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Improving Coloration, quality and Storability of "Kelsey" Plum Fruits by some Pre-Harvest Applications

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Abstract

Kelsey" plum is one of the late season cultivars in Egypt, but under environmental conditions, the fruit suffering from poor color development, causing economic losses. This experiment was conducted during 2018 and 2019 seasons on 5-years-old "Kelsey" plum cultivar budded on Nemaguard rootstock and located in a private orchard at El-Nubaria district, El-Behira governorate to study the effect of pre-harvest spraying with ProTone (Active ingredient, Abscisic acid (ABA 10 %)) at 50 and 100 ppm and jasmonic acid at 1000 and 2000 ppm in comparison to the control treatment on coloration, quality and storability. The fruits were stored for 30 days at (0±1° C and 90-95% relative humidity) then, evaluated in each treatment at 0, 10, 20 and 30 days to determine the changes in fruit quality characteristics during cold storage. Results showed that exogenous application of jasmonic acid at 2000 ppm was the best treatment for improving some fruit quality properties in terms of fruit weight, size, flesh weight, flesh/stone ratio. Moreover, under cold storage this treatment increased fruit anthocyanin, total sugars contents and TSS/Acid ratio, simultaneously reduced fruit weight loss and fruit disorders percentage, in addition gave the intermediate values of fruit firmness.

***Key words**:* ProTone, jasmonic acid, coloration, quality, storability, "Kelsey" plum

Introduction

In Egypt, The cultivated area with plum reached 1120 hectares in 2018 produced 14775 tons (FAO, 2018).The Low-chilling plum cultivars grow well under the Egyptian environmental conditions like Kelsey cultivar which classified as climacteric fruits. This cultivar faced many problems related with worse of some fruit quality attributes as fruit color, low storing ability and some difficulties with handling in the market (Farag and Attia, 2018).

The previous studies indicated the importance of some factors affected on anthocyanin accumulation in peel fruit such as fruit position on the tree, leaf-fruit ratio, shading fruit, nutrition and foliar application with some growth regulators (Creelman and Mullet, 1997; Martinez-Romero, *et al* 2003; Murray *et al.,* 2005 and Roberto *et al.,*2012). On the other hand, Growth regulators could be used for alleviating the quality losses at the cold storage (Meheriuk *et al.,* 1995 and Sayyari *et al.,* 2011).

Using Ethrel for enhancing the fruit coloration has drawbacks as leaves defoliation and low yield in the next season (Roberto *et al.,* 2012). While, exogenous application with Abscisic acid (ABA) or Jasmonic acid (JA) enhance anthocyanin synthesis, chlorophyll degradation (Lichter *et al.,* 2006; Wang *et al.,* 2006 and Francescatto, 2013) and does not cause excessive senescence. In addition, reduced the sensitivity to fungal decay during storage with the ProTone (ABA) treatments (Lichter *et al.,* 2006) and Jasmonic application (Moline *et al.,* 1997 and Cao *et al.,* 2008). Furthermore, Jasmonic acid (JA) reduces post-harvest quality losses of fruits and prolongs shelf life (Fan *et al.,* 1998).

Therefore, this research aimed to study the effects of spraying ProTone and Jasmonic acid on coloration, quality and storability of "kelsey" plum fruits stored at (0±1° C with 90-95% R.H.).

Materials and Methods

Five-years-old of "Kelsey" plum (*Prunussalicina*L.) budded on Nemaguard rootstock was used in this trial during 2018 and 2019seasons. The trees were spaced at 3.5× 4 m, planted in sandy soil under fertigation system and located in a private orchard at El-Nubaria district, El-Behira governorate, Egypt. Fifteen uniform trees were similar vigor; healthy and free from defects were used for this investigation. This experiment consisted of five treatments arranged in factorial analysis in a randomized complete block design. Three replicates were chosen for each treatment with one tree in each replicate. The trees were sprayed two times at (1^{st} and 7^{th}July during 2018 and 2019, respectively) by using the following treatments:

T_1: Control (water only).
T_2: ProToneat 50 ppm (Active ingredient, ABA 10 %, Shoura Chemicals Company).
T_3: ProTone at (100 ppm).
T_4: Jasmonic acid at1000 ppm, obtained from (Sigma-Aldrich Company).
T_5: Jasmonic acid at (2000 ppm).

Random samples were collected from each tree two week after the application, and then placed into cardboard boxes in single rows and stored for 30 days at 0±1° C with 90-95% R.H. The treated fruits were evaluated in each treatment at 0, 10, 20 and 30 days of treatment.

Measurements

At harvest

Fruit weight (g), fruit size (cm^3), fruit length (cm), fruit diameter (cm), flesh weight (g), stone weight (g) and flesh/stone ratio were measured.

At cold storage

Fruit firmness was determined as ($Ib/inch^2$) using Effigi Pressure Tester (mod. Ft327).TSS% was estimated in fruit juice using a digital refractometer. Titratable acidity was determined as a malic acid by titration with 0.1 N of NaOH according to (A.O.A.C, 1985).Fruit TSS/Acid ratio was calculated as a ratio between TSS (%) and acidity (%).Total sugars were estimated by using the phenol sulfuric acid method described by (Smith, 1956), and the concentration was calculated from a standard curve of glucose (mg. per g. fresh weight of fruit tissue).Chlorophylls a & b were determined according to (Wintermans and Mat, 1965). Anthocyanin was determined on the fruit as (mg/100g fresh weight) according to the method described by Rabino *et al.* (1977). A carotene pigment in fruit pulp was expressed as mgs / 100 gm fresh weight and determined according to the procedure outlined by Wensttein (1957) and expressed as mg/100 g fresh weight. Fruit weight loss percentage was calculated as follows:

$$\text{Weight loss \%} = \frac{\text{Fruit weight at the beginning storage} - \text{Fruit weight at sampling date}}{\text{Fruit weight at the beginning storage}} \times 100$$

Fruits affected with either pathological or physiological disorders were counted by visual and calculated as a percentage to the initial number of fruits per each sample (replicate) and treatment too.

Statistical analysis:

The obtained data were statistically analyzed for some parameters at harvest time as a Randomized Complete Block Design by analysis of variance (ANOVA) using Statistical Analysis System (CoStat) program.

In the other side, for some parameters at cold storage, as a factorial Randomized Complete Block Design by analysis of variance (ANOVA) using Statistical Analysis System (CoStat) program. Where the first factor was five treatments mentioned before, the second factor was storage period. The means of treatments were compared using LSD at 0.05 according to Snedecor and Cochran (1989).

Results and Discussion

Fruit weight, fruit length, fruit diameter and fruit size:

The results in Table 1 represented the effect of pre harvest spraying of ProTone and jasmonic acid treatments on fruit weight, fruit length, fruit diameter and fruit size of "Kelsey" plums in both seasons. Data indicated that, ProTone at (50 & 100 ppm) caused a significant decrease in fruit weight, fruit diameter and fruit size as compared with the untreated fruits (control). On the contrary, both concentration of Jasmonic acid caused a marked increase in fruit weight, fruit length, diameter and fruit size comparing with the untreated fruits (control). The significant increases in fruit size obtained with the higher concentration could be ascribed to mitigating the influence of ethylene on the processes of fruit ripening which delay harvest while the assimilation and translocation of carbohydrate is going on which could reflect on increasing fruit size (Farag *et al.,* 2015).

Similar results obtained by (Ağlar and Öztürk, 2018) on Fuji Apple. This positive effect by Jasmonic acid treatments on fruit weight, fruit length, diameter and fruit size could be due to its role in enhancing auxin (IAA) biosynthesis (Hentrich *et al.,* 2013).

Table. 1: Effect of pre-harvest spraying of ProTone and jasmonic acid on fruit weight (g), fruit length (cm), fruit diameter (cm) and fruit size (cm^3) of "kelsey" plum in 2018 and 2019 seasons.

Treatments	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		Fruit size (cm^3)	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Control	76.29	78.38	4.01	4.01	3.88	3.91	69.31	77.31
ProTone at 50 ppm	72.05	73.74	3.91	3.88	3.71	3.80	65.31	66.51
ProTone at 100 ppm	70.65	72.51	3.82	3.30	3.64	3.76	63.86	64.62
Jasmonic acid at 1000 ppm	81.96	87.04	4.38	4.32	4.07	4.19	80.18	82.42
Jasmonic acid at 2000 ppm	87.38	89.56	4.54	4.44	4.20	4.28	84.01	86.22
$LSD_{at\ 0.05}$	**3.03**	**2.07**	**0.31**	**0.15**	**0.07**	**0.06**	**1.44**	**1.33**

Flesh weight, stone weight and flesh/stone ratio:

Data illustrated in Table 2 showed the effect of pre harvest spraying of ProTone and jasmonic acid treatments on flesh weight, stone weight and flesh/stone ratio. Data revealed that, ProTone at (50 & 100 ppm) decreased flesh weight, while, jasmonic acid at (1000 & 2000 ppm) increased flesh weight and the differences of all treatments were significant when compared with control.

Moreover, as for stone weight, data showed that, ProTone at 100 ppm, jasmonic acid at (1000 & 2000 ppm) treatments increased stone weight, while, ProTone at 50 ppm tended to a significant reduction in stone weight compared with control.

Furthermore, results in Table 2 showed that, ProTone at 50 ppm, jasmonic acid at 1000 ppm and jasmonic acid at 2000 ppm treatments significantly increased flesh/stone ratio, except for jasmonic acid at 1000 ppm in 2019 season, where the difference is not big enough to be significant as compared with control. On contrary, ProTone at 100 ppm significantly decreased flesh/stone ratio compared with control in two season of study.

These increase in flesh weight and flesh/stone ratio by exogenous application with jasmonic could be attributed to the increase in fruit size (Table 1) led to higher proportionate fresh weight. These conclusions support the results of (Zayan *et al.,* 2016) who reported increase in peach fruit size is often accompanied by a decrease in firmness.

Table. 2: Effect of pre-harvest spraying of ProTone and jasmonic acid on flesh weight (g), stone weight (g) and flesh/stone ratio of "kelsey" plum in 2018 and 2019 seasons.

Treatments	Flesh weight (g)		Stone weight (g)		Flesh/stone ratio	
	2018	2019	2018	2019	2018	2019
Control	74.15	76.27	2.14	2.11	32.43	36.21
ProTone at 50 ppm	70.18	71.89	1.87	1.85	37.74	39.52
ProTone at 100 ppm	68.50	70.34	2.15	1.17	31.93	32.52
Jasmonic acid at 1000 ppm	78.90	84.95	2.32	2.26	34.46	39.15
Jasmonic acid at 2000 ppm	85.71	87.03	2.27	2.22	38.33	39.23
$LSD_{at\ 0.05}$	**1.64**	**1.16**	**0.30**	**0.27**	**4.23**	**4.52**

Fruit firmness:

In both season, all treatments significantly decreased fruit firmness compared with control. In addition, both concentration of jasmonic acid significantly gave the best fruit firmness values compared with ProTone at 50 & 100 ppm (Table 3).

Regarding storage periods, data in Table 3 showed that, in both seasons of study, fruit firmness significantly decreased gradually with the progress of cold storage.

The reducing in fruit firmness affecting by spraying ProTone and jasmonic acid treatments in comparison to control may be explained by their inhibitor effect on some enzymes causing decrease in flesh firmness particular lypolygalacturonase biosynthesis (Fan *et al.,* 1998 and Moustakime *et al.,* 2017). These results are in harmony with those obtained by (Balbontín *et al.,* 2018) on sweet cherry reported pre harvest applications of abscisic acid (ABA), methyl jasmonate (MeJA) gave higher fruit firmness than the control.

Krishna *et al.* (2012) showed the role of growth regulators in preservation the fruit firmness during cold storage. Also, Gonzalez-Aguilar *et al.* (2003); Janoudi and Flore (2003); Rudell *et al.* (2005) and Altuntas *et al.* (2012) confirmed this trend for peach and apple fruits. MeJA dose produced higher fruit firmness than control because the effect of methyl jasmonate on enzymes caused softening of fruit flesh (Fan *et al.*, 1998). Contrarily, Khan and Singh (2007) reported that methyl jasmonate application enhanced plum fruit softening.

Fruit weight loss:

Data concerning the effect of pre harvest spraying of ProTone and jasmonic acid on weight loss of "Kelsey" plums fruits in 2018 and 2019 seasons are reported in Table (4). Statistical analysis showed that fruit weight loss percentages increased with increasing storage periods, and the differences among all tested storage periods were significant comparing with the initial date in the two seasons of study.

Furthermore, ProTone at 50 ppm in both seasons and ProTone at 100 ppm in first season caused a non-significant increase in fruit weight loss compared with control. On the other hand, ProTone at 100 ppm in the second season and both concentrations of jasmonic acid at (1000 & 2000 ppm) in both seasons caused a significant decreased in fruit weight loss.

Loss fruit moisture through transpiration and respiration is the main factor for loss in fruit weight (Srivastava and Dwivedi, 2000 and Wang *et al.,* 2006). Moreover, The decrease in fruit weight loss observed in trees treated with jasmonic acid due to its antioxidant capacity ability to overcome free radicals as hydrogen peroxide (H_2O_2) and malondialdehyde (MDA) levels (Kovacik *et al.,* 2011 and Dar *et al.,* 2015).

These results are agreed with those obtained by Kucuker and Ozturk (2014) investigated the effect of pre-harvest methyl jasmonate treatment (MeJA) on different plum fruit cultivars during the

cold storage. They reported that, methyl jasmonate treatment decreased plum fruit weight loss than the control through the cold storage.

Resistance of fruit to moisture loss, due to its low water vapor pressure in comparison to water at the same temperature because of dissolved substances, mostly sugars. More reasons caused loss in fruit weight not water loss alone like changes in cell wall, respiration and ethylene production especially in climacteric fruits during cold storage(Singh and Khan, 2010; Paul *et al.,* 2012). In addition, storage conditions, pre-storage treatments (growth regulators), ripening level of fruits and cultivar are the main factors affected on weight loss degree (Valero *et al.,* 2003; Casquero and Guerra, 2009; Krishna *et al.,* 2012).

Table. 3: Effect of pre-harvest spraying of ProTone and jasmonic acid on firmness of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
	Season 2018				
Control	9.90	9.61	9.22	8.67	**9.35**
ProTone at 50 ppm	8.11	7.57	7.24	6.92	**7.46**
ProTone at 100 ppm	7.92	7.38	6.98	6.74	**7.25**
Jasmonic acid at 1000 ppm	8.74	7.79	7.37	7.20	**7.77**
Jasmonic acid at 2000 ppm	8.85	7.98	7.54	7.33	**7.92**
Means	**9.55**	**8.86**	**8.47**	**8.22**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.22 Storage Periods (S): 0.19 Interaction (T×S): 0.44**				
	Season 2019				
Control	9.48	9.22	8.72	8.10	**8.88**
ProTone at 50 ppm	7.64	7.23	6.93	6.68	**7.12**
ProTone at 100 ppm	7.53	7.19	7.21	6.62	**7.14**
Jasmonic acid at 1000 ppm	9.05	8.84	8.01	7.59	**8.37**
Jasmonic acid at 2000 ppm	9.44	8.99	8.51	7.76	**8.67**
Means	**9.82**	**9.39**	**9.03**	**8.50**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.19 Storage Periods (S): 0.17 Interaction (T×S): 0.37**				

Table. 4: Effect of pre-harvest spraying of ProTone and jasmonic acid on weight loss percentage of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
				Season 2018	
Control	0.00	3.80	4.39	4.84	**3.26**
ProTone at 50 ppm	0.00	3.89	4.46	4.91	**3.32**
ProTone at 100 ppm	0.00	3.84	4.43	4.87	**3.28**
Jasmonic acid at 1000 ppm	0.00	3.69	4.22	4.51	**3.10**
Jasmonic acid at 2000 ppm	0.00	3.58	4.14	4.26	**2.99**
Means	**0.00**	**3.76**	**4.33**	**4.68**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.13 Storage Periods (S): 0.12 Interaction (T×S): 0.26**				
				Season 2019	
Control	0.00	3.48	4.18	5.11	**3.19**
ProTone at 50 ppm	0.00	3.58	4.30	4.87	**3.18**
ProTone at 100 ppm	0.00	3.53	4.24	5.15	**3.23**
Jasmonic acid at 1000 ppm	0.00	3.22	3.32	4.87	**2.85**
Jasmonic acid at 2000 ppm	0.00	3.06	3.14	4.03	**2.56**
Means	**0.00**	**3.37**	**3.83**	**4.81**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.14 Storage Periods (S): 0.12 Interaction (T×S): 0.27**				

Fruit disorders:

Fruit disorders percentage during cold storage at 0±1° C and 90-95% R.H. of "kelsey" plum are shown in (Table 5).Data indicate that, a significant increases in fruit disorders percentage were observed with the advancement of cold storage period at 0±1ºC in both seasons.

Our results reveal that, pre harvest spraying of ProTone at (50 & 100 ppm) significantly increased fruit disorders compared with the control. On other hand, jasmonic acid at 1000&2000 ppm caused a significant decrease in "kelsey" plum fruit disorders as compared with control in two seasons of study. Reducing post-harvest diseases, chilling injury and prolong shelf life by MeJA, is considered important natural compound, may attributed to the role of JA in increasing plant tolerance against biotic and abiotic stress (Dar *et al.,* 2015) or reducing in ion leakage and an increase in PAL activity (Cao *et al.,* 2009 and Nilprapruck *et al.,* 2008).

Table. 5: Effect of pre-harvest spraying of ProTone and jasmonic acid on disorders percentage of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.)in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
				Season 2018	
Control	0.00	6.80	7.25	7.77	**5.45**
ProTone at 50 ppm	0.00	7.08	7.38	7.97	**5.61**
ProTone at 100 ppm	0.00	7.24	7.45	8.08	**5.69**
Jasmonic acid at 1000 ppm	0.00	6.45	6.80	7.44	**5.17**
Jasmonic acid at 2000 ppm	0.00	6.29	6.55	7.31	**5.04**
Means	**0.00**	**6.77**	**7.09**	**7.71**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.12 Storage Periods (S): 0.11 Interaction (T×S): 0.24**				
				Season 2019	
Control	0.00	7.09	7.34	7.89	**5.58**
ProTone at 50 ppm	0.00	7.20	7.41	8.07	**5.67**
ProTone at 100 ppm	0.00	7.34	7.47	8.26	**5.77**
Jasmonic acid at 1000 ppm	0.00	6.38	6.65	7.38	**5.10**
Jasmonic acid at 2000 ppm	0.00	6.27	6.45	7.29	**5.00**
Means	**0.00**	**6.85**	**7.06**	**7.78**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.09 Storage Periods (S): 0.08 Interaction (T×S): 0.19**				

Total soluble solids:

With respect to the effect of various applied treatments on total soluble solids contents of "kelsey" plum fruit, in both experimental seasons, the data in Table 6 showed that, fruit total soluble solids contents significantly increased as the storage period extended till the end of storage period 30 days compared with initial time. Moreover, all treatments caused a significant increase in total soluble solids percentage compared with control in two seasons of study. Also, jasmonic acid at 2000 ppm was more effective on increasing total soluble solids contents compared with other treatments.

These results are in harmony with those obtained by Kucuker and Ozturk (2014) investigated the effect of pre-harvest methyl jasmonate treatment on different plum fruit cultivars during the cold storage. They reported that, plum fruit SSC values was better in the methyl jasmonate treatments than the control on entire analysis storage periods. In contrast, Rudell *et al.* (2005) cleared in 'Fuji' apple cultivar the negative effect of methyl jasmonate on conversion of starch into sugar. Higher fruit SSC content as a result of methyl jasmonate treatments, possibly, its inhibition effect on pectin and polygalactronase enzyme activities leading to glucose, fructose and sucrose-like sugars accumulation.

Table. 6: Effect of pre-harvest spraying of ProTone and jasmonic acid on total soluble solids percentage of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.)in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
	Season 2018				
Control	10.09	10.70	11.38	11.99	**11.04**
ProTone at 50 ppm	13.08	13.81	14.64	14.80	**14.08**
ProTone at 100 ppm	13.51	13.95	15.07	15.33	**14.46**
Jasmonic acid at 1000 ppm	13.81	14.17	14.67	15.12	**14.44**
Jasmonic acid at 2000 ppm	14.35	14.45	14.82	15.33	**14.74**
Means	**12.97**	**13.42**	**14.11**	**14.51**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.24 Storage Periods (S): 0.21 Interaction (T×S): 0.47**				
	Season 2019				
Control	10.66	11.35	11.80	12.35	**11.54**
ProTone at 50 ppm	13.57	13.96	14.92	15.00	**14.36**
ProTone at 100 ppm	13.86	14.13	15.18	15.55	**14.68**
Jasmonic acid at 1000 ppm	14.00	14.26	14.93	15.38	**14.64**
Jasmonic acid at 2000 ppm	14.51	14.67	15.07	15.43	**14.94**
Means	**13.32**	**13.67**	**14.38**	**14.74**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.19 Storage Periods (S): 0.17 Interaction (T×S): 0.37**				

Acidity:

The response of acidity content of "kelsey" plum fruits during cold storage to pre harvest spraying of ProTone and jasmonic acid in 2018 and 2019 seasons was reported in (Table 7). The data revealed that there was a significant decrease in acidity contents as the storage period prolonged. Also**,** all treatments significantly decreased acidity percentages compared with untreated fruits during both seasons, In addition, ProTone at 100 ppm treatment was more effective in decreasing fruit acidity contents compared with other treatments in both seasons. This reduction in fruit acidity during cold storage could be due to the delaying in physiological ageing and alteration in metabolism, which ultimately resulted in higher retention of acidity. Meanwhile, decrease acidity in control fruits had high changes of acidity probably due to high respiratory rate and therefore acids consumption quickly and related to increases in metabolic activity.

In agreement with these results are those obtained by Kucuker and Ozturk (2014) investigated the effect of pre-harvest methyl jasmonate treatment (MeJA) on different plum varieties during the cold storage and they reported that, the MeJA application reduced fruit TA values than the control in different plum varieties. Consumption organic acids through respiration process leads to lower TA (Jan *et al.,* 2012).

Table. 7: Effect of pre-harvest spraying of ProTone and jasmonic acid on acidity percentage of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
			Season 2018		
Control	1.27	1.97	1.13	1.09	**1.17**
ProTone at 50 ppm	1.23	1.19	1.09	1.06	**1.14**
ProTone at 100 ppm	1.20	1.15	1.04	1.00	**1.09**
Jasmonic acid at 1000 ppm	1.24	1.19	1.15	1.11	**1.17**
Jasmonic acid at 2000 ppm	1.21	1.16	1.11	1.07	**1.14**
Means	**1.23**	**1.18**	**1.10**	**1.07**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.02 Storage Periods (S): 0.03 Interaction (T×S): 0.05**				
			Season 2019		
Control	1.61	1.54	1.49	1.43	**1.52**
ProTone at 50 ppm	1.33	1.21	1.16	1.12	**1.20**
ProTone at 100 ppm	1.23	1.87	1.13	1.09	**1.16**
Jasmonic acid at 1000 ppm	1.44	1.44	1.41	1.27	**1.39**
Jasmonic acid at 2000 ppm	1.29	1.24	1.15	1.14	**1.21**
Means	**1.38**	**1.32**	**1.27**	**1.21**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.03 Storage Periods (S): 0.03 Interaction (T×S): 0.06**				

TSS/Acid ratio:

Data illustrated in (Table 8) showed that all treatments caused a significantly increase in fruit TSS/Acid ratio compared with control in the two seasons of study. In addition, ProTone at 100 ppm and jasmonic acid at 2000 ppm were more effective on increasing TSS/Acid ratio and significant compared with other treatments.

As for the effect of storage periods on the changes in fruit TSS/Acid ratio, data in Table 8 showed that, TSS/Acid ratio increased gradually and significantly with the progress of cold storage in both seasons of study.

Total sugars:

Tabulated data in Table 9 declared that all used treatments increased fruit total sugars than the control fruits and the differences were big enough to be significant in both seasons. Fruit total sugars contents significantly increased with prolonging cold storage period as a compared with initial time in two seasons of study. The increase in sugars content of fruits could be due to ripening process that led to the transformation of some carbohydrates components as starch to sugars by the enzymatic activities (Karemera and Habimana, 2014).

In general, from abovementioned results, in comparison to control all treatments improved fruit total soluble solids and total sugars content in addition the TSS/Acid ratio meanwhile, reduced fruit acidity % during cold storage. These positive effects of ProTone and jasmonic acid due to their role in increasing ethylene production through inducing the expression of genes involved in its biosynthesis (Fan *et al.,* 1998).These results are in harmony with those obtained by Kucuker and Ozturk (2014) on different plum cultivars mentioned that fruit SSC content increased, while acidity decreased during storage as a result of MeJA application.

Table. 8: Effect of pre-harvest spraying of ProTone and jasmonic acid on TSS/Acid ratio of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	10	20	30	Means (A)
			Season 2018		
Control	7.95	8.97	10.10	10.97	**9.50**
ProTone at 50 ppm	10.66	11.64	13.39	14.01	**12.42**
ProTone at 100 ppm	11.26	12.13	14.58	15.34	**13.33**
Jasmonic acid at 1000 ppm	11.14	11.91	12.75	13.58	**12.35**
Jasmonic acid at 2000 ppm	11.82	12.42	12.31	14.41	**12.99**
Means	**10.57**	**11.41**	**12.83**	**13.66**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.38 Storage Periods (S): 0.34 Interaction (T×S): 0.75**				
			Season 2019		
Control	6.62	7.35	7.90	8.64	**7.63**
ProTone at 50 ppm	10.25	11.50	12.82	13.39	**11.99**
ProTone at 100 ppm	11.27	11.92	13.40	14.22	**12.70**
Jasmonic acid at 1000 ppm	9.72	9.90	10.58	12.05	**10.56**
Jasmonic acid at 2000 ppm	11.22	11.83	13.06	13.54	**12.41**
Means	**9.82**	**10.50**	**11.55**	**12.37**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.26 Storage Periods (S): 0.23 Interaction (T×S): 0.51**				

Table. 9: Effect of pre-harvest spraying of ProTone and jasmonic acid on total sugars percentage of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	10	20	30	Means (A)
			Season 2018		
Control	7.46	7.72	7.80	7.88	**7.72**
ProTone at 50 ppm	8.64	8.83	9.16	9.35	**8.99**
ProTone at 100 ppm	8.77	8.92	9.35	9.60	**9.16**
Jasmonic acid at 1000 ppm	8.81	8.94	9.30	9.64	**9.17**
Jasmonic acid at 2000 ppm	8.89	9.07	9.44	9.73	**9.28**
Means	**8.51**	**8.69**	**9.01**	**9.24**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.05 Storage Periods (S): 0.04 Interaction (T×S): 0.10**				
			Season 2019		
Control	7.29	7.54	7.69	7.75	**7.65**
ProTone at 50 ppm	8.51	8.77	8.93	9.16	**8.87**
ProTone at 100 ppm	8.69	8.83	9.25	9.56	**9.08**
Jasmonic acid at 1000 ppm	8.63	8.83	9.20	9.52	**9.04**
Jasmonic acid at 2000 ppm	8.82	9.09	9.41	9.65	**9.17**
Means	**8.39**	**8.60**	**8.89**	**9.13**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.06 Storage Periods (S): 0.04 Interaction (T×S): 0.12**				

Anthocyanin, carotene and chlorophyll a, b:

Results of the present investigation, presented in Tables (10, 11, 12 and 13) showed the effect of pre harvest spraying of ProTone and jasmonic acid treatments on fruit anthocyanin, carotene and chlorophyll a, b contents of "Kelsey" plum fruits in 2018 and 2019 seasons. Data showed that, ProTone and jasmonic acid treatments significantly increased anthocyanin and carotene contents of "Kelsey" plums fruits as compared with control in both seasons of study. In addition, jasmonic acid at 2000 ppm was more effective on increasing anthocyaninand carotene contents and the differences are big enough to be significant compared with other treatments. Moreover, the statistical analysis showed that, ProTone at (50 & 100 ppm) and jasmonic acid at (1000 & 2000 ppm) treatments significantly decreased chlorophyll a and b compared with control. In addition, spraying jasmonic acid at 2000 ppm significantly decreased fruit chlorophyll a and b contents comparing with other treatments in both seasons.

As for the effect of storage periods, dataproved that, fruit anthocyanin contents significantly increased with prolonging storage periods as compared with initial time. Where, it was declared that, carotene and chlorophyll a, b contents decreased significantly increased with prolonging storage periods as compared with initial time.

Pre harvest applications of MeJA enhanced apple and strawberry fruit color (Rudell *et al.,* 2005 and Concha *et al.,* 2013). Also, Kondo (2006) there were increasing in the expression of anthocyanin biosynthesis-related genes in cherry. In another study, Kucuker and Ozturk (2015) reported that, MeJA have a positive effect on the color of cherry fruit. Nevertheless, Saracoglu *et al.* (2017) stated that the lightness were higher in MeJA and/or ABA treatments in comparison to the control. In general, chlorophyll degradation and anthocyanin's and total carotenoids, appearance are responsible for the plum coloration. In this study, an increase in fruit anthocyanin and carotene content at the same time decrease in chlorophyll values were observed with the ProTone (ABA) and jasmonic acid treatments as compared to control. This positive effect of JA and ABA in enhancing chlorophyll degradation and stimulates color pigments find support from the previous studies (Perez *et al.,* 1993) on Golden Delicious' apple (Khan and Singh, 2007) on plum and (Omran, 2011) on grapevine.

Table. 10: Effect of pre-harvest spraying of ProTone and jasmonic acid on anthocyanin (mg/100g F.W) of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.)in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
				Season 2018	
Control	3.64	4.10	4.54	5.12	**4.35**
ProTone at 50 ppm	24.06	24.75	25.29	25.77	**24.97**
ProTone at 100 ppm	25.22	25.86	26.18	26.90	**26.04**
Jasmonic acid at 1000 ppm	25.06	25.27	26.00	26.26	**25.65**
Jasmonic acid at 2000 ppm	26.01	26.13	26.53	26.29	**26.28**
Means	**20.79**	**21.26**	**21.71**	**22.07**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.31 Storage Periods (S): 0.28 Interaction (T×S): 0.62**				
				Season 2019	
Control	3.06	3.54	4.11	4.86	**3.89**
ProTone at 50 ppm	23.16	24.21	24.73	25.49	**24.39**
ProTone at 100 ppm	24.51	25.09	25.83	26.37	**25.45**
Jasmonic acid at 1000 ppm	25.41	25.45	26.36	26.52	**25.93**
Jasmonic acid at 2000 ppm	26.54	26.86	26.96	26.97	**26.83**
Means	**20.54**	**21.03**	**21.57**	**22.04**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.36 Storage Periods (S): 0.32 Interaction (T×S): 0.72**				

Table. 11: Effect of pre-harvest spraying of ProTone and jasmonic acid on carotene (mg/100g) of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	Storage Periods (Days)				
	0	**10**	**20**	**30**	**Means (A)**
				Season 2018	
Control	0.57	0.36	0.24	0.16	**0.33**
ProTone at 50 ppm	0.61	0.42	0.28	0.19	**0.38**
ProTone at 100 ppm	0.64	0.49	0.31	0.23	**0.42**
Jasmonic acid at 1000 ppm	0.63	0.84	0.33	0.22	**0.42**
Jasmonic acid at 2000 ppm	0.66	0.52	0.37	0.27	**0.45**
Means	**0.62**	**0.46**	**0.30**	**0.21**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.03 Storage Periods (S): 0.03 Interaction (T×S): 0.06**				
				Season 2019	
Control	0.56	0.32	0.22	0.15	**0.31**
ProTone at 50 ppm	0.59	0.44	0.33	0.22	**0.39**
ProTone at 100 ppm	0.66	0.53	0.37	0.25	**0.45**
Jasmonic acid at 1000 ppm	0.63	0.56	0.36	0.24	**0.45**
Jasmonic acid at 2000 ppm	0.69	0.54	0.42	0.31	**0.49**
Means	**0.63**	**0.48**	**0.34**	**0.23**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.02 Storage Periods (S): 0.02 Interaction (T×S): 0.04**				

Table. 12: Effect of pre-harvest spraying of ProTone and jasmonic acid on chlorophyll a(mg/100g) of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019 seasons.

Treatments	**Storage Periods (Days)**				
	0	**10**	**20**	**30**	**Means (A)**
				Season 2018	
Control	0.154	0.114	0.099	0.094	**0.115**
ProTone at 50 ppm	0.136	0.107	0.097	0.091	**0.108**
ProTone at 100 ppm	0.133	0.104	0.091	0.088	**0.104**
Jasmonic acid at 1000 ppm	0.130	0.104	0.093	0.086	**0.103**
Jasmonic acid at 2000 ppm	0.127	0.093	0.087	0.078	**0.096**
Means	**0.136**	**0.105**	**0.094**	**0.087**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.004 Storage Periods (S): 0.003 Interaction (T×S): 0.007**				
				Season 2019	
Control	0.131	0.113	0.097	0.091	**0.108**
ProTone at 50 ppm	0.133	0.106	0.093	0.089	**0.105**
ProTone at 100 ppm	0.129	0.103	0.087	0.086	**0.101**
Jasmonic acid at 1000 ppm	0.129	0.101	0.089	0.085	**0.101**
Jasmonic acid at 2000 ppm	0.124	0.092	0.085	0.077	**0.094**
Means	**0.129**	**0.103**	**0.090**	**0.086**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.004 Storage Periods (S): 0.003 Interaction (T×S): 0.008**				

Table. 13: Effect of pre-harvest spraying of ProTone and jasmonic acid on chlorophyll b (mg/100g) of "kelsey" plum fruits during cold storage at (0±1° C and 90-95% R.H.) in 2018 and 2019seasons.

Treatments	Storage Periods (Days)				
	0	10	20	30	Means (A)
			Season 2018		
Control	0.197	0.101	0.092	0.086	**0.119**
ProTone at 50 ppm	0.181	0.096	0.085	0.081	**0.111**
ProTone at 100 ppm	0.162	0.091	0.083	0.078	**0.103**
Jasmonic acid at 1000 ppm	0.177	0.091	0.078	0.073	**0.105**
Jasmonic acid at 2000 ppm	0.155	0.088	0.074	0.069	**0.097**
Means	**0.174**	**0.093**	**0.082**	**0.077**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.002 Storage Periods (S): 0.002 Interaction (T×S): 0.004**				
			Season 2019		
Control	0.213	0.105	0.089	0.085	**0.123**
ProTone at 50 ppm	0.207	0.094	0.086	0.084	**0.118**
ProTone at 100 ppm	0.180	0.090	0.083	0.079	**0.108**
Jasmonic acid at 1000 ppm	0.180	0.092	0.081	0.075	**0.107**
Jasmonic acid at 2000 ppm	0.167	0.089	0.077	0.073	**0.101**
Means	**0.189**	**0.094**	**0.083**	**0.079**	
$LSD_{at\ 0.05}$	**Treatments (T): 0.003 Storage Periods (S): 0.002 Interaction (T×S): 0.005**				

Conclusion

Depending on the obtained results, it could be concluded that exogenous application of jasmonic acid at 2000 ppm was the best treatment for improving some fruit quality properties in terms of fruit weight, fruit size, flesh weight, flesh/stone ratio. Moreover, under cold storage this treatment increased fruit anthocyanin, total sugars contents and TSS/Acid ratio, simultaneously reduced fruit weight loss and fruit disorders percentage, in addition gave the intermediate values of fruit firmness.

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الملخص العربي

تحسين التلوين والجودة والقدرة التخزينية لثمار البرقوق صنف "الكلزى" برش بعض المعاملات قبل الحصاد

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يعتبر البرقوق الكلزى واحد من الأصناف متاخرة النضج فى مصر, لكن تحت الظروف المصرية يعانى من ضعف التلوين مسببا خسائر أقتصادية. أجريت هذه الدراسة خلال موسمين متتاليين (2018 , 2019) على اشجار برقوق صنف الكلزى عمرها خمس سنوات مطعومة على أصل نيماجارد بمنطقة النوبارية – محافظة البحيرة, لدراسة تأثير الرش قبل الحصاد بكل من البروتون (50 , 100 جزء فى المليون), الجاسمونيك أسيد (1000و 2000 جزء فى المليون) والكنترول على تحسين التلوين والجودة والقدرة التخزينية لثمار البرقوق صنف "الكلزى". تم تخزين الثمار لمدة 30 يوم على درجة حرارة صفر±1 ° م ورطوبة نسبية 90– 95٪ وتم تقييم صفات الثمار عند صفر, 10, 20, 30 يوم لتحديد التغيرات فى خصائص جودة الثمار خلال التخزين المبرد. أوضحت النتائج أنه عند الحصاد فأن معاملة الجاسمونيك أسيد (2000 جزء فى المليون) كانت الأفضل فى تحسين بعض خصائص الجودة من حيث وزن الثمار, حجم الثمار, وزن اللحم ونسبة اللحم إلى البذرة. علاوة على ذلك, خلال ظروف التخزين المبرد للثمار, فان معاملة الجاسمونيك أسيد قد زادت من محتوى الثمار من صبغة الأنثوسيانين, السكريات الكلية ونسبة المواد الصلبة الذائبة الكلية إلى الحموضة. إضافة إلى ذلك فإنها قللت من النسبة المئوية للفقد فى وزن الثمار وكذلك نسبة الأصابة بالأمراض الفطرية والفسيولوجية مع أعطاء قيم متوسطة لصلابة الثمار.