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Preharvest Treatments to Enhance "Keitt" Mangoes Ripening and to Extend Their Shelf Life

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Abstract: Mango fruit growers and producers have been facing many major problems that influence the yield, quality and shelf life. In this study, a new approach was followed to achieve the balance between reducing fruit abscission, improving fruit quality especially coloration while enhancing the harvested mangoes shelf life. This research was carried out in a private orchard at Wady El- Natroun region, Beheira governorate, Egypt using "Keitt" mango trees during the two successive seasons 2016 and 2017. In addition to the control (water spray), eight more treatments were used which included: lysophosphatidylethanolamine (LPE) at 400 or 800 ppm, Ethrel at either 50 or 100 ppm and the combinations of these concentrations of LPE preceded Ethrel. In case of spraying various combinations, LPE spray preceded Ethrel spray by 2 hours. With all treatments, the surfactant Tween- 20 was added at 0.05% (v / v) and the spray was done by using a hand sprayer to the run off point. At harvest, the results revealed that LPE whether at 400 or 800 ppm was able to mitigate the adverse effect of Ethrel (at 50 or 100 ppm) on fruit abscission as compared with the sole application of Ethrel. In a similar manner, the shelf life assessment proved that weight loss was significantly reduced by the combined application of LPE followed by Ethrel at all used concentrations when compared with Ethrel alone. In addition, the combination treatments especially LPE at 800 followed by Ethrel at 50 ppm were able to retard the loss of pulp firmness. Meanwhile, carotene contents in the pulp and peel (skin) were significantly increased by Ethrel concentrations alone and by the combinations of LPE (at 800 ppm) preceded Ethrel at 50 or 100 ppm in both seasons. The least electrolyte leakage was obtained with the same above combinations while the greatest electrolyte leakage was obtained with the individual application of Ethrel at 50 or 100 ppm in both seasons. The outcomes of this study recommend spraying "Keitt" mango with a combination that included LPE at 800 ppm followed by Ethrel 50 ppm to overcome many production problems and to prolong the shelf life of fruits.

Key words: Mangoes · Keitt · Abscission · Coloration · Ripening · Quality · Shelf life · LPE · Ethrel

INTRODUCTION

The mango (*Mangifera indica* L.) is one of the demanded and highly favored fruits in the developing countries of the tropic and sub- tropical regions as well as by the Egyptian consumers. Mango cultivars vary in their aroma and intensity of pulp and peel coloration. Thus, variations of taste and perishability have been influencing the acceptance of several mango cultivars over the others. Controlling fruit ripening before harvest has been a main concern of mango growers and producers. Delaying fruit ripening to allow for long distance shipping and transport is hindered by the high susceptibility to fruit diseases and to physiological disorders. Thus, postharvest technologies are designed for disease control and protection against injuries resulting from packaging and transport in addition to the sensitivity to chilling stress.

No wonder, it is found in India, the main producer of the largest mango volume in the world, mango export is largely in the processed form as juice, puree, slices, or pickles.

On the other hand, in spite of the endocarp hardening, the fruit follows a single sigmoid growth curve with a climacteric pattern [1]. However, the reported increase in ethylene production prior to full maturity on the tree was followed by a decline again, ten days later and was not associated with a rise in respiration [2]. It was

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reported by Burg and Burg [3] that mature but unripe mangoes had high ethylene levels even while attached to the tree. It was suggested that this ethylene is rendered ineffective by a ripening inhibitor from parent plant. This idea of the ripening inhibitor was consistent with the stimulation of respiration observed after detachment in mangoes harvested in different stages during maturation [1, 4]. Moreover, Lakshminarayana [4] further observed an earlier onset of the climacteric peak as they matured beyond the ninth week after fruit set.

Aforementioned, many attempts have tried to induce or stimulate mango fruit ripening. Preharvest spray of the ethylene- releasing compound, namely Ethrel, was reported to cause leaf and fruit abscission while adversely affects mangoes shelf life and storability [5]. Furthermore, the sprinkling of mango fruits with calcium carbide powder or crystals to ripen them quickly is very hazardous since calcium carbide is carcinogenic [6]. Meanwhile, Alar or B- 9 (succinic acid 2, 2 dimethyl hydrazide) which has been used for some time to enhance peel color of fruit and to prolong its storability was banned to use due to the possibility to cause cancer.

A common practice especially in many developing countries and in many Egyptian farms, is harvesting fully mature mangoes, then exposing them to higher temperature by covering fruits with straw or a piece of cotton cloths. This process stimulates the ripening changes especially the conversion of starch to sugars. The starch hydrolysis with the increase in amylase activity results in a complete disappearance of starch granules in the ripe fruits [7, 8]. However, juice acidity decreases due to the stimulation of the process of gluconeogenesis (conversion of some acids to sugars) which impairs the balance between sugars and acids.

In addition, many undesired effects were reported to artificially ripened mango fruits such as, the lack of the natural fresh aroma, the smooth skin, the outer yellow coloration while the inside tissues stay green, formation of patches of green color on the yellow skin and the loss of juicy fruit tissue. Since lysophosphatidylethanolamine (LPE) or lisophos, as the commercial name, is a natural compound and was reported to enhance fruit coloration without accompanied softening and to mitigate the loss of firmness and delay tissue senescence. This compound has been utilized to reduce fruit abscission of many fruits and to inhibit cell wall degrading enzymes [9, 10].

Thus, the objectives of this study were to mitigate the damaging effects of Ethrel on mangoes by various concentrations of LPE, to further stimulate mangoes color and quality, to extend the shelf life of preharvest- treated fruits and to assess the possibility of synergism between LPE and Ethrel under field conditions.

MATERIALS AND METHODS

This study was conducted during the two consecutive seasons 2016 and 2017 on "Keitt" mango trees grown in a private orchard at Wady El- Natroun region, Beheira governorate, Egypt. Trees were five years old, grafted on “Sukkary” rootstock, uniform, healthy, grown in a sandy soil, spaced at 6 x 6 m and received common horticulture practices. Twenty seven mango trees were selected for implementing the investigation treatments (nine treatments) and each three of these trees (replicates) were exposed to the same treatment and were separately sprayed to the run off using a hand sprayer on 19 of August during 2016 and 2017, seasons (at the mature stage) with one of the following solutions:- Control (water); lysophosphatidylethanolamine (LPE) at 400 ppm; LPE at 800 ppm; Ethrel at 50 ppm; Ethrel at 100 ppm; LPE at 400 ppm plus Ethrel at 50 ppm; LPE at 400 ppm plus Ethrel at 100 ppm; LPE at 800 ppm plus Ethrel at 50 ppm and finally LPE at 800 ppm plus Ethrel at 100 ppm. In case of spraying various combinations, LPE sprays preceded Ethrel sprays by 2 hours. Tween- 20, as a surfactant agent with 0.05%, was added to all these solutions.

Fruits were counted on each tree at spraying and harvest dates which were on 19 and 30 August, respectively for the two successive seasons and the percentage of fruit drop in response to applied treatments was calculated as follows:

$$\text{Fruit drop (\%)} = \frac{\text{Total No. of fruits at spraying} - \text{No. of fruits at harvest}}{\text{Total No. of fruits at spraying}} \times 100$$

Moreover, fruit weight was also determined.

The data of fruit drop and fruit weight, as the first part of this study, was arranged in a randomized complete blocks design (RCBD) with three replicates.

The second part of the same study was concerned with the effect of sprayed treatments and storage at room temperature (22 °C ± 2) on fruit characteristics.

Two representative samples of various treatments were collected from the experimental trees for the assessment of fruit quality. Each sample consisted of 81 fruits (3 fruits in each replicate, one tree represented one replication and each treatment consisted of three replicates) and the first sample was subjected to the analyses at harvest. In addition, the second sample (another 81 fruits) was used for the shelf life test. Then, these mango fruits were washed with running tap water, dipped for 2 minutes in sodium hypochloride

solution (0.05% v/v) for a surface sterilization, washed again in distillated water for 3 minutes and then air dried. The treated mango fruits were detected for their initial weight (gm), packed in foam dishes with 3 fruits per dish (replicate) and then left on the shelf at ambient temperature (nearly 22 °C ± 2) for 7 days. Quality assessments included weight loss which was calculated as a percentage of the initial weight according to Ghoname [11] and pulp firmness was measured by a hand Magness Taylor pressure tester (Ib/ in^2) and the values were converted into Newton unit.

Moreover, the percentage of electrolyte leakage of fruit peel was calculated as percentage of electrolyte leakage values of fresh then total electrolyte content (before and after killing) according to the method of Ahrenes and Ingram [12].Vitamin C was determined as mg ascorbic acid per 100 ml juice using the technique of A.O.A.C. [13]. Furthermore, the percentage of total sugars was assessed by using the procedure of Egan *et al.* [14]. The percentage of total soluble solids was also detected by using a hand refractometer, the percentage of titratable acidity was measured as gm citric acid per 100 ml juice according to the method of A.O.A.C. [13] and their ratio (TSS/ acidity) was calculated.

In addition, anthocyanin pigment of mango fruit peel was extracted and calculated according to the method of Fuleki and Francis [15]. In the same way, carotene contents of peel and pulp, chlorophyll a and chlorophyll b contents of mango- fruit peel were extracted, calculated and recorded as mg / 100 gm according to Wintermans and Mots [16].

Finally, the data of the second part of this study was laid out as split plot analysis in randomized complete blocks design (RCBD) where nine spraying applications represented the main plot and two dates (initial and one week later) were devoted as the sub plot. The analysis was done by using Costat program version 6.4 [17]. The means were compared according to the least significant difference (LSD) at 0.05 level.

RESULTS AND DISCUSSION

The Effect of Treatments on Fruit Drop and Fruit Weight at Harvest: The effect of applied treatments on the percentage of "Keitt" mango fruit drop was reported in Table 1. There was a significant increase in fruit drop by the application of Ethrel at 50 or100 ppm while the combinations of Ethrel at either 50 or 100 ppm with LPE (lisophos) at 400 or 800 ppm mitigated the effect of Ethrel. There was actually no recorded abscission of fruits as a result of spraying LPE at 400 or 800 ppm. Moreover, the addition of LPE (800 ppm) to Ethrel at 50 or 100 ppm resulted in no abscission. The control- fruit abscission ranged between 20.00 to 23.00% in the two seasons. Less abscission of fruits was found with LPE (400 ppm) followed by Ethrel at 100 ppm (Table 1) when compared with the control in both seasons.

Fruit weight at harvest of "Keitt" mangoes, however, did not vary among various used treatments. This trend was consistent in both seasons (Table 1).

The Effect of Treatments, Time Factor and Their Interaction on on Fruit Physical Characteristics: The effect of various applied treatments before harvest on weight loss of "Keitt" mangoes after one week of harvest at ambient temperature was reported in Table 2. The data revealed that there was a significant increase in weight loss caused by both Ethrel concentrations (50 or 100 ppm) when each was applied individually. However, when LPE (400 ppm) preceded Ethrel at either 50 or 100 ppm, a significant reduction occurred in weight loss after such period of time on the shelf as compared to Ethrel alone. Moreover, when LPE

Table 1: Effect of the preharvest applied treatments on fruit drop percentage and weight of "Keitt" mango fruits during the two seasons 2016 and 2017.

	Fruit drop (%)		Fruit weight (gm)	
Treatments	2016	2017	2016	2017
Control	20.53 c*	23.32 c	750.00Ns**	776.67Ns
LPE (400ppm)	0.00 e	0.00 e	762.33	770.00
LPE (800ppm)	0.00 e	0.00 e	740.67	777.39
Ethrel(50ppm)	43.40 b	68.42 b	755.00	763.11
Ethrel(100ppm)	62.26 a	78.95 a	743.33	755.00
LPE (400ppm)followed by Ethrel (50ppm)	0.00 e	5.26 d	761.67	765.00
LPE (400ppm)followed by Ethrel (100ppm)	1.70 d	5.66 d	735.33	762.23
LPE (800ppm)followed by Ethrel (50ppm)	0.00 e	0.00 e	748.00	781.67
LPE (800ppm)followed by Ethrel (100ppm)	0.00 e	0.00 e	720.00	769.45

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

** Ns: - Non significant.

Table 2: Effect of the preharvest applied treatments, the time factor and their interaction on weight loss percentage and pulp firmness of "Keitt" mango fruits during the two seasons 2016 and 2017

	Season 2016			Season 2017		
Treatments	Initial	After 7 days	Mean	Initial	After 7 days	Mean
			Weight loss (%)			
Control	0.00 h*	14.31 f	7.16 e	0.00 h	16.26 e	8.13 d
LPE (400ppm)	0.00 h	10.55 g	5.28 f	0.00 h	9.00 f	4.50 e
LPE (800ppm)	0.00 h	10.13 g	5.07 f	0.00 h	8.21 g	4.11 f
Ethrel(50ppm)	0.00 h	37.11 a	18.55 a	0.00 h	33.81 b	16.91 b
Ethrel(100ppm)	0.00 h	35.00 b	17.50 b	0.00 h	36.45 a	18.23 a
LPE (400ppm)followed by Ethrel (50ppm)	0.00 h	19.64 c	9.82 c	0.00 h	19.55 d	9.78 c
LPE (400ppm)followed by Ethrel (100ppm)	0.00 h	19.92 c	9.96 c	0.00 h	20.14 c	10.07 c
LPE (800ppm)followed by Ethrel (50ppm)	0.00 h	15.66 d	7.83 d	0.00 h	16.00 e	8.00 d
LPE (800ppm)followed by Ethrel (100ppm)	0.00 h	15.09 e	7.55 d	0.00 h	16.00 e	8.00 d
Mean	0.00 b	19.71 a	_	0.00 b	19.49 a	_
			Pulp firmness (Newton)			
Control	23.57 a	18.89 e	21.23 a	24.01 a	19.63 d	21.82 a
LPE (400ppm)	22.68 b	18.34 e	20.51 b	22.24 b	18.23 e	20.23 b
LPE (800ppm)	23.12 ab	18.79 e	20.95ab	23.57 a	19.57 d	21.57 a
Ethrel(50ppm)	11.12 h	6.67 l	8.89 f	10.23 i	5.78 l	8.01 f
Ethrel(100ppm)	9.78 i	5.33 m	7.56 g	10.00 i	4.89 m	7.44 g
LPE (400ppm)followed by Ethrel (50ppm)	20.01 d	16.05 f	18.03 c	21.35 c	16.45 f	18.90 d
LPE (400ppm)followed by Ethrel (100ppm)	12.00 g	8.00 k	10.00 e	13.79 g	8.01 k	10.90 e
LPE (800ppm)followed by Ethrel (50ppm)	20.91c	16.05 f	18.48 c	21.79 bc	17.79 e	19.79 c
LPE (800ppm)followed by Ethrel (100ppm)	12.28 g	8.88 j	10.58 d	12.90 h	9.34 j	11.12 e
Mean	17.27 a	13.00 b	_	17.76 a	13.30 b	_

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

application at 800 ppm preceded the application of each Ethrel concentration (50 or 100 ppm), further- significant reduction occurred in weight loss as compared with LPE at 400 ppm. This was the general trend in both seasons.

Furthermore, the lowest weight loss of “Keitt” mangoes was occurred when fruits were treated before harvest with LPE alone at either 400 or 800 ppm in both seasons. Such reduction by the sole application of LPE was even less than that occurred in the control fruits and ranged between 4- 5% while in the control ranged between 7 to 8% in the two seasons. Thus, it was beneficial to precede the application of Ethrel to mango fruits on the tree under field conditions by the application of LPE alone especially at 800 ppm.

With regard to the effect of the time factor, it was obvious that weight loss was markedly increased after 7 days of storage at ambient temperature (22 ± 2 °C) compared to that recorded before storage, in both seasons (Table 2).

As for the effect of the interaction between various used treatments and the time factor, it was evident from the data in Table 2 that over one week of incubation at room temperature, LPE – individual treatment was able to halt the process of water loss while Ethrel treatments regardless the concentration caused a significant increase in water loss much more than the control in both seasons (Table 2). The advanced application of LPE at 400 or 800 ppm was able to alleviate the negative effect of Ethrel over time.

With regard to the influence of various applied treatments before harvest, the data in Table 2 showed that LPE at 800 ppm alone was able to delay the loss of “Keitt” firmness and gave equal firmness to that found in the control fruits. Meanwhile, LPE at 400 ppm was also able to retard the loss of firmness in a similar manner to that obtained with LPE at 800 ppm. Moreover, there was a significant reduction in flesh firmness by other treatments relative to the control. However, the most reduction in “Keitt” flesh firmness was found when Ethrel was applied alone whether at 50 or 100 ppm. Furthermore, when LPE at 400 or 800 ppm preceded Ethrel treatments, each concentration of LPE was able to alleviate the adverse effect of Ethrel on flesh firmness in a consistent manner in both seasons. Such influence on mitigating the undesired response to Ethrel by LPE was concentration dependent in the two seasons, which meant that more the LPE concentration, less the adverse effect of Ethrel on flesh firmness.

Table 3: Effect of the preharvest applied treatments, the time factor and their interaction on electrolyte leakage, vitamin C and total sugars of "Keitt" mango fruits during the two seasons 2016 and 2017

	Season 2016			Season 2017		
Treatments	Initial	After 7 days	Mean	Initial	After 7 days	Mean
			Electrolyte leakage (%)			
Control	12.37 i*	27.00 cd	19.69 e	13.72 i	30.12 c	21.92 d
LPE (400ppm)	10.00 j	13.00 i	11.50 g	12.22 jk	13.72 i	12.97 f
LPE (800ppm)	10.13 j	12.96 i	11.55 g	11.81 k	13.13 ij	12.47 f
Ethrel(50ppm)	22.81 f	45.09b	33.95 b	24.09 e	42.00 b	33.05 b
Ethrel(100ppm)	25.72 de	48.00 a	36.86 a	27.48 d	48.73 a	38.11 a
LPE (400ppm)followed by Ethrel (50ppm)	19.52 g	25.00 e	22.26 d	19.25 f	28.00 d	23.63 c
LPE (400ppm)followed by Ethrel (100ppm)	18.69 g	27.07 c	22.88 c	18.00 fg	28.66 d	23.33 c
LPE (800ppm)followed by Ethrel (50ppm)	13.00 i	17.04 h	15.02 f	13.96 i	17.21 g	15.59 e
LPE (800ppm)followed by Ethrel (100ppm)	13.00 i	16.81 h	14.91 f	13.00 ij	15.72 h	14.36e
Mean	16.14 b	25.77 a	_	17.06 b	26.37 a	_
			Vitamin C (mg/ 100 ml juice)			
Control	38.10 a	31.37cdef	34.74 b	40.28 a	34.40bc	37.34a
LPE (400ppm)	37.44 a	34.12 b	35.78 a	38.60 a	32.93cdef	35.77b
LPE (800ppm)	36.75 a	33.54 bc	35.15ab	38.56 a	34.00cd	36.28b
Ethrel(50ppm)	27.14 hi	25.11 i	26.13 e	29.25 i	23.10 j	26.18 f
Ethrel(100ppm)	25.00 i	22.39 j	23.70 f	21.91 j	18.00 k	19.96 g
LPE (400ppm)followed by Ethrel (50ppm)	33.28bcd	30.25 fg	31.77 c	35.92 bc	32.08 efg	34.00 c
LPE (400ppm)followed by Ethrel (100ppm)	32.71bcde	30.59 ef	31.65 c	35.96 b	31.19 fgh	33.58 c
LPE (800ppm)followed by Ethrel (50ppm)	30.75 ef	28.25 gh	29.50 d	32.12defg	29.99 hi	31.06 e
LPE (800ppm)followed by Ethrel (100ppm)	31.00 def	29.40 fgh	30.20 d	33.38cde	31.00 ghi	32.19 d
Mean	32.46 a	29.45 b	_	33.99 a	29.63 b	_
			Total sugars (%)			
Control	10.12 h	16.52 g	13.32 e	13.00 d	17.38 c	15.19 d
LPE (400ppm)	16.62 fg	22.00 b	19.31 d	17.17 c	23.91 a	20.54bc
LPE (800ppm)	16.74efg	22.28 ab	19.51cd	17.34 c	23.32 a	20.33 c
Ethrel(50ppm)	18.85 c	23.39 a	21.12 a	18.70bc	24.57 a	21.64ab
Ethrel(100ppm)	18.17 cd	23.00 ab	20.59ab	19.55 b	24.69 a	22.12 a
LPE (400ppm)followed by Ethrel (50ppm)	17.40defg	22.83 ab	20.12bcd	17.39 c	24.17 a	20.78bc
LPE (400ppm)followed by Ethrel (100ppm)	16.74efg	22.03 b	19.39 d	17.57 c	23.97 a	20.77bc
LPE (800ppm)followed by Ethrel (50ppm)	17.89cdef	22.87 ab	20.38abc	18.04 bc	24.29 a	21.17abc
LPE (800ppm)followed by Ethrel (100ppm)	17.98cde	23.00 ab	20.49 ab	18.29 bc	24.41 a	21.35abc
Mean	16.72 b	21.99 a	_	17.45 b	23.41 a	_

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

The effect of the time factor on “Keitt” mangoes was also reported in Table 2. It was clear that a significant reduction in flesh firmness occurred after 7 days of harvest in a similar magnitude in both seasons which ranged between 17 to about 13 Newton in the two seasons.

Moreover, effect of the interaction between treatments and the time factor was also documented in Table 2, it was evident from the data that the loss of firmness between the initial sample and after 7 days on the shelf was very dramatic with the individual application of Etherl whether at 50 or 100 ppm while such reduction in flesh firmness was much slower with the use of LPE at 400 or 800 ppm. Meanwhile, all Ethrel treatments that contained LPE were able to maintain greater flesh firmness when compared with Ethrel applications alone especially with using Ethrel at 50 ppm relative to the mitigation by LPE to Ethrel at 100 ppm. That trend was consistent in the two seasons.

The Effect of Treatments, Time Factor and Their Interaction on on Fruit Chemical Characteristics: The effect of applied treatments before harvest on the percentage of electrolyte leakage of “Keitt” fruits was reported in Table 3. There was a clear trend showing the increase in such leakage by Ethrel alone whether at 50 or 100 ppm when compared with the control. On the contrary, LPE treatments whether at 400 or 800 ppm resulted in much reduction of electrolyte leakage of fruit tissue consistently. When Ethrel at 50 or 100 ppm was

preceded by the application of LPE at 800 ppm, a significant reduction in electrolyte leakage occurred. However, when LPE at 400 ppm preceded the application of Ethrel at 50 or 100 ppm, the magnitude of such reduction in electrolyte leakage was recorded which resulted in an electrolyte leakage values slightly greater than that obtained by the control.

The time factor assessment also proved the significant increase in electrolyte leakage after 7 days on the shelf at ambient temperature relative to the initial values in both seasons.

Meanwhile, the interaction between the treatments and the time factor (Table 3) showed that the greatest increase in electrolyte leakage was found in Ethrel- treated fruits at 100 ppm followed by those treated with 50 ppm. The individual applications of lisophos at both concentrations (400 or 800 ppm) were able to reduce electrolyte leakage relative to the control and to other treatments whereas its combination with Ethrel alleviated the adverse effect on electrolyte leakage even after seven days on the shelf.

The influence of various applied treatments on vitamin C content of "Keitt" mangoes was reported in Table 3. The data in this table showed that there was a reduction in vitamin C by all used treatments except with LPE at 400 and 800 ppm that gave inconsistent trend between the two seasons, when compared with the control. However, the magnitude of such reduction was relatively less by the application of LPE (400 ppm) followed by Ethrel (at 50 or 100 ppm) than that occurred by other LPE at 800 ppm followed by Ethrel at 50 or 100 ppm. That was also true for the reduction of vitamin C by the individual application of LPE at 400 or 800 ppm in the second season.

The time factor also indicated to a similar trend since vitamin C was reduced after 7 days of the incubation on the shelf in both seasons.

Furthermore, the interaction between treatments and the time factor revealed that the greatest change in vitamin C occurred after one week on the shelf by the two Ethrel concentrations that was higher than the reduction occurred by the individual use of LPE at either 400 or 800 ppm.

Concerning the influence of various used treatments on the percentage of total sugars in treated- "Keitt" mangoes, it was clear again that Ethrel applications at either 50 or 100 ppm resulted in the greatest increase in total sugars in both seasons as compared with the control. Moreover, such increase in total sugars was similar to that obtained by LPE at 800 ppm followed by Ethrel at 50 or 100 ppm (Table 3).

The time factor also revealed that total sugars were significantly increased over the seven days of incubation on the shelf.

Furthermore, the effect of the interaction between applied treatments and the time factor (Table 3) revealed that all treatments in the second season had superior values of total sugars after 7 days on the shelf when compared with the control and they were equally effective on increasing total sugars. That was almost the same trend in the first season except with Ethrel (50 ppm) which caused an increase in total sugars more than LPE (400 ppm) followed by Ethrel at 100 ppm after the seven days of incubation.

Changes in total soluble solids in relation to preharvest applied treatments on "Keitt" mangoes were reported in Table (4) for the seasons 2016 and 2017. The data showed a significant increase in TSS by many treatments especially by Ethrel (100 ppm), but its effect on TSS was similar to that found by Ethrel at 50 ppm (especially in the first season) in addition to the combination of LPE at 800 ppm followed by Ethrel at 100 ppm. Even LPE alone at either applied concentrations (400 or 800 ppm) was able to significantly increase the percentage of TSS compared with the control in both seasons.

With regard to the influence of the time factor in both seasons (Table 4), the data revealed that there was a significant increase of TSS between the initial values and 7 days later (with a magnitude averaged as 2.86).

On the other hand, the interaction between the treatments and the time factor was shown in the same Table 4. The data revealed a general increase in TSS between the initial detection at harvest and after seven days on the shelf even in the control fruits. The greatest increase over that week on the shelf was achieved by Ethrel at 100 ppm alone and its combination with LPE at 800 ppm. Moreover, LPE alone whether at 400 or 800 ppm was able to increase TSS in "Keitt" mangoes over time after one week on the shelf.

The influence of various applied treatments on juice acidity in both seasons was reported in Table 4. The data provided evidence that there was a significant reduction in such acidity especially with Ethrel treatments whether at 50 or 100 ppm when compared with the control. Treatments of LPE alone either at 400 or 800 ppm were able to reduce "Keitt" juice acidity but magnitude of such reduction was lower than that obtained by Ethrel. Thus, the greatest acidity values were found in the control during both seasons. When LPE (800 ppm) was combined with Ethrel applications at 50 or

Table 4: Effect of the preharvest applied treatments, the time factor and their interaction on total soluble solids percentage, acidity content and their ratio of "Keitt" mango fruits during the two seasons 2016 and 2017.

	Season 2016			Season 2017		
Treatments	Initial	After 7 days	Mean	Initial	After 7 days	Mean
			TSS (%)			
Control	10.22g*	12.13 f	11.17e	12.15 j	14.60 h	13.37 f
LPE (400ppm)	12.36 f	16.16 b	14.26d	13.80 i	17.40d	15.60 e
LPE (800ppm)	13.27 e	16.46 b	14.86c	15.00 gh	17.86 cd	16.43 d
Ethrel(50ppm)	14.70 c	17.26 a	15.98ab	16.46 ef	19.13b	17.80b
Ethrel(100ppm)	14.76 c	17.60 a	16.18 a	16.83e	19.67 a	18.25 a
LPE (400ppm)followed by Ethrel (50ppm)	13.36 e	16.53 b	14.95 c	15.33 g	18.00 c	16.66 d
LPE (400ppm)followed by Ethrel (100ppm)	14.00 d	17.16 a	15.58 b	15.33 g	17.53 cd	16.43 d
LPE (800ppm)followed by Ethrel (50ppm)	14.50cd	17.20 a	15.85ab	16.03 f	18.76 b	17.40 c
LPE (800ppm)followed by Ethrel (100ppm)	14.63 c	17.20 a	15.91ab	16.30f	19.80 a	18.05ab
Mean	13.53 b	16.41 a	_	15.25 b	18.08 a	_
			Acidity (gm/ 100 ml juice)			
Control	0.403 a	0.340 bc	0.371 a	0.500 a	0.390 b	0.445 a
LPE (400ppm)	0.320cd	0.300 de	0.310 c	0.310 ef	0.276 gh	0.293de
LPE (800ppm)	0.320 cd	0.293 e	0.306 c	0.340 cd	0.290 fg	0.315cd
Ethrel(50ppm)	0.320 cd	0.260 g	0.290 d	0.310 ef	0.260 h	0.285 e
Ethrel(100ppm)	0.300 de	0.263 fg	0.281 d	0.286fgh	0.280 gh	0.283 e
LPE (400ppm)followed by Ethrel (50ppm)	0.330bc	0.323 cd	0.326b	0.340 cd	0.290 fg	0.315cd
LPE (400ppm)followed by Ethrel (100ppm)	0.340 bc	0.285ef	0.312c	0.340 cd	0.280 gh	0.310cd
LPE (800ppm)followed by Ethrel (50ppm)	0.350 b	0.320 cd	0.335 b	0.350 c	0.300 efg	0.325bc
LPE (800ppm)followed by Ethrel (100ppm)	0.340 bc	0.330 bc	0.335 b	0.360 c	0.320 de	0.340 b
Mean	0.335 a	0.302 b	_	0.348 a	0.298 b	_
			TSS / acidity (ratio)			
Control	25.34 k	35.78 j	30.56 d	24.35 f	37.46 e	30.90 c
LPE (400ppm)	38.64 ij	53.89 cd	46.26 c	44.60 d	63.10 b	53.85 b
LPE (800ppm)	41.68 hi	56.20 c	48.94 bc	44.17 d	61.61 b	52.89 b
Ethrel(50ppm)	45.93 fg	66.57 a	56.25 a	53.11 c	73.91 a	63.51 a
Ethrel(100ppm)	49.34 ef	66.96 a	58.15 a	58.73 b	70.49 a	64.61a
LPE (400ppm)followed by Ethrel (50ppm)	40.50 hi	51.18 de	45.84 c	45.17 d	62.26 b	53.71 b
LPE (400ppm)followed by Ethrel (100ppm)	41.25 hi	60.23 b	50.74 b	45.10 d	62.76 b	53.93 b
LPE (800ppm)followed by Ethrel (50ppm)	41.44 hi	53.89 cd	47.66 bc	45.98 d	62.55 b	54.27 b
LPE (800ppm)followed by Ethrel (100ppm)	43.03 gh	52.16 de	47.60 bc	45.39 d	62.04 b	53.71 b
Mean	40.79 b	55.20 a	_	45.17 b	61.79 a	_

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

100 ppm, there was a further increase in juice acidity as compared with the sole application of Ethrel at either concentrations.

Meanwhile, the time factor showed a significant reduction in juice acidity between the initial values and after seven days on the shelf in the two seasons (Table 4).

Furthermore, the interaction between treatments and the time factor revealed that the greatest reduction in juice acidity occurred with the application of Ethrel at 50 and 100 ppm after 7 days on the shelf followed by LPE (400 ppm) alone or when combined with Ethrel (100 ppm) in both seasons. Moreover, “Keitt” mangoes treated with LPE at 800 ppm alone or followed by Ethrel 50 or 100 ppm were able to maintain their acidity even after 7 days on the shelf only in the first season.

The effect of preharvest treatments on the ratio of TSS to acidity in “Keitt” mangoes was reported in Table 4. The data revealed that all applied treatments caused a significant increase in such ratio relative to the control, with varying degrees of effect. The application of Ethrel alone whether at 50 or 100 ppm resulted in the greatest increase in TSS / acidity ratio in both seasons. That effect was reduced when each Ethrel concentration was combined with LPE either at 400 or 800 ppm in a consistent manner in both seasons. Meanwhile, the individual application of LPE either at 400 or 800 ppm were able to increase TSS to acidity in a magnitude similar to that obtained by their combination with Ethrel especially in the second season.

Table 5: Effect of the preharvest applied treatments, the time factor and their interaction on anthocyanin and carotene contents of "Keitt" mango fruits during the two seasons 2016 and 2017.

Treatments	Season 2016			Season 2017		
	Initial	After 7 days	Mean	Initial	After 7 days	Mean
	Anthocyanin content of peel (mg/100gm)					
Control	0.19 i*	2.55 f	1.37 e	0.23 i	2.85 f	1.54 f
LPE (400ppm)	1.85 h	3.89 b	2.87 d	1.94 h	4.58 b	3.26 d
LPE (800ppm)	2.50 f	4.55 a	3.53 c	2.71 fg	3.37 e	3.04 e
Ethrel(50ppm)	3.60 cd	3.75 bc	3.67 bc	3.55 de	3.81cd	3.68 c
Ethrel(100ppm)	3.65 cd	3.89 b	3.77 b	3.84 c	3.97 c	3.91 b
LPE (400ppm)followed by Ethrel (50ppm)	2.21 g	3.27 e	2.74 d	2.50 g	3.37 e	2.94 e
LPE (400ppm)followed by Ethrel (100ppm)	2.50 f	3.14 e	2.82 d	2.67 fg	3.37 e	3.02 e
LPE (800ppm)followed by Ethrel (50ppm)	3.21 e	4.55a	3.88 ab	3.41 e	4.88 a	4.15 a
LPE (800ppm)followed by Ethrel (100ppm)	3.54 d	4.55a	4.05 a	3.72 cd	4.91 a	4.32 a
Mean	2.58 b	3.79 a	_	2.73 b	3.90 a	_
	Carotene content of peel (mg/ 100gm)					
Control	1.33 h	2.79 d	2.06 d	1.48 h	3.00 e	2.24 e
LPE (400ppm)	1.81 fg	4.00 b	2.91 c	2.04 f	4.18 c	3.11 c
LPE (800ppm)	1.90 ef	4.48 a	3.19 ab	2.04 f	4.21 c	3.13 bc
Ethrel(50ppm)	1.75 fg	3.83 c	2.79 c	1.89 fg	3.95 d	2.92 d
Ethrel(100ppm)	1.78 fg	3.92 bc	2.85 c	1.85 fg	3.95 d	2.90 d
LPE (400ppm)followed by Ethrel (50ppm)	1.72 g	4.42 a	3.07 b	1.75 g	4.60 b	3.18 bc
LPE (400ppm)followed by Ethrel (100ppm)	1.84 fg	4.53 a	3.19 ab	1.75 g	4.75 ab	3.25 b
LPE (800ppm)followed by Ethrel (50ppm)	1.99 e	4.36 a	3.18 ab	2.00 f	4.82 a	3.41 a
LPE (800ppm)followed by Ethrel (100ppm)	1.99 e	4.48 a	3.24 a	1.95 fg	4.86 a	3.40 a
Mean	1.79 b	4.09 a	_	1.86 b	4.26 a	_
	Carotene content of pulp (mg/ 100gm)					
Control	1.94 j	4.57 f	3.26 g	2.18 g	4.08 d	3.13 f
LPE (400ppm)	3.45 h	6.11 bcd	4.78 e	3.55 ef	6.30 a	4.93 bc
LPE (800ppm)	3.89 g	6.98 a	5.44 a	3.94 de	6.59 a	5.27 a
Ethrel(50ppm)	3.00 i	5.45 e	4.23 f	3.31 f	5.00c	4.16 e
Ethrel(100ppm)	3.77 gh	5.81 de	4.79 de	3.94 de	5.77 b	4.86 c
LPE (400ppm)followed by Ethrel (50ppm)	3.90 g	6.11 bcd	5.01 bc	3.97 d	5.40 b	4.69 d
LPE (400ppm)followed by Ethrel (100ppm)	3.85 gh	6.00 cd	4.93 cd	3.97 d	5.55 b	4.76 cd
LPE (800ppm)followed by Ethrel (50ppm)	3.79 gh	6.22 bc	5.01 bc	3.79 de	6.30 a	5.05 b
LPE (800ppm)followed by Ethrel (100ppm)	3.85 gh	6.43 b	5.14 b	3.88 de	6.59 a	5.24 a
Mean	3.49 b	5.96 a	_	3.61 b	5.73 a	_

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

In addition, the time factor indicated to a trend of increase of such ratio in both seasons.

With regard to the effect of the interaction between treatments and the time factor (Table 4), it was evident that all treatments and the control achieved an increase in TSS to acidity ratio while the greatest increase over the time on the shelf was found with Ethrel- treated mangoes whether at 50 or 100 ppm in both seasons.

The changes in anthocyanin content of “Keitt” mango fruit peel in response to various applied treatments were reported in Table 5. The data proved that all applications were able to significantly increase anthocyanin in the peel with variations in the magnitude of such increase. For example, the combinations of LPE at 800 ppm followed by Ethrel at either 50 or 100 ppm resulted in higher anthocyanin content than the separate use of each component. Moreover, the sole application of Ethrel at 50 or 100 ppm was effective on enhancing anthocyanin content when compared with the control. However, LPE alone whether at 400 or 800 ppm was able to enhance anthocyanin formation in “Keitt” mangoes peel.

Meanwhile, the time factor showed that there was an increase in anthocyanin after 7 days on the shelf in both seasons.

The interaction between treatments and the time factor provided evidence that when LPE at 800 ppm was combined with Ethrel at 50 or 100 ppm, it resulted in the highest increase in anthocyanin content after one week on the shelf as compared with the control and all other

treatments. However, the least efficacy was obtained with LPE at 400 ppm followed by Ethrel at 50 or 100 ppm after one week of the shelf life at room temperature.

Effect of preharvest treatments on carotene content of "Keitt" mangoes in the peel was reported in Table 5. The data indicated to a significant increase of carotenes by all treatments when compared with the control. Ethrel application at 50 or 100 ppm also increased carotene content but the magnitude of the increase was less than that obtained by LPE alone at 800 ppm in both seasons. The combination of LPE at 800 ppm followed by each of Ethrel concentrations (50 or 100 ppm) resulted in a remarkable increase of carotenes in the peel much more than that occurred with the individual use of LPE or Ethrel. Meanwhile, LPE at 400 ppm combined with Ethrel at 50 or 100 ppm were more effective on enhancing carotene formation in "Keitt" mangoes as compared with the application of Ethrel alone.

On the other hand, the time factor indicated to a significant increase of carotenes over time between the initiation time and after seven days on the shelf.

With regard to the effect of the interaction between treatments and the time factor, the data in Table 5 also provided evidence that the greatest increase of carotene content was obtained with the application of LPE at 800 ppm preceded each of Ethrel concentrations (50 or 100 ppm) followed by the application of LPE at 400 ppm preceded Ethrel at 100 ppm when compared with other treatments by the end of the incubation on the shelf after one week.

Carotene content in the pulp of "Keitt" mangoes as influenced by applied treatments was reported in Table 5. The data proved that there was an increase in carotene content by all used treatments relative to the control in both seasons. Even the individual application of LPE at either 400 or 800 ppm caused a significant increase in carotene content of the pulp as compared with the control. There was a synergistic effect resulting from combining LPE at 800 ppm followed by Ethrel at either 50 or 100 ppm. Such combinations had greater influence on pulp carotenes than that obtained with the individual application of Ethrel at 50 or 100 ppm in both seasons. Eventhough, the combination of LPE at 400 ppm followed by Ethrel at 100 ppm had a significant influence in increasing pulp carotenes. However, such positive effect was still less than that obtained with the application of LPE at 800 ppm followed by Ethrel at 100 ppm.

Meanwhile, the time factor proved that there was a significant increase in pulp carotenes over time between the initiation and at the end of the shelf life test.

Concerning the effect of the interaction between the treatments and the time factor, the data indicated that LPE at 800 ppm whether alone or when combined with Ethrel at 100 ppm after the seven days on the shelf had superior influence on pulp carotenes when compared with other treatments.

The influence of applied treatments on chlorophyll a content of "Keitt" mango peels was reported in Table 6. The data showed that there was a significant reduction in chlorophyll a by all used treatments in both seasons relative to the control. However, the magnitude of such reduction varied among treatments. Since both Ethrel concentrations resulted in the lowest chlorophyll a content followed by the combinations of LPE at 800 ppm followed by either Ethrel at 50 or 100 ppm. Meanwhile, LPE as an individual treatment at 400 or 800 ppm was also able to reduce chlorophyll a, but in much amount than its use in formulation with Ethrel at both concentrations.

Moreover, the time factor showed a significant reduction over the incubation period for seven days in both seasons.

With regard to the effect of the interaction between the treatments and the time factor, it was found that Ethrel alone at either 50 or 100 ppm resulted in the highest chlorophyll a breakdown after seven days on the shelf followed by the combination of LPE at 800 ppm preceded Ethrel at 100 ppm after the same period of incubation (Table 6).

Concerning the effect of preharvest treatments of "Keitt" mangoes on the content of chlorophyll b in fruit peels, the data revealed that all used treatments were able to reduce chlorophyll b with varying degrees of efficacy in both seasons (Table 6). However, the greatest reduction of chlorophyll b was obtained with the application of LPE at 800 ppm followed by Ethrel at 50 or 100 ppm. The magnitude of such reduction was equal to that obtained with Ethrel alone at 50 or 100 ppm especially in the second season. Even LPE alone at 400 or 800 ppm was also able to cause a significant breakdown of chlorophyll b, but in less efficacy than that found with Ethrel especially in the second season.

Moreover, the time factor indicated to a significant reduction in chlorophyll b after 7 days of the incubation on the shelf.

Meanwhile, the interaction between treatments and the time factor indicated that the highest effect on chlorophyll b breakdown was found with the applications of LPE at 800 ppm preceded Ethrel at 50 or 100 ppm after 7 days of incubation followed by LPE alone at 800 ppm as compared with all other treatments.

Table 6: Effect of the preharvest applied treatments, the time factor and their interaction on chlorophyll a and b contents of "Keitt" mango- fruit peel during the two seasons 2016 and 2017

	Season 2016			Season 2017		
Treatments	Initial	After 7 days	Mean	Initial	After 7 days	Mean
			Chlorophyll a content (mg/ 100gm)			
Control	1.00 a*	0.75 d	0.88 a	0.89 a	0.55 c	0.72 a
LPE (400ppm)	0.89 b	0.45 g	0.67 b	0.80 b	0.39 e	0.60 b
LPE (800ppm)	0.78 c	0.30 i	0.54 c	0.81 b	0.20 h	0.50 c
Ethrel(50ppm)	0.28 j	0.12 mn	0.20 g	0.21 h	0.11 j	0.16 h
Ethrel(100ppm)	0.22 l	0.14 m	0.18 h	0.20 h	0.11 j	0.16 h
LPE (400ppm)followed by Ethrel (50ppm)	0.47 f	0.25 k	0.36 d	0.40 e	0.15 i	0.28 e
LPE (400ppm)followed by Ethrel (100ppm)	0.51 e	0.22 l	0.36 d	0.49 d	0.15 i	0.32 d
LPE (800ppm)followed by Ethrel (50ppm)	0.38 h	0.22 l	0.30 e	0.30 f	0.11 j	0.21 f
LPE (800ppm)followed by Ethrel (100ppm)	0.38 h	0.11 n	0.25 f	0.27 g	0.08 k	0.18 g
Mean	0.55 a	0.28 b	_	0.49 a	0.21 b	_
			Chlorophyll b content (mg/ 100gm)			
Control	2.00 a	1.43 b	1.72 a	1.84 a	1.22 b	1.53 a
LPE (400ppm)	0.83 de	0.48 g	0.66 b	0.91 c	0.51 f	0.71 b
LPE (800ppm)	0.79 e	0.28 i	0.54 d	0.63 e	0.20 jk	0.42 e
Ethrel(50ppm)	0.63 f	0.53 g	0.58 c	0.47 f	0.31 h	0.39 ef
Ethrel(100ppm)	0.51 g	0.50 g	0.51 de	0.41 g	0.25 i	0.33 g
LPE (400ppm)followed by Ethrel (50ppm)	0.91 c	0.37 h	0.64 b	0.95 c	0.21 ij	0.58 c
LPE (400ppm)followed by Ethrel (100ppm)	0.88 cd	0.37 h	0.63 b	0.78 d	0.18 jk	0.48 d
LPE (800ppm)followed by Ethrel (50ppm)	0.66 f	0.29 i	0.48 e	0.59 e	0.15 k	0.37 fg
LPE (800ppm)followed by Ethrel (100ppm)	0.61 f	0.25 i	0.43 f	0.59 e	0.10 l	0.35 g
Mean	0.87 a	0.50 b	_	0.79 a	0.35 b	_

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

This study provided evidences to mango producers with many problems associated with mango production such as the ability to produce a tree- ripe fruit which acquired better taste and aroma. The application of the natural lysophospholipid called lysophosphatitylethanolamine (LPE) along with a relatively lower concentration of Ethrel was able to significantly reduce fruit abscission and to retard the loss of tissue firmness. Such positive and demanded achievements were first reported by Farag and Palta [9, 18] then were further supported by the findings of Farag and Attia [19].

Retarding tissue senescence and softening could be attributed to the inhibition of cell wall hydrolyses, namely polygalacturonase and galactosidase by LPE [10]. The effect of LPE on ethylene production was reported to be concentration dependent since LPE at 100 ppm was able to stimulate ethylene production in apple tissue without increasing the respiration rate of “Red Delicious” apple fruit [20].

The increase in LPE concentration enhances skin coloration without any adverse effect on tissue firmness. It has been also reported that LPE can repair the damage of the plasma membrane in addition to ceasing further breakdown of the cell walls. Thus, halting the progress toward tissue senescence [18].

Furthermore, the increase in total soluble solids by Ethrel alone or when combined with LPE could be due to the stimulation of the conversion of starch to sugars by the released ethylene from the diffused Ethrel across the fruit cuticle. The exogenous ethylene can also lead to enhancing the autocatalysis which means further increase in internal ethylene production in a climacteric fruit such as mangoes [21]. The exogenous application of Ethrel preceded by the application of relatively high concentration of LPE was essential to enhance the tree-ripe fruit since it was reported that a natural ripening inhibitor exist in the mango tree that hinders the natural ripening process [3].

On the other hand, the detected increase in peel and pulp carotene content was further supported by exposure to warm temperature at 53 ^{0}C in water for 5 minutes [22]. Thus, pulp increase in total carotene content after harvest was also supported by the findings of Lizada *et al*. [23] that confirmed the disappearance of the green color in the peel in “Caraboa” mangoes. The increase in peel color development was accompanied by ultrastructural changes associated with chloroplast- to- chromoplast changes or transition. The thylakoid membrane systems in the peel of “Alphonso” and “Tommy Atkins” gradually breakdown, while osmiophilic globules enlarge and increase in number [8]. Since mango coloration enhances its attractiveness

and marketability, it was also important to be very concerned with anthocyanin formation especially on mango fruit peels. The available information about the role of the critical light intensity or the effect of direct sunlight on anthocyanin biosynthesis still need further research to reach to the desired color. Moreover, the pattern of light penetration within mango canopies has not well documented.

Due to the vigorous growth habit of the tree with rare selectivity of the pruning pattern [24]. Chemical spray to enhance the formation of anthocyanin would really benefit mango growers and producers especially with the application of a natural compound that obtained the approval of the Food and Drug Administration of the USA, namely the LPE compound. The ability of LPE to mitigate the undesired influence of Ethrel on mango fruit storability could be attributed to the ability of LPE to delay senescence and to inhibit the activity of phospholipase- D [25].

The ability of LPE to enhance anthocyanin biosynthesis could be due to its role on enhancing the activity of the enzyme phenylalanine ammonia- lyase which is responsible for the key step in the formation of anthocyanin namely the conversion of phenylalanine to trans- cinamic acid [26].

In conclusion, this study recommends using the combined treatment of LPE at 800 ppm followed by Ethrel at 50 ppm to reduce fruit abscission, reduce electrolyte leakage and improve fruit quality especially enhancing coloration as shown by the consistent increase of anthocyanin and carotene content. Meanwhile, this combination of LPE when preceded Ethrel was still able to prolong the shelf life of treated “Keitt” mangoes.

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