage at 10ºC in 2015 and 2016 seasons.

Treatments			First season (2015)			Second season (2016)		
Dipping	Packaging	Days after storage	Firmness (kg/cm^2)	Total soluble solids %	Titratable acidity	Firmness (kg/cm^2)	Total soluble solids %	Titratable acidity
Fumaric acid 10%	Polyolefin bags	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	5.02 bc	6.20 def	0.310 f	4.71 d	5.73 cd	0.300 e
		14	4.42 hi	6.10 efghi	0.320 de	4.11 i	5.50 fghij	0.313 cd
		21	4.02 k	5.93 ijklmn	0.330 bc	3.74 m	5.37 ijklm	0.323 abc
		28	3.13 op	5.90 jklmno	0.330 bc	2.81 s	5.27 lmnop	0.323 abc
		35	2.33 t	5.83 lmnop	0.333 abc	1.95 y	5.10 pqrs	0.320 abcd
	Polypropylene bags	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	4.96 cd	6.20 def	0.310 f	4.61 e	5.70 cde	0.300 e
		14	4.32 ij	6.07 efghij	0.320 de	4.02 j	5.47 ghijk	0.313 cd
		21	3.91 kl	5.93 ijklmn	0.330 bc	3.63 n	5.33 jklmn	0.323 abc
		28	2.90 qr	5.90 jklmno	0.330 bc	2.66 tu	5.20 mnopq	0.330 a
		35	2.03 u	5.77 nopq	0.340 a	1.72 z	5.03 qrs	0.330 a
	Control	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	4.54 gh	6.10 efghi	0.310 f	4.16 h	5.57 defgh	0.300 e
		14	3.92 kl	5.97 hijklm	0.320 de	3.61 n	5.47 ghijk	0.310 de
		21	3.27 o	5.80 mnopq	0.330 bc	2.92 r	5.17 nopqr	0.323 abc
		28	2.40 t	5.80 mnopq	0.330 bc	2.11 x	4.97 stu	0.323 abc
		35	1.73 v	5.53 rs	0.337 ab	1.42 b	4.80 uvw	0.323 abc
β-aminobutyric acid 250 ppm	Polyolefin bags	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	5.41 a	6.47 ab	0.310 f	5.01 b	5.93 ab	0.300 e
		14	5.03 bc	6.30 bcd	0.310 f	4.73 d	5.77 bc	0.313 cd
		21	4.65 fg	6.20 def	0.320 de	4.33 g	5.73 cd	0.320 abcd
		28	3.85 lm	6.13 defgh	0.330 bc	3.52 o	5.57 defgh	0.320 abcd
		35	2.91 qr	6.03 fghijk	0.333 abc	2.63 u	5.50 fghij	0.320 abcd
	Polypropylene bags	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	5.15 b	6.40 abc	0.310 f	4.82 c	5.80 bc	0.300 e
		14	4.77 ef	6.17 defg	0.317 ef	4.61 e	5.70 cde	0.313 cd
		21	4.35 ij	6.13 defgh	0.327 cd	4.03 j	5.63 cdefg	0.323 abc
		28	3.65 n	6.07 efghij	0.330 bc	3.33 q	5.47 ghijk	0.323 abc
		35	2.71 s	5.93 ijklmn	0.330 bc	2.44 w	5.37 ijklm	0.323 abc

Table 2: Continued

	Control	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	4.81 de	6.23 cde	0.310 f	4.53 f	5.67 cdef	0.300 e
		14	4.23 j	6.10 efghi	0.320 de	3.90 k	5.53 efghi	0.320 abcd
		21	3.64 n	6.00 ghijkl	0.330 bc	3.34 q	5.40 hijkl	0.323 abc
		28	2.85 rs	5.87 klmno	0.330 bc	2.54 v	5.30 klmno	0.320 abcd
		35	2.04 u	5.67 pqr	0.333 abc	1.74 z	5.07 qrs	0.327 ab
Control	**Polyolefin bags**	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	5.02 bc	6.07 efghij	0.313 ef	4.75 d	5.27 lmnop	0.300 e
		14	4.46 hi	5.73 opq	0.320 de	4.11 i	5.13 opqrs	0.310 de
		21	3.93 kl	5.23 t	0.330 bc	3.71 m	5.00 rst	0.327 ab
		28	3.01 pq	5.07 tu	0.330 bc	2.71 t	4.80 uvw	0.323 abc
		35	2.14 u	5.00 u	0.337 ab	1.77 z	4.57 x	0.330 a
	Polypropylene bags	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	4.81 de	6.00 ghijkl	0.317 ef	4.53 f	5.13 opqrs	0.300 e
		14	4.21 j	5.63 qrs	0.320 de	3.83 l	5.00 rst	0.310 de
		21	3.72 mn	5.03 u	0.330 bc	3.42 p	4.77 vw	0.327 ab
		28	2.83 rs	4.80 vw	0.337 ab	2.55 v	4.63 wx	0.330 a
		35	1.82 v	4.63 wx	0.340 a	1.52 a	4.53 x	0.330 a
	Control	0	5.56 a	6.50 a	0.310 f	5.21 a	6.00 a	0.300 e
		7	4.03 k	5.90 jklmn	0.320 de	3.69 m	5.07 qrs	0.300 e
		14	3.04 pq	5.47 s	0.330 bc	2.81 s	4.83 tuv	0.317 bcd
		21	1.83 v	4.90 uv	0.333 abc	1.56 a	4.67 vwx	0.330 a
		28	1.03 w	4.70 w	0.337 ab	1.05 c	4.53 x	0.330 a
		35	0.83 x	4.47 x	0.340 a	0.73 d	4.33 y	0.330 a
Fumaric acid 10 %			3.87 B	6.03 B	0.323 B	3.95 B	5.43 B	0.314 B
β-aminobutyric acid 250 ppm			4.26 A	6.18 A	0.321 C	3.55 A	5.64 A	0.314 B
Control			3.52 C	5.45 C	0.326 A	3.24 C	5.01 C	0.316 A
	Polyolefin		4.22 A	5.98 A	0.321 C	3.90 A	5.46 A	0.314 B
	Polypropylene		4.05 B	5.90 B	0.323 B	3.74 B	5.38 B	0.315 A
	Control		3.38 C	5.78 C	0.324 A	3.10 C	5.24 C	0.315 A
		0	5.56 A	6.50 A	0.310 F	5.21 A	6.00 A	0.300 C
		7	4.86 B	6.17 B	0.312 E	4.53 B	5.54 B	0.300 C
		14	4.27 C	5.95 C	0.320 D	3.97 C	5.38 C	0.313 B
		21	3.70 D	5.69 D	0.329 C	3.41 D	5.23 D	0.324 A
		28	2.85 E	5.58 E	0.332 B	2.59 E	5.08 E	0.325 A
		35	2.06 F	5.43 F	0.336 A	1.77 F	4.92 F	0.326 A

Values followed by the same letter (s) are not significantly different at 5%

Data presented indicated titratable acidity content in cherry tomato fruits were gradually and continuously increased till 35 days.

Results of firmness showed similarities to weight loss, thus a strong relationship between firmness and weight loss was reported by Lurie *et al* .,(1986).

The interaction among the treatments, packaging materials and storage period on fruit firmness showed that cherry tomato fruits dipped β-aminobutyric acid at 250 ppm and then packed in polyolefin bags maintained the fruit firmness for 35 days in both seasons.

Total soluble solids (TSS) contents:-

Data in Table (2) indicates that TSS contents cherry tomato fruits were significantly affected by the treatments, packaging materials and storage period in both seasons.

Concerning the effect of the treatments on TSS contents of fruits during storage, data revealed that, fruit dipped in β-aminobutyric acid at 250 ppm or fumaric acid at 10% had the highest content of TSS as compared with untreated. However, fruit dipped in β-aminobutyric acid was the most effective treatment in maintain this character. fumaric acid at 10% treatment was less effective than β-aminobutyric acid in this concern.

The results of TSS changes during storage as affected by the different packaging indicated that there is clear evidence that cherry tomato fruits packed in the two packaging hold more TSS contents during storage than unpacked fruits, whereas the highest TSS were found from fruit packed in polyolefin bagsin both seasons, similar results were reported by Nazmy *et al.* (2012) and Bakry *et al*. (2015).

Regarding the effect of interaction among treatments, packaging films and storage period it was clear that fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin bags had the highest values of TSS as compared with all treatments till 35 days of storage in both seasons.

Titratable acidity (mg. citric acid /100g FW):-

Data in Table (2) show that there were significant differences between the treatments and packaging materials during storage. However, cherry tomato fruits dipped in solution of β-aminobutyric acid exhibited lowest value of titratable acidity content. The highest value of titratable acidity content was observed in untreated fruits in both seasons. No significant differences between β-aminobutyric acid and fumaric treatments in the second season.These results agree with Zhang *et al.* (2011) and EL-Metwally *et al*. (2014).

The fruits packed in polyolefin bags had the lowest value of titratable acidity content in both seasons. The highest value of titratable acidity content was observed in fruits packed in polypropylene bags and unpacked fruits with no significant differences between them in the second season.

With respect to the effect of the interaction among the treatments, packaging and storage period on the titratable acidity content, data showed that titratable acidity contents of cherry tomatoes dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin bags gave the highest values of titratable acidity contents after 35 days of storage followed by packed in polypropylene films (PP) in both seasons.

Total sugars (mg /100g FW):-

Data in Table (3) indicated that total sugars content of cherry tomato fruits was significantly affected by the treatments, packaging materials and storage period in both seasons.

Concerning the treatments data indicated that fruits untreated had significantly higher total sugars than fruits dipped in β-aminobutyric acid at 250 ppm or fumaric acid at 10%. However, β-aminobutyric acid treatment was less effective than fumaric acid with significant differences between them.

Cherry tomato fruits packed in the two packaging had retained less total sugars content compared to unpacked fruits, which gave the highest ones.

The fruits packed in polyolefin bags had the lowest value of total sugars content when compared to those packed in polypropylene bags and control. The highest value of total sugars content was observed in unpacked fruits in both seasons, similar results were reported by Nazmy *et al.* (2012) and Bakry *et al*. (2015).

Data presented indicated total sugars contents in cherry tomato fruits were gradually and continuously increased till end of the storage period in both seasons.

Table 3: Effect of fumaric acid, β-aminobutyric acid and packaging materials treatments on total sugars, lycopene and ascorbic acid of cherry tomato fruit during storage at 10ºC in 2015 and 2016 seasons.

Treatments			First season (2015)			Second season (2016)		
Dipping	**Packaging**	**Days after storage**	**Total sugars**	**Lycopene**	**Ascorbic acid**	**Total sugars**	**Lycopene**	**Ascorbic acid**
Fumaric acid 10%	Polyolefin bags	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.07 su	0.83 v	39.85 c	4.37 yz	1.04 vwx	39.53 c
		14	4.64 q	1.45 t	38.47 f	4.92 uvw	1.74 stuvw	38.32 e
		21	6.12 k	2.43 q	36.94 m	6.43 opq	2.72 pqrs	36.71 k
		28	6.63 hi	3.71 n	36.36 p	6.93 klmn	4.05 mno	36.06 m
		35	6.93 gh	5.80 i	35.34 t	7.24 ijkl	6.10 hij	35.05 p
	Polypropylene bags	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.36 r	1.03 uv	39.13 de	4.71 wxy	1.57 tuvwx	38.86 d
		14	4.99 o	1.85 s	38.03 gh	5.34 tu	2.07 rstuv	37.78 f
		21	6.64 hi	2.97 op	37.44 jk	6.93 klmn	3.22 opq	37.10 j
		28	7.14 fg	4.62 kl	36.60 o	7.48 hij	4.97 klm	36.40 l
		35	7.53 e	6.71 g	35.93 q	7.86 fgh	7.03 fgh	35.65 n
	Control	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	5.21 n	1.17 tu	38.51 f	5.68 st	1.47 tuvwx	38.22 e
		14	5.53 m	2.62 p	37.64 ij	5.87 rs	2.93 pqr	37.33 hij
		21	7.26 f	4.53 kl	35.94 q	7.50 hi	6.16 hij	35.64 n
		28	7.90 d	6.52 gh	35.41 s	8.26 def	6.84 gh	35.12 p
		35	8.26 cd	8.51 d	34.41 vw	8.60 cd	8.87 bcd	34.12 r
β-aminobutyric acid 250 ppm	Polyolefin bags	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	3.81 u	0.55 w	40.76 b	4.20 z	0.89 wx	40.49 b
		14	4.43 r	0.95 uv	39.20 d	5.75 st	1.32 uvwx	39.01 d
		21	5.82 l	1.88 rs	38.51 f	6.06 qrs	2.22 qrstu	38.26 e
		28	6.32 j	3.18 o	37.79 i	6.68 mno	3.46 nop	37.55 fgh
		35	6.52 i	5.12 jk	36.91 mn	6.84 lmno	5.43 jkl	36.57 kl
	Polypropylene bags	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.12 s	0.74 vw	39.86 c	4.42 xyz	1.05 vwx	39.66 c
		14	4.84 op	1.13 u	38.42 fg	5.16 uv	1.52 tuvwx	38.12 e
		21	6.20 j	2.32 q	37.82 hi	6.57 nop	2.67 pqrs	37.51 gh
		28	6.70 h	4.02 l	37.04 lm	7.06 jklm	4.43 lmn	36.71 k
		35	6.98 g	6.23 h	36.23 p	7.34 ijk	6.56 ghi	36.01 m

Table 3: Continued

	Control	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.82 op	0.81 v	39.03 e	5.04 uvw	1.15 vwx	38.81 d
		14	5.32 mn	2.32 q	38.14 g	5.63 st	2.64 pqrs	37.81 f
		21	6.97 g	4.05 l	36.81 n	7.33 ijk	4.37 lmn	36.53 kl
		28	7.51 e	6.17 h	35.82 qr	7.84 fgh	6.41 ghij	35.52 no
		35	7.94 d	8.15 de	35.03 u	8.30 de	8.45 cde	34.71 q
Control	**Polyolefin bags**	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.47 qr	1.08 u	38.04 gh	4.80 vwx	1.35 uvwx	37.78 f
		14	5.07 no	2.14 r	37.41 k	5.33 tu	2.43 pqrst	37.13 ij
		21	6.51 i	3.92 lm	35.81 qr	6.83 lmno	4.28 mno	35.56 no
		28	7.15 fg	5.42 j	34.88 u	7.43 hij	5.74 ijk	34.57 q
		35	7.35 ef	7.72 e	34.19 wx	7.64 ghi	8.04 def	34.00 rs
	Polypropylene bags	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	4.83 op	1.45 t	37.91 h	5.06 uvw	1.75 stuvw	37.66 fg
		14	5.95 k	3.95 lm	37.32 kl	6.24 pqr	4.30 mn	37.40 ghi
		21	7.74 de	4.68 k	35.72 r	8.02 efg	5.03 klm	35.41 no
		28	8.46 c	5.91 i	34.52 v	8.74 bc	6.23 hij	34.22 r
		35	8.77 b	8.91 c	34.04 x	9.05 ab	9.23 bc	33.77 st
	Control	0	3.73 uv	0.33 w	41.20 a	4.09 z	0.61 x	41.00 a
		7	5.63 lm	2.06 r	37.51 j	5.93 rs	2.37 qrstu	37.22 ij
		14	6.03 k	5.22 jk	37.03 lm	6.46 opq	5.55 ijk	36.71 k
		21	7.86 d	7.17 f	35.60 rs	8.11 ef	7.43 efg	35.31 op
		28	8.74 b	9.52 b	34.30 w	9.12 ab	9.93 b	34.05 rs
		35	9.03 a	12.14 a	33.84 y	9.41 a	12.43 a	33.58 t
Fumaric acid 10 %			5.80 B	3.10 B	37.76 B	6.13 B	3.48 B	37.49 B
β-aminobutyric acid 250 ppm			5.53 C	2.70 C	38.39 A	5.92 C	3.02 C	38.13 A
Control			6.38 A	4.57 A	36.76 C	6.69 A	4.88 A	36.52 C
	Polyolefin		5.39 C	2.62 C	38.00 A	5.76 C	2.92 C	37.76 A
	Polypropylene		5.91 B	3.19 B	37.76 B	6.24 B	3.52 B	37.52 B
	Control		6.40 A	4.55 A	37.15 C	6.74 A	4.94 A	36.87 C
		0	3.73 F	0.33 F	41.20 A	4.09 F	0.61 F	41.00 A
		7	4.59 E	1.08 E	38.96 B	4.91 E	1.40 E	38.69 B
		14	5.20 D	2.40 D	37.96 C	5.63 D	2.72 D	37.74 C
		21	6.79 C	3.77 C	36.73 D	7.09 C	4.23 C	36.45 D
		28	7.40 B	5.45 B	35.86 E	7.73 B	5.78 B	35.58 E
		35	7.70 A	7.70 A	35.10 F	8.03 A	8.02 A	34.83 F

Values followed by the same letter (s) are not significantly different at 5%

The increase in total sugars in the first period of storage might owe much to the higher rate moisture loss through transpiration than the rate of dry matter loss through respiration. Also, the reduction in total sugars during storage might owe much to the higher rate of sugar loss through respiration than water loss through transpiration (Wills *et al*., 1981).

The interaction among treatments, packaging material, and storage period was significant in the two seasons. Data showed that fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin bags were the most effective treatments in maintaining total sugars content with significant differences between them at the same period in the two seasons.

Lycopene content (mg/100 gFW):-

Data in Table (3) lycopene content there were significant differences between the treatments and packaging materials during storage period in both seasons. Fruits untreated had significantly higher lycopene content than fruits dipped in β-aminobutyric acid at 250 ppm or fumaric acid at 10%. However, β-aminobutyric acid treatment was less effective than fumaric acid with significant differences between them.These results were relevant to this obtained by Gharezi *et al*. (2012).

The fruits packed in polyolefin bags had the lowest value of lycopene content when compared to those packed in polypropylene bags and unpacked fruits. The highest value of lycopene content was observed in unpacked fruits in both seasons, similar results were reported by Nazmy *et al.* (2012).

With respect to the effect of the interaction among the treatments, packaging and storage period on the lycopene content, data showed that after 35 days of storage, lycopene content of control treatment (untreated and unpacked fruits) gave the highest values of lycopene content, however, the lowest one was obscured from fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin bags.

Ascorbic acid content (mg /100g FW):-

Data presented in Table (3) indicate that there were significant differences between the treatments during storage period in both seasons. Cherry tomato fruits dipped in β-aminobutyric acid at 250 ppm or dipped in fumaric acid at 10%, exhibited highest ascorbic acid content compared with untreated. However, all over storage period fruits treated with β-aminobutyric acid were the most effective treatment in maintaining ascorbic acid content during storage, these results were agreement with those obtained by Zhang *et al.* (2011) and EL-Metwally *et al*. (2014).

Two packaging materials used were increased ascorbic acid content in the fruit significantly compared to unpacked fruits. However, the most delay in ascorbic acid degradation was observed in fruits packed in polypropylene bags in both seasons. Reduction in O_2 concentration inside the packages can protect these characters, presumable through prevention of oxidation Arvanitoyannis *et al*. (2005).

It was also obvious that there were significant reduction in ascorbic acid content with the increase of storage period in both seasons.

Wills *et al.* (1981) attributed the reduction of vit. C during storage to great metabolic activity during storage as it is respired. Paradis *et al.* (1995) found that the reduction in ascorbic acid content during storage period might have been due to the higher rate of sugar loss through respiration than water loss through transpiration. These results agree with Trail *et al.* (1992)

Regarding the interaction among the treatments, packaging and storage period, data revealed that fruits were treated for β-aminobutyric acid and packed in polyolefin bags exhibited the highest ascorbic acid content during all storage period compared to all other tested treatments.

Color (*L and *a** value):-**

Data in Table (4) the color of cherry tomato fruits were significant differences between the treatments and packaging materials during storage period in both seasons. Fruits dipped in β-aminobutyric acid at 250 ppm or fumaric acid at 10% had lighter color (high *L** value) than fruits untreated had darker color (low *L** value). However, β-aminobutyric acid treatment was lighter color (high *L** value) than fumaric acid with significant differences between them.

In general, value for *a**increased during storage for all treatment. Concerning the treatments data indicated that fruits dipped in β-aminobutyric acid at 250 ppm had lower a value (low *a**value)

Table 4: Effect of fumaric acid, β-aminobutyric acid and packaging materials treatments on *a** and *L** value of cherry tomato fruit during storage at 10ºC in 2015 and 2016 seasons.

Treatments			First season (2015)		Second season (2016)	
Dipping	**Packaging**	**Days after storage**	***L**Value**	***a**Value**	***L**Value**	***a**Value**
Fumaric acid 10%	**Polyolefin bags**	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	42.08 c	24.93 x	41.22 c	25.44 r
		14	38.72 fg	27.73 rs	37.93 ef	28.25 p
		21	34.65 lm	31.53 n	33.84 j	32.06 lm
		28	30.64 qr	36.06 hi	29.85 n	36.73 gh
		35	25.05 w	41.02 d	24.24 s	41.57 d
	Polypropylene bags	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	41.93 c	25.72 uv	41.03 c	26.25 qr
		14	38.43 g	28.33 r	37.65 ef	28.92 op
		21	34.32 m	32.27 m	33.42 jk	32.75 l
		28	30.26 qrs	36.95 h	29.42 no	37.43 fg
		35	24.72 wx	41.86 c	23.93 st	42.39 c
	Control	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	41.05 de	26.07 u	40.25 d	26.55 q
		14	37.05 j	28.91 q	36.24 h	29.42 o
		21	31.63 p	33.03 l	30.86 m	33.54 kl
		28	27.22 uv	37.72 g	26.43 q	38.25 f
		35	22.03 y	42.83 b	21.14 v	43.35 b
β-aminobutyric acid 250 ppm	**Polyolefin bags**	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	43.83 b	23.62 y	43.02 b	24.13 t
		14	39.63 f	26.44 tu	38.83 e	26.93 q
		21	35.83 k	30.35 p	35.03 i	30.85 n
		28	31.65 p	34.16 k	30.84 m	34.71 j
		35	26.13 v	39.51 fg	25.74 qr	40.03 e
	Polypropylene bags	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	43.24 b	23.94 y	42.43 b	24.53 st
		14	39.14 f	26.82 t	38.35 e	27.44 pq
		21	35.42 kl	30.93 o	34.62 ij	31.43 mn
		28	31.34 pq	35.72 ij	30.53 mn	35.25 ij
		35	25.62 vw	39.92 f	24.81 rs	40.55 e

Table 4: Continued

	Control	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	41.54 cd	24.84 x	40.73 c	25.36 rs
		14	37.92 ghi	27.55 s	37.17 fg	28.16 p
		21	32.63 o	31.63 n	31.86 l	32.14 lm
		28	28.03 u	35.81 i	27.24 pq	36.35 h
		35	22.84 y	40.83 de	22.07 u	41.37 d
Control	**Polyolefin bags**	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	41.33 cd	25.14 w	40.52 cd	25.63 r
		14	37.72 ij	28.03 r	36.93 g	28.53 p
		21	33.83 n	32.17 m	33.03 k	32.64 l
		28	29.72 rs	36.54 h	28.92 o	37.06 g
		35	24.03 xy	41.54 c	23.23 t	42.05 c
	Polypropylene bags	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	40.73 e	25.55 v	39.94 d	26.07 qr
		14	37.13 ij	28.85 q	36.33 gh	29.37 o
		21	33.24 no	33.25 l	32.42 kl	33.75 k
		28	29.32 t	37.69 g	28.56 op	38.16 f
		35	23.63 xy	42.83 b	22.84 t	43.33 b
	Control	0	46.12 a	21.50 z	45.30 a	22.02 u
		7	38.15 gh	27.53 s	37.32 f	28.13 p
		14	34.23 mn	30.16 p	33.43 jk	30.72 n
		21	28.83 tu	35.46 j	28.03 p	35.93 hi
		28	23.53 xy	40.54 e	22.74 tu	41.07 de
		35	18.71 z	45.73 a	17.94 w	46.25 a
Fumaric acid 10 %			35.45 B	31.08 B	34.63 B	31.61 B
β-aminobutyric acid 250 ppm			36.29 A	29.81 C	35.51 A	30.29 C
Control			34.03 C	31.97 A	33.23 C	32.49 A
	Polyolefin		36.29 A	30.18 C	35.50 A	30.70 C
	Polypropylene		35.94 B	30.84 B	35.12 B	31.31 B
	Control		33.54 C	31.84 A	32.74 C	32.37 A
		0	46.12 A	21.50 F	45.30 A	22.02 F
		7	41.54 B	25.26 E	40.72 B	25.79 E
		14	37.77 C	28.09 D	36.98 C	28.64 D
		21	33.38 D	32.29 C	32.57 D	32.79 C
		28	29.08 E	36.80 B	28.28 E	37.22 B
		35	23.64 F	41.79 A	22.88 F	42.32 A

Values followed by the same letter (s) are not significantly different at 5%

followed by fumaric acid 10% compared to untreated had higher *a**value (high *a** value). Indeed, with this treatment the color of cherry tomato fruits was maintained,
these results agreement with Kaymak *et al*. (2010) and Gharezi *et al*. (2012).

It is clear from data presented that the *L** value of fruits cherry tomatoes packed in polyolefin bags gave lighter color (high *L** value) followed by polypropylene bags compared to unpacked had darker color (low *L**value). While, fruits cherry tomatoes packed in polyolefin bags gave lower *a**value (low *a**value) followed by polypropylene bags compared to unpacked had higher *a**value (high *a**value) in both seasons (Khairi *et al.,* 2015).

The interaction among treatments, packaging material, and storage period, showed that fruits dipped in β-aminobutyric acid at 250 ppm and then packed in polyolefin bags gave lightest color (high *L** value) and lowest *a** value after 35 days of storage compared to all other tested treatments in both seasons.

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