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RETENTION OF COLORED-MATURE GREEN LEMONS BY POSTHARVEST-SAFE NATURAL TREATMENTS

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ABSTRACT: Since the retention of mature green lemons has been required in the American and some European markets, this study was conducted during 2017 and 2018 seasons to prolong it in "Eureka" lemon rind by some postharvest treatments that are safe and natural. Fruits were treated by dipping then stored at either 4-5 °C in the refrigerator or at ambient temperature (22±2°C), following cleaning, surface sterilization, and air drying. Fruits were kept in foam plates and covered with polyethylene. The treatments included oleic acid (at 400 ppm), lysophosphatidylethanolamine (400 ppm) (LPE), putrescine (176.30 ppm) and their combinations in addition to the control. The data revealed that the combination of oleic acid plus LPE at cold storage resulted in the best green color retention of the rind while increasing quality in terms of preserving TSS, acidity and greater ascorbic acid. Such applications are valuable and could be adopted on a commercial scale.

Key words: Eureka lemon, oleic acid, lysophosphatidylethanolamine, putrescine, postharvest, storage.

INTRODUCTION

Eureka lemon (*Citrus limon* L. Burm) is one of the most important cultivars mainly due to its high contents of antioxidants, vitamins in addition to its nutritional value.

Egypt has been self-sufficient in lemon production and did not need to import lemons or limes, as the total exports of lemon amounted to 96,207 tonnes according to FAO statistics through 2019.

On the other hand, there were many other countries that were importing large amounts of lemon, for example, the United States of America, whose imports were 793405 tonnes according to FAO statistics through 2019. Consumers demand the mature green fruit in the USA market and some European countries.

Delaying ripening of lemon fruits ensures the arrival of the fruits and their continuation in the markets in excellent conditions to prevent their decay as long as possible. The retention of green color of lemons peel throughout the postharvest life is necessary for fruits to get best prices **(Pranmornkith *et al.*, 2005).** Moreover, the mature green lemons are less susceptible to fruit flies in the field, this result agreed with **(Rattanapun *et al.*, 2009).**

Changes in external color of rind are influenced by environmental conditions, nutrient availability, and some phytohormones **(Iglesias *et al.*, 2001).**

There has been a lack of more research attempts in this area. Various studies have attempted to retain peel green color by using antiethylene compounds such as 1-methylcyclopropene **(Win *et al.*, 2006)**, UV-B treatments **(Kaewsuksaeng *et al.*, 2011; Srilaong *et al.*, 2011)**, lignin extracts **(Jonglertjunya *et al.*, 2014)** and heat treatments **(Kaewsuksaeng *et al.*, 2015; Opio *et al.*, 2017).**

Porat *et al.* (2001) illustrated that low temperature storage and gibberellic acid applications were required for retention of green color or reduction of chlorophyll loss, but under certain conditions in citrus, gibberellins and cytokinins may promote regreening **(Lewis, 1982)**.

Previous studies on how endogenous polyamines work in *Citrus* have been limited, and most studies focused on different factors such as chilling injury (CI). Application of putrescine exogenously in mango significantly inhibited ethylene production, which resulted in reducing yellow coloration.

Kusano *et al.* (2007) found that increased ethylene production was associated with a decrease in the content of polyamine and vice versa.

Lysophosphatidylethanolamine (LPE) is relatively new plant growth regulator that was reported to retard leaf senescence, inhibited polygalacturonase activity **(Farag and Palta, 1993 and Hong, 2008),** reduced the defoliation action of Ethrel and delayed senescence of leaf and fruits in cranberry and plum **(Ozgen *et al*., 2005; Farag and Attia, 2016)**.

Many previous studies reported that both "pre- and postharvest" applications with lysophosphatidylethanolamine (LPE) delayed aging and enhanced the shelf life of different fruits **(Ahmed and Palta, 2011).**

Furthermore, it was found that LPE inhibited the activity of phospholipase D (PLD), which has been known to increase during plant senescence period **(Ryu *et al.*, 1997).**

Maxfield and Tabas (2005) proved that oleic acid affects fruit firmness by changing cellular membrane properties, such as fluidity, rigidity membrane permeability.

Thus, the objectives of this study were:

1- To extend the duration of the green skins of mature lemons to meet the demand of the consumers especially in the American market and some European countries.

2- To preserve the juice quality and some chemical characteristics of treated lemons to keep the high demand of consumers.

3- To provide the growers with a safe-treatment regime that is feasible and could be adopted on a large scale.

MATERIAL AND METHOD

Plant material

The present study was performed during the two successive seasons 2017 and 2018. Eureka lemon (*Citrus limon* [L.] Burm. f. cv Eureka) fruits were harvested (448 fruits, 64 fruits/ treat., 8 fruits/ rep.) from a private orchard located in Badr District, Beheira governorate, Egypt from mature trees and free of physiological disorders or visible pathological problems as possible. Fruits were carefully transferred to the laboratory, completely washed then surface sterilized with sodium hypochlorite (NaClO) at 0.05% (v/v) for 3 min, rinsed quickly again in water then left for air drying before the treatments. Treatments were conducted on October in both seasons at the mature green stage of lemons. Fruits were divided into 8 replicates for every treatment (4 replicates were stored at ambient temperature 22±2°C, while the other four replicates were stored in refrigerator at 4-5°C) before implementing the treatments. A preliminary sample (initial) was analyzed to estimate the state of the fruits.

Experimental procedure

Seven treatments were conducted on lemon, for both seasons, these treatments included:

1- Control (distilled water).

2- Oleic Acid (400 ppm).

3- Lysophosphatidylethanolamine - LPE (400 ppm).

4- Putrescine (176.30 ppm).

5- Oleic Acid (400 ppm) + LPE (400 ppm).

6- Oleic Acid (400 ppm) + putrescine (176.30 ppm).

7- LPE (400 ppm) + putrescine (176.30 ppm).

The surfactant (Tween 20) at a concentration of 0.05% v/v was used, in order to reduce tension and the contact angle with the surface of the fruits. Fruits of each treatment were dipped for 20 minutes then kept in the laboratory. After air drying, they were arranged in foam plates and stored either in the refrigerator (4-5°C) or at ambient temperature (22±2°C). Fruits were assessed for various quality parameters either after one week or three weeks later. The provided data in this study focused on:

Chemical characteristics

In the juice, the percentage of TSS was measured by using a hand refractometer, total acidity content as citric acid (dominant acid in lemon fruits) was determined by titration with 0.1 NaOH according to **A.O.A.C. (2006)** and the TSS/ acidity ratio was estimated. Moreover, content of L-ascorbic acid was determined as follow: 5 milliliters (ml) of Eureka lemon juice was diluted with 5 ml of acid solution, and the solution was titrated with 2, 6-dichloroindophenol dye to light pink color end point according to **A.O.A.C. (2006)** Furthermore, chlorophylls a, b and Beta-carotene in the peel were determined according to **Lichtenthaler and Wellburn (1985)**, aforementioned by **Manuela *et al.* (2012).** as follow: 0.5 g of fresh peel was extracted by 15 ml of 85% acetone and 0.5g calcium carbonate, the mixture was filtered through a glass funnel and the residue was washed with a small volume of acetone and completed to 25 ml. the optical density of a constant volume of filtrate was measured at wave length of 470 nm using spectrophotometer for (Beta-carotene) for chlorophyll at (662 nm) and chlorophyll b (645 nm). Knowing that, samples of each extract were placed in cuvettes and readings were taken when the figure in the display window became steady.

Statistical Analysis

The data of this study was designed out as split-split plot analysis in Completely Randomized Design (CRD) where types of storage represented as the main factor, seven dipping treatments as the sub plot factor and durations of storage were devoted as the sub-sub

plot factor. The analysis was done by using Costat program version 6.4 **(Costat, 2008)**. The means regardless of durations of storage were compared according to the least significant difference (LSD) at 0.05 levels.

RESULTS

Total soluble solid content

The response of "Eureka" lemon juice content of total soluble solid (TSS) in relation to applied treatments, the used types of storage and their interaction was reported in **Table (1)**. The data indicated that all treated lemons had significantly lower TSS than the control in both seasons. The lowest TSS values in the two seasons were obtained with the application of oleic acid plus LPE. Meanwhile, it did not make a significant difference to store at ambient temperature or in the cold with such regime since the difference between the two types of storage was not significant, regardless the used treatment. Moreover, the interaction between treatments and the storage type revealed that the control lemons had greater TSS at ambient temperature or at cold storage than all treated fruits in both seasons.

Table 1. Effect of some postharvest applied treatments, the types of storage and their interaction on total soluble solid content of "Eureka" lemons during the two successive seasons (2017-2018)

Total soluble solid content (Brix)						
Season 2017				**Season 2018**		
Treatments	**Types of storage**		**Mean**	**Types of storage**		**Mean**
	Ambient temperature	**Cold storage**		**Ambient temperature**	**Cold storage**	
Control	11.63 a*	11.39 ab	11.51 a**	10.43 ab	10.70 a	10.57 a
Oleic Acid (400 ppm)	11.02 cd	10.91 d	10.97 d	9.92 abcd	9.75 bcd	9.83 cd
LPE (400 ppm)	11.11 bcd	11.09 bcd	11.10 bcd	9.94 abcd	9.75 bcd	9.85 cd
Putrescine (176.30 ppm)	11.10 bcd	11.08 bcd	11.09 cd	9.85 bcd	9.54 cd	9.70 d
Oleic Acid (400 ppm +LPE (400 ppm)	10.94 cd	10.31 e	10.62 e	9.39 d	9.47 cd	9.43 e
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	11.16 bcd	11.13 bcd	11.15 bc	10.07 abcd	9.84 bcd	9.95 c
LPE (400 ppm) + Putrescine (176.30 ppm)	11.24 bc	11.25 bc	11.24 b	10.20 abc	10.25 abc	10.23 b
Mean	11.17 a***	11.02 a	-	9.97 a	9.90 a	-

* Values, within a year, of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.
** Means of treatments having similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.
*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Total acidity

The effect of some postharvest treatments, the types of storage and their interaction on total acidity of "Eureka" lemons during 2017 and 2018 seasons was reported in **Table (2)**. The data indicated that regardless the type of storage, there was a significant increase in juice acidity in fruits treated with oleic acid plus LPE as compared with the control. In general, most-treated fruits had greater acidity than the control in both seasons except LPE plus putrescine in the first season that resulted in similar acidity to that found in the control. With regard to the used-storage type, the data revealed that lemons stored in the cold following their treatments had lower juice acidity as compared with ambient temperature-stored fruits **(Table 2).**

Table 2. Effect of some postharvest applied treatments, the types of storage and their interaction on total acidity content of "Eureka" lemons during the two successive seasons (2017-2018)

Total acidity content (g/100 ml juice)						
	Season 2017			Season 2018		
Treatments	Types of storage		Mean	Types of storage		Mean
	Ambient temperature	Cold storage		Ambient temperature	Cold storage	
Control	6.69 d*	6.20 e	6.44 c**	6.69 abcd	6.15 d	6.42 e
Oleic Acid (400 ppm)	7.25 a	6.95 bcd	7.10 b	7.32 ab	6.87 abcd	7.10 b
Lisophos (400 ppm)	7.35 a	6.86 d	7.11 b	7.41 a	6.62 bcd	7.02 bc
Putrescine (176.30 ppm)	7.27 a	6.91 cd	7.09 b	7.30 ab	6.68 abcd	6.99 c
Oleic Acid (400 ppm) +Lisophos (400 ppm)	7.42 a	7.17 abc	7.30 a	7.46 a	7.13 abc	7.30 a
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	7.22 ab	6.86 d	7.04 b	7.07 abc	6.89 abcd	6.98 c
Lisophos (400 ppm) + Putrescine (176.30 ppm)	6.80 d	6.31 e	6.56 c	6.80 abcd	6.35 cd	6.57 d
Mean	7.14 a***	6.75 b	-	7.15 a	6.67 b	-

* Values, within a year, of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.
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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

TSS/acidity ratio

The effect of different treatments, the used types of storage and their interaction on TSS/acidity ratio of "Eureka" lemons during 2017 and 2018 seasons was presented in **Table (3)**. Data indicated that all treated lemons had significant lower TSS/acidity ratio than control in both seasons, regardless the type of storage. In general, the data revealed that oleic acid at 400 ppm plus LPE at 400 ppm treatment resulted in the lowest value in both seasons while the highest values of TSS/acidity were obtained with the control. Meanwhile, there was no significant difference between the treatment values of oleic acid alone, LPE or putrescine in both seasons.

Meanwhile, there was a significant difference between storage at ambient temperature and cold storage where the values of TSS/acidity at ambient temperature storage were lower than in cold storage, regardless the used treatments.

In addition, the interaction between treatments and the storage type revealed that values of TSS/acidity ratio in second season were lower than first season but had the same trend. The control lemons had greater TSS/acidity ratio at cold storage as compared with all treated fruits at ambient temperature in both seasons except LPE plus putrescine in the first season that resulted in similar TSS/acidity ratio to that found in the control.

L-ascorbic acid content

The changes in content of L-ascorbic acid as affected by some postharvest treatments, the storage type and their interaction on treated "Eureka" lemon juice during 2017 and 2018 seasons were shown in **Table (4)**. The data indicated that the highest values of L-ascorbic acid content were found with lemons treated with LPE at 400 ppm alone then oleic acid alone or when combined with LPE then putrescine alone, such treatments were effective on increasing L-ascorbic acid content as compared with control in both seasons. The lowest reduction of L-ascorbic acid in both seasons was obtained with the control regardless to the impact of storage types. On the other hand, the L-ascorbic acid was not affected by the storage type, whether at ambient temperature or cold storage, regardless the effect of the treatments.

Moreover, with regard to the interaction between the effect of the treatments and the effect of the storage type on the L-ascorbic acid content in the "Eureka" lemon fruits, LPE treatment gave the highest L-ascorbic acid content wither at ambient temperature or cold storage in both seasons.

Table 3. Effect of some postharvest applied treatments, the types of storage and their interaction on TSS/acidity ratio of "Eureka" lemons during the two successive seasons (2017-2018)

TSS/acidity ratio						
	Season 2017			Season 2018		
Treatments	Types of storage		Mean	Types of storage		Mean
	Ambient temperature	Cold storage		Ambient temperature	Cold storage	
Control	1.747 abc*	1.876 a	1.811 a**	1.571 c	1.799 a	1.685 a
Oleic Acid (400 ppm)	1.514 bcd	1.571 bcd	1.543 d	1.353 g	1.429 f	1.391 d
Lisophos (400 ppm)	1.506 bcd	1.619 abcd	1.563 cd	1.337 g	1.481 de	1.409 cd
Putrescine (176.30 ppm)	1.507 cd	1.603 abcd	1.555 cd	1.350 g	1.436 ef	1.393 d
Oleic Acid (400 ppm) +Lisophos (400 ppm)	1.468 cd	1.439 d	1.454 e	1.255 h	1.331 g	1.293 e
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	1.542 bcd	1.623 abcd	1.582 c	1.434 ef	1.434 ef	1.434 c
Lisophos (400 ppm) + Putrescine (176.30 ppm)	1.653 abcd	1.809 ab	1.731 b	1.51 d	1.648 b	1.579 b
Mean	1.562 b***	1.648 a	-	1.401 b	1.508 a	-

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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Table 4. Effect of some postharvest applied treatments, the types of storage and their interaction on L-ascorbic acid content of "Eureka" lemons during the two successive seasons (2017-2018)

L-ascorbic acid content (mg/100 ml juice)						
	Season 2017			Season 2018		
Treatments	Types of storage		Mean	Types of storage		Mean
	Ambient temperature	Cold storage		Ambient temperature	Cold storage	
Control	46.67 gh*	46.36 h	46.52 d**	47.95 ef	47.70 f	47.83 d
Oleic Acid (400 ppm)	48.39 abc	47.69 cdef	48.04 b	49.59 c	49.28 cd	49.43 b
Lisophos (400 ppm)	49.05 a	49.08 a	49.06 a	50.42 ab	50.51 a	50.46 a
Putrescine (176.30 ppm)	47.81 bcde	47.19 efg	47.50 bc	49.27 cd	48.61 de	48.94 bc
Oleic Acid (400 ppm) +Lisophos (400 ppm)	48.49 ab	48.02 bcd	48.26 b	49.78 bc	49.39 c	49.59 b
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	47.33 defg	47.10 efg	47.22 cd	48.56 e	48.44 e	48.50 cd
Lisophos (400 ppm) + Putrescine (176.30 ppm)	46.76 gh	46.98 fgh	46.87 cd	48.51 e	48.38 ef	48.44 cd
Mean	47.79 a***	47.49 a	-	49.15 a	48.90 a	-

* Values, within a year, of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.

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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Chlorophyll A content

The influence of various postharvest treatments, the type of storage and their interaction on the chlorophyll A content of "Eureka" lemons was reported in **Table (5)**. The data indicated that "Eureka" lemons had significant increase in chlorophyll A content in response to all applied postharvest treatments as compared with control during the two seasons. However, the application of oleic acid at 400 ppm plus LPE at 400 ppm was able to cause the highest value of chlorophyll A content, followed by oleic acid at 400 ppm alone and putrescine at 176.30 ppm alone that were equally effective during the two seasons regardless the types of storage.

Furthermore, the results in **Table (5)** also indicate that there was a significant difference between the types of used storage, treated lemons had greater chlorophyll A content when stored in the cold as compared with ambient temperature storage in both seasons.

The interaction between treatments and types of storage **(Table 5)** also revealed that there were significant differences between the two used types of storage, since the highest values of chlorophyll A content were obtained with oleic acid at 400 ppm mixed with LPE at 400 ppm in cold storage. Meanwhile, the lowest values were recorded with the control in both types of storage in both seasons.

Chlorophyll B content

The effect of postharvest treatments, the storage types and their interaction on chlorophyll B content during 2017 and 2018 seasons was reported in **Table (6)**, regardless the storage durations factor. The data revealed that all treatments caused a significant increase in chlorophyll B content as compared with the control with exception of LPE at 400 ppm mixed with putrescine at 176.30 ppm which had non-significant differences than the control in both seasons. The highest value was obtained with oleic acid (400 ppm) mixed with LPE (400 ppm) compared to control and LPE (400 ppm) mixed with putrescine (176.30 ppm) which had lowest values of chlorophyll B content regardless of types of storage in both seasons. As for the effect of the storage types on the chlorophyll B content, it was found that the cold-stored lemons had higher content of chlorophyll B than those stored at the ambient temperature in both seasons, regardless of the effect of the treatments.

As for the interaction between the post-harvest treatments and the storage types, it was evident that chlorophyll B values in cold stored lemons were higher than those stored at ambient temperature. The highest value of chlorophyll B was recorded in cold storage with oleic acid (400 ppm) mixed with (LPE 400 ppm), and the lowest value was recorded at ambient temperature in the control, as there was no significant difference between it and the treatment of LPE (400 ppm) mixed with putrescine (176.30 ppm).

β-carotene content

The response of lemons β-carotene content in the rind during different types of storage and their interaction was reported in **Table (7)**. The data mentioned that all treated "Eureka" lemons had lower β-carotene content than the control regardless the storage types in both seasons. The lowest value of β-carotene content was obtained with oleic acid at (400 ppm) mixed with LPE 400 ppm which corresponded with the highest values of chlorophyll a and b then oleic acid (400 ppm) alone and putrescine (176.30 ppm) alone as compared with the control in both seasons. Meanwhile, the value of β-carotene content at cold storage lemons was less than its value at ambient temperature, regardless of post-harvest treatments.

Table 5. Effect of some postharvest applied treatments, the types of storage and their interaction on chlorophyll A content of "Eureka" lemons during the two successive seasons (2017-2018)

Chlorophyll A content (mg/100 g)						
	Season 2017			Season 2018		
Treatments	Types of storage		Mean	Types of storage		Mean
	Ambient temperature	Cold storage		Ambient temperature	Cold storage	
Control	0.986 f*	1.073 ef	1.030 e**	0.975 f	1.103 e	1.039 e
Oleic Acid (400 ppm)	1.165 cde	1.330 b	1.248 b	1.167 cde	1.369 b	1.268 b
Lisophos (400 ppm)	1.131 de	1.184 cd	1.158 c	1.133 de	1.213 cd	1.173 c
Putrescine (176.30 ppm)	1.154 cde	1.318 b	1.236 b	1.165 cde	1.362 b	1.264 b
Oleic Acid (400 ppm) + Lisophos (400 ppm)	1.247 bc	1.464 a	1.356 a	1.251 c	1.490 a	1.370 a
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	1.119 de	1.172 cd	1.146 c	1.127 de	1.209 cd	1.168 c
Lisophos (400 ppm) + Putrescine (176.30 ppm)	0.998 f	1.111 de	1.055 d	1.003 f	1.141 de	1.072 d
Mean	1.114 b***	1.236 a	-	1.117 b	1.269 a	-

* Values, within a year, of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.
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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Table 6. Effect of some postharvest applied treatments, the types of storage and their interaction on chlorophyll B content of "Eureka" lemons during the two successive seasons (2017-2018)

Chlorophyll B content (mg/100 g)						
	Season 2017			Season 2018		
Treatments	Types of storage		Mean	Types of storage		Means
	Ambient temperature	Cold storage		Ambient temperature	Cold storage	
Control	0.820 f*	0.953 bcd	0.886 f**	0.824 e	0.911 cd	0.867 f
Oleic Acid (400 ppm)	0.944 cd	1.046 b	0.995 b	0.944 cd	1.099 b	1.021 b
Lisophos (400 ppm)	0.924 de	0.966 bcd	0.945 d	0.928 cd	0.980 c	0.954 d
Putrescine (176.30 ppm)	0.928 d	1.032 bc	0.980 c	0.929 cd	1.060 b	0.994 c
Oleic Acid (400 ppm) +Lisophos (400 ppm)	0.972 bcd	1.200 a	1.086 a	0.974 c	1.224 a	1.099 a
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	0.950 bcd	0.904 def	0.927 e	0.881 de	0.923 cd	0.902 e
Lisophos (400 ppm) + Putrescine (176.30 ppm)	0.828 ef	0.951 bcd	0.889 f	0.829 e	0.917 cd	0.873 f
Mean	0.909 b***	1.008 a	-	0.901 b	1.016 a	-

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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

Table 7. Effect of some postharvest applied treatments, the types of storage and their interaction on β-carotene content of "Eureka" lemons during the two successive seasons (2017-2018)

β- carotene content (mg/100 g)						
Season 2017				**Season 2018**		
Treatments	**Types of storage**		**Mean**	**Types of storage**		**Mean**
	Ambient temperature	**Cold storage**		**Ambient temperature**	**Cold storage**	
Control	1.508 a*	0.953 c	1.231 a**	1.504 a	0.914 c	1.209 a
Oleic Acid (400 ppm)	0.627 f	0.487 g	0.557 e	0.633 ef	0.457 hi	0.545 e
Lisophos (400 ppm)	0.746 de	0.520 g	0.633 d	0.745 d	0.483 h	0.614 d
Putrescine (176.30 ppm)	0.672 ef	0.432 g	0.552 e	0.700 de	0.393 ij	0.547 e
Oleic Acid (400 ppm) +Lisophos (400 ppm)	0.442 gh	0.369 h	0.405 f	0.506 gh	0.332 j	0.419 f
Oleic Acid (400 ppm) + Putrescine (176.30 ppm)	0.772 d	0.605 f	0.689 c	0.770 d	0.567 fg	0.668 c
Lisophos (400 ppm) + Putrescine (176.30 ppm)	1.245 b	0.895 c	1.070 b	1.424 b	0.858 c	1.141 b
Mean	0.859 a***	0.608 b	-	0.897 a	0.572 b	-

* Values, within a year, of similar letters are not significantly different according to the least significant difference (LSD) at 0.05 levels.
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*** Means of types of storage having similar letter are not significantly different according to the least significant difference (LSD) at 0.05 levels.

DISCUSSION

Since the retention of green color in treated "Eureka" lemons is one of the main objectives of this study, it was logic to focus on the use of some safe and natural compounds that retard senescence such as lisophos and oleic acid. The effect of lisophos on delaying leaf and fruit senescence was recently discovered **(Farag and Palta, 1993, Farag *et al.*, 2003 and 2005)**.

Most research studies took the changes in chlorophylls as an evidence for the progress toward senescence **(Barry, 2009; Yin *et al*., 2016).** Recently, it was also found that oleic acid was able to retard senescence whether alone or when combined with ethephon **(Farag and Attia, 2016).** Furthermore, it was reported that citrus rind at maturity could behave like a climacteric tissue while the pulp of citrus fruit is non-climacteric. Thus, it was critical to treat "Eureka" lemon with LPE at 400 ppm since previous work proved that the response of fruits to lysophospho lipid, namely lysophosphatidylethanolamine (LPE or Lisophos) has proved to be a concentration dependent **(Ryu *et al.*, 1997).**

Aforementioned trends have been supported by the finding that LPE was able to cause a specific inhibition to the activity of phospholipase D (PLD), the enzyme involved in the progress of tissue senescence **(Ryu *et al.*, 1997; Wang, 2001, 2002),** which explained the green color retention of "Eureka" lemon fruits**.** Thus, many reported parameters, in this study, were in agreement with the above trends.

It was well documented that the treatments that retard tissue senescence were also able to inhibit the destruction of chlorophylls whether A or B **(Farag *et al*., 1992; Ozgen *et al*., 1999; Ozgen and Palta, 2003; Farag *et al*., 2005; Maxfield and Tabas, 2005).**

On the other hand, putrescine, as one of the polyamines, acts against the effects of ethylene. Even the deviation from the natural biosynthesis of ethylene at the step of S-adenosyl methionine to ACC results in the formation of putrescine, which was effective on reducing the damage **(Barman *et al*., 2011 and Yang *et al*., 2016).**

No wonder, to find a delay of peel senescence of "Eureka" lemons by the application of putrescine alone or in combination with oleic acid or with LPE in a consistent manner in both seasons.

It was very important to emphasize the significance of the applied treatments after harvest since they are natural compounds and acceptable in the world market or the environmental protection agency.

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