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The Effect of Post-Harvest Treatments of Packaged "Kelsey" Plum Fruits with Oleic Acid Kept in Light, Dark or at Low Temperature

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Abstract : In order to manipulate poor coloration and progress forwards ripening and to enhance marketable appearance and storability of plum (*Prunus salicina* L),"Kelsey" plum fruits were treated with oleic acid then kept at light, dark or low temperature. The results of this investigation proved that plum fruits treated with oleic acid then kept at low temperature (4-5°C) for one week gained more anthocyanin pigment, possessed higher firmness and reduced weight loss and electrolyte leakage. In addition, no internal browning or other chilling injury symptoms was appeared. On the other hand, keeping plum fruits in dark or under artificial light at room temperature (22 ±2°C) lowered quality of "Kelsey" plums especially fruit firmness. Thus, the manipulation of coloration and ripening progress of plum with post-harvest treatment with oleic acid then incubation at low temperature (4- 5°C) for seven days would be practical for increasing fruit coloring and marketable acceptance of "Kelsey" plums. These results suggest that low temperature plays an important role in regulating anthocyanin biosynthesis of plum fruits even after harvest.
Keywords: Packaged Kelsey, Plum Fruits, Oleic Acid.

Introduction

Plum color and storability are major factorsthat mainly influence consumer choice and the marketability.Color is caused by the accumulation of anthocyanin pigment located in the peel and pulp of plum fruit. Moreover, anthocyanins have many benefits to human nutritional and health acting as a powerful antioxidant and free radical scavengers**{16}**.Therehave been many attempts to enhance coloration and keep storability of fresh plums especially those that produce low amount of ethylene through late stage of development and ripening. One known approach is to use ethylene **{3}**. Another approach is to use some natural compounds such as LPE and oleic acid alone or in combination with Ethrel to alleviate its adverse effects **{6}**. In this study, a new approach was used to enhance coloration of plumsand to overcome poor coloration and weak storability of "Kelsey" plums by harvesting all plum fruits from the tree at maturity stage then keepingthem at in low temperature for one week, then transfer to market by using safe and natural compound such as oleic acid.**{7}** it was reported that use of oleic acid as a natural compound before harvest resulted in keeping plums quality after harvest by preserving the fluidity of plasma membrane and its natural integrity. Furthermore, low temperature stimulated

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anthocyanin accumulation and improved fruit coloration as found in grapes **{2}**, apples **{23}**, plums **{6}**and orange **{12}.** Moreover, Light induced anthocyanin biosynthesis by increasing the expression of anthocyanin biosynthetic genes **{22, 10}**. Artificial light provoke synthesis of phenylpropanoid compounds and isoprenoid pigments **{18}**, whereas dark treatment reduces flavonoid accumulation**{14, 2}**.This paper addressed the possibility of using low temperature (4- 5°C) and oleic acid treatments to enhance coloration and keep fruit quality of "Kelsey" plum especially fruit firmness without using ethylene.Thus, the objectives of this study were to enhance coloration of "Kelsey" plums by a novel approach after harvest and keeping their quality especially their shelf life which reflects on their marketable acceptance and to provide plum producers with a novel procedure to reduce the loss after harvest and to increase their profits.

Materials and Methods

Fresh "Kelsey" plum fruits were harvested at maturity stage from a commercial private orchard located in Elboustan region, Behiragovernorate, Egypt. Fruit were harvested on July 9, 7 during 2014 and 2015 season, respectively.Fruits were immediately transferred to laboratory after harvest, where fruit of uniform size, free from visual defects were selected and dipped in water to clean the surfaces, then dipped in diluted sodium hypochlorite solution for surface sterilization for three minute, then washed thoroughly in distilled water and air dried.Fruits were divided into eight groups, four replicates were used for each treatment and every replicate contained ten fruits. Plum fruit was treated at the day of harvest with oleic acidat 400 ppm, fruit was soaked into the solution for 5 minutes, air dried and packed into plastic polyethylene bags. Then, each packaged fruits were subjected to one of the following treatments:

1- Normal light stored at room temperature under (22 ±2°C).
2- Dark storedata room temperature under (22 ±2°C).
3- Florescent light (965 lux) for 3 days then storedat room temperature under (22 ±2°C).
4- Darkin refrigerator stored under (4- 5°C).
5- Normal light storedat room temperature under (22 ±2°C) + oleic acid 400ppm.
6- Dark storedat room temperature under (22 ±2°C) + oleic acid 400ppm.
7- Florescent light for 3 days, then storedat room temperature under (22 ±2°C) + oleic acid 400ppm.
8- Dark refrigerator stored under (4- 5°C) + oleic acid 400ppm.

After one week, the following measurements were taken:

1- Weight loss %:at the beginning of experiment, the initial weight of fruit was taken, then after seven days the final weight (g) was then used to determine the weight loss percentage.

$$\text{Weight loss\%} = \frac{\text{initial weight} - \text{final weight}}{\text{Initial weight}} \times 100.$$

2- Fruit firmness: was determined as (Ib/in^2) using Effigi pressure tester (mod. Ft327).

3- Electrolytes leakage % of flesh fruit: was calculated as a ratio between the ion leakage of fresh tissue then the total ion leakage after killing (%) by using the conductivity meter according to a standard method of **{4}**.

4- Total Soluble Solids (TSS %): was determined in plum fruit juice using a hand refractometer.

5- Juice acidity%: was calorimetrically estimated based on malic acid using five milliliters of the fruit juice of each fruit sample and titrated with sodium hydroxide solution of a known normality using phenolphthalein as an indicator **{1}**.

6- TSS: Acidity ratio: was calculated as a ratio between TSS (%) and acidity (%).

7- Total sugars %: were determined by using the phenol sulfuric acid method**{20}.**

7- Anthocyanin: was determined according to the method of {**8}.**

8- Chlorophylls a, b and Beta-carotene in fruit peel: were determined according to**{11}**, aforementioned by**{13}**by using spectrophotometer.

9- Carotene in fruit flesh:was determined according to**{15}** by using spectrophotometer. The following equation was used:

$$C\ (\mu g/\ g) = \frac{A\times \text{Volume (ml)} \times 10^{4}}{A^{1\%}\times 1\ \text{cm}\times \text{sample weight (g)}}$$

Where, C= concentration of carotene. A= absorbance (450 nm).

$A^{1\%}$= absorption coefficient of β-carotene (2592).

10- Vitamin Ccontent: was determined according to**{1}**.

Statistical analysis:

The obtained data was subjected to analysis of variance (ANOVA) using SAS statistical programs**{19}**. Means were separated using the Least Significant Differences (LSD) at 0.05 levels according to**{21}**.

Results and Discussion

1- Physical characteristics of "Kelsey" plum fruit:

The data in Table 1 showed that all treatments included oleic acid before storage significantly increased firmness of "Kelsey" plum fruits after one week as compared with normal light stored at room temperature under 22 ±2°C (T1), dark stored at a room temperature under 22 ±2°C (T2)and florescent light (965 lux) for 3 days then stored at room temperature under 22 ±2°C (T3) treatments storedunder refrigerated conditions (4- 5°C)or others that werestored under ambient temperature (22 ±2°C). Highest firmness was recorded in dark in refrigerator stored under 4- 5°C (T4), dark refrigerator stored under (4- 5°C) + oleic acid 400ppm (T8), dark stored at room temperature under (22 ±2°C) + oleic acid 400ppm (T6)and florescent light for 3 days, then stored at room temperature under (22 ±2°C) + oleic acid 400 ppm (T7)ascompared with T1, T2, T3 and normal light stored at room temperature under (22 ±2°C) + oleic acid 400 ppm (T5).The increase in fruit firmness by oleic acid might be due to the positive role of oleic acid by maintaining membrane integrity and fluidity {**5}**. **{6,7}** it was observed that "Kelsey" plums treated with oleic acid then stored at refrigerated (4- 5°C) kept their firmness during their ripening process in contrast to non-treated fruits.Low temperature prevents physiological disorder, reduces rate of respiration and slow down ripening process, thus prolonging refrigerated shelf life of fruits {**9}**.On the other hand, the decrease in plum fruit firmness under room temperature might be due tothe increase in respiration rate and fresh mass index {**17}**.

The data in Table 1 illustrated that both weight loss and electrolyte leakage were decreased with storage plum fruits at (4- 5°C) treated with or without oleic acid as compared with all other treatments during 2014 and 2015 seasons. The results are in harmony with the findings of**{5-7}**. Moreover, **{25}** reported that mandarin fruits that were coated with oleic acid and cold stored reduced weight and firmness loss, decreased the water vapor and oxygen gas transfer resulting in diminished respiration rate thus increased the shelf life of the fruit. The reduction in EC by oleic acid or low temperature could be attributed to retarding senescence of fruit.

Table 1: Effect of various applied treatments at postharvest during the two seasons 2014 and 2015 on physical properties of "Kelsey" plums at the end of the shelf life period.

Treatments	Firmness (Lb./Inch^2)		Weight loss %		Electrolyte leakage of fruit %	
	2014	2015	2014	2015	2014	2015
T1**	10d*	11.55bc	9.05a	12.81a	80.21b	76.75bc
T2	9.8d	11.33bc	9.28a	13.7a	80.8ab	77.45ab
T3	9.15e	10.83c	9.61a	13.25a	82.47a	78.92a
T4	11.65b	15.35a	4.57c	4.88b	76.97c	67.92e
T5	10.85c	11.85b	9.14a	12.57a	79.19b	74.12d
T6	10.73c	12.1b	7.02b	11.41a	79.49b	74.58d
T7	10.25cd	11.6bc	9.76a	12.74a	80.06b	75.35cd
T8	12.76a	14.75a	4.25c	5.28b	75.67c	68.45e

*Values, within each column, of similar letter (s)were not significantly different according to the least significant difference (LSD) at 0.05 levels.

**Each packaged plum fruits was subjected to one of the following treatments: normal light and room temperature (T1), darkness and room temperature (T2), florescent light and room temperature (T3), darkness in refrigerator (4- 5°C) (T4), normal light and room temperature for oleic acid-treated fruits (T5), darkness and room temperature for oleic acid-treated fruits (T6), florescent light and room temperature for oleic acid-treated plums (T7), and finally darkness and refrigeration at (4- 5°C) for oleic acid-treated plums (T8). Four replications were used with each treatment.

2- Skin pigments characteristics of "Kelsey" plum fruit:

The skin color of "Kelsey" plum was still green at harvest, after one week of harvest and storage at (4- 5°C), the skin of plum fruits changed from green to red after one week of storage at (4- 5°C) whether treated with oleic acid or not. The highest anthocyanin amount was recorded by treatments dark in refrigerator stored under 4- 5°C (T4)anddark refrigerator stored under (4- 5°C) + oleic acid 400ppm (T8) as compared with normal light stored at room temperature under 22 ±2°C (T1) and other treatments. Furthermore, possessedlowest chlorophyll a or b content. Meanwhile,they possessed higher carotene contents (Table 2 and Fig. 1). The role of temperature in inducing anthocyanin formation was due to activatingphehylalanine ammonia lyase (PAL), chalcone synthase (CHS), dihydroflavonol 4-reductase (DFR), and UDP-glucose flavonoid glucosyltransferase (UFGT) enzymes and up-regulating the expression of genes involved in anthocyanin biosynthesis and regulation**{12, 24}**. Moreover**, {23}**reported that low temperatures promote anthocyanin accumulation and fruit coloration by up-regulating the expression of genes involved in anthocyanin biosynthesis and regulation in apples. **{2}** indicated that the accumulation of anthocyanin in grape skin is dependent on both low temperature and light. On the other hand, high temperature and dark treatment suppressed anthocyanin accumulation.Furthermore, florescent light induced anthocyanin formation as compared with normal light and dark condition**{18}**.

Table 2: Effect of various applied treatments at postharvest during the two seasons 2014 and 2015 on coloration properties of "Kelsey "plums at the end of the shelf life period.

Treatments	Anthocyanin peel (mg/100 g)		Anthocyanin flesh (mg/100 g)		Chlorophyll a peel (mg/100 g)		Chlorophyll b peel (mg/100 g)		Carotene peel (mg/100 g)		Carotene flesh (µg/ g)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T1**	3.45d*	3.25d	2.58c	2.47c	1.94b	2.03b	1.61a	1.63b	0.324d	0.266d	11.24c	10.66b
T2	6.27c	6.08c	4.6a	4.29b	1.81bc	1.88b	1.55ab	1.54b	0.406cd	0.378b	11.53c	10.95b
T3	5.77c	5.05d	4.41ab	4.19b	1.86cd	1.65c	1.43bc	1.3c	0.49c	0.553b	16.59ab	15.53a
T4	11.38b	13.32b	3.85ab	4.92a	1.51de	1.47cd	1.26de	1.24c	0.722a	0.558b	18.86a	16.01a
T5	3.58d	3.39e	2.69c	2.58c	1.91b	1.98b	1.59a	1.62b	0.452c	0.435c	15.1b	14.04a
T6	3.58d	3.08e	2.99c	2.88c	2.17a	2.21a	1.6a	1.82a	0.467c	0.373c	16.67ab	15.19a
T7	4.73cd	6.07c	4.78a	4.88a	1.76bc	1.57c	1.39cd	1.33c	0.599b	0.562ab	16.06ab	15.48a
T8	16.35a	20.96a	4.53ab	5.05a	1.45e	1.37d	1.24e	1.18c	0.759a	0.645a	16.88ab	15.82a

*Values, within each column, of similar letter (s) are not significantly different according to the least significant difference (LSD) at 0.05 levels.

**Each packaged plum fruits was subjected to one of the following treatments: normal light and room temperature (T1), darkness and room temperature (T2), florescent light and room temperature (T3), darkness in refrigerator (4- 5°C) (T4), normal light and room temperature for oleic acid-treated fruits (T5), darkness and room temperature for oleic acid-treated fruits (T6), florescent light and room temperature for oleic acid-treated plums (T7), and finally darkness and refrigeration at (4- 5°C) for oleic acid-treated plums (T8). Four replications were used with each treatment.

Fig. 1: Effects of post-harvest treatments on coloration and ripening of plums after one week (T1: normal light and room temperature,T2: darkness and room temperature T3: florescent light and room temperature, T4: darkness in refrigerator (4- 5°C), T5: normal light and room temperature for oleic acid-treated fruits, T6: darkness and room temperature for oleic acid-treated fruits, T7: florescent light and room temperature for oleic acid-treated plums and finally T8: darkness and refrigeration at (4- 5°C) for oleic acid-treated plums).

3- Chemical characteristics of "Kelsey" plum fruit:

The data in Table 3 showed that plum fruits exposed to dark and room temperature and florescent light increased the total soluble solids and total sugars as compared with all other treatments in both seasons. On the other hand, plum fruits storage at low temperature and treated with oleic acid possessed highest acidity percentage. The above trend of results whether for TSS, acidity and total sugars were in agreement with the findings of **{6, 7}**.The data in Table 3 indicated that all treatments did not result in a significant change in ascorbic acid of plum fruits.

Table 3: Effect of various applied treatments at postharvest during the two seasons 2014 and 2015 on chemical properties of "Kelsey" plums at the end of the shelf life period.

Treatments	TSS%		Acidity %		TSS/Acidity %		Total Sugars %		L-Ascorbic acid (mg/100 g)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T1**	15.55b*	12.6de	1.61c	1.81c	9.76cd	6.97bc	8.71b	7.88ed	1.86a	1.65b
T2	16.95a	13.58b	1.73a	1.99a	9.8bcd	6.82bc	9.5a	8.48b	1.92a	1.78a
T3	17.13a	14.48a	1.65b	1.88b	10.37ab	7.72a	9.69a	9.05a	1.97a	1.69ab
T4	15.63b	12.23e	1.61bc	1.82bc	9.68cd	6.72c	8.75b	7.64e	1.97a	1.69ab
T5	15.6b	13.5bc	1.79a	1.95a	9.17d	6.93bc	8.73b	8.44bc	1.97a	1.74ab
T6	15.5b	12.08e	1.56d	1.74d	9.93bc	6.95bc	8.68b	7.55e	1.86a	1.69ab
T7	15.9b	12.9cd	1.58cd	1.78cd	10.06bc	7.25b	8.9b	8.06cd	1.97a	1.74ab
T8	15.93b	12.93de	1.47e	1.61e	10.8a	7.79a	8.92b	7.83de	1.92a	1.69ab

*Values, within each column, of similar letter (s) are not significantly different according to the least significant difference (LSD) at 0.05 levels.

**Each packaged plum fruits was subjected to one of the following treatments: normal light and room temperature (T1), darkness and room temperature (T2), florescent light and room temperature (T3), darkness in refrigerator (4- 5°C) (T4), normal light and room temperature for oleic acid-treated fruits (T5), darkness and room temperature for oleic acid-treated fruits (T6), florescent light and room temperature for oleic acid-treated plums (T7), and finally darkness and refrigeration at (4- 5°C) for oleic acid-treated plums (T8). Four replications were used with each treatment.

Conclusion

It could be concluded that "Kelsey" plums treated with oleic acid packaged in plastic polyethylene bags and stored under refrigerated conditions (4- 5°C) for one week had an enhanced coloration, quality and shelf life in a remarkable appearance which indicates to the feasibility of such treatment on a commercial scale.

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