Enhancement yield and fruit quality of Washington Navel orange by application of spraying potassium microencapsulated biodegradable polylactic acid

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Abstract: This research seeks to improve the fertilizer use efficiency, particularly potassium nutrient, and to minimize any possible dose losses. The improvement was applied by the use of foliar sprays by encapsulated potassium element into biodegradable polymer. The potassium polylactic acid microspheres (K-PLA) were characterized by Gel Permeation Chromatography (GPC) and Scanning Electron Microscope (SEM). Piratical size and zeta potential measurements were investigated. Thermal behavior (TGA and DTA) was studied. In capsulation percentage of potassium into PLA microspheres was 4.5 W %. Cumulative release was estimated by inductive coupled plasma-atomic emission spectrometry (ICP-AES), the maximum cumulative release was 3.74% after 12 hours. Washington Navel orange trees treated with uploaded potassium (K_2O) and loaded potassium (K-PLA) or in their mixture (three times in the year) during two successive seasons 2015 and 2016 in private orchard located at El-Kalubia Governorate to evaluate the dual benefit (yield and fruit quality). The results showed that, the sole treatments significantly increase yield and fruit quality than control (zero % K formulation). However, K-PLA can stabilize K and can significant improve yield and coloring percentage than uploaded K. Both treatments decrease juice acidity %. Whereas, increase content of total soluble solids and vitamin C, especially K-PLA (100%), and ascending order with applying formulations (75% K_2O+25% K-PLA), (50% K_2O +50% K-PLA) and (25% K_2O+75% K-PLA). It can be recommendation, foliar spray of Washington Navel orange orchards by loaded potassium formulation is promising to improve the dual benefit, providing fertilizers and environmentally safe.

Keywords: Washington Navel orange, yield quality and quantity, potassium, stabilized fertilizer, slow release, biodegradable polymer

Citation: Hafez, O. M., M. Sultan, S. Ibrahim, M. A. Saleh. 2017. Enhancement yield and fruit quality of Washington Navel orange by application of spraying potassium microencapsulated biodegradable polylactic acid. Agricultural Engineering International: CIGR Journal, Special issue: 101–110.

1 Introduction

Citrus occupies the largest fruit trees area in Egypt. It is considered the first among economic fruits crops in the world. Washington Navel orange in one of the most popular citrus fruits for its taste and nutrition's with vitamin C and minerals.

The fertilizers engineering faces a continuing challenge to enhance its performance and to avoid or at least reduce losses. Thus, special fertilizers categories were fabricated like foliar fertilizers, (encapsulated/ coated) slow and or controlled-release fertilizers with long run of nutrients release over several days to months. The term controlled-release fertilizer (CRF) means the release of the nutrient at a slower rate which is classic, but the rate, pattern and duration of release are not well controlled. Potassium is considered as macroelements which highly mobile in plants as all from individual cell xylem and phloem transport. This cation plays a major role in enzyme activity, protein synthesis, Stomata function, stabilization of internal PH, photosynthesis, turgor related processes and transport of metabolites (Aly

Reveived date: 2017-05-28 **Accepted date:** 2017-12-29

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et al., 2015). Foliar application of potassium on citrus was found to increase yield and improve fruit properties during the proper period of growth (Maksound et al., 2003). Controlled-release fertilizers may contain only N or K, NP or NK (with different forms of K), NPK or NPK plus secondary nutrients and/or different micronutrients. The permanence of these products can range from 20 days to 18 months (Aquaye and Inubushi, 2004). Many literatures have been achieved global regarding the microencapsulation of mineral fertilizers, fungicides, pesticides, and drugs (Vert, 2005; Quaglia et al., 2001).

Various techniques were utilized to obtain a controlled release fertilizer; thereby avoiding overdosing with the accompanying negative effects (Suherman and Anggoro, 2011, Shuping et al., 2011; Riyajan et al., 2012). Studies were performed on encapsulation of commercial granular fertilizer of NPK with polysulphone using spray drying method (Jarosiewicz and Tomaszewska, 2006). The controlled nutrient released from polymer coated fertilizer (CRFs) is proposed and consisted of three stages: I. a lag period during which water penetrates the coating of the granule dissolving part of the solid fertilizer in it; II. A period of linear was release during which water penetration into and release out occur concomitantly while the total volume of the granules remains practically constant; and III. A period of decaying release, starting as the concentration inside the granule starts to decrease. The product of granule was radius and coating thickness, water and solute permeability, saturation concentration of the fertilizer and its density (Shaviv et al., 2003). Furthermore, the fertilizers demand that the plant can be met more closely by designing an acceptable controlled release system from biodegradable natural polymer to increase efficiency and reduce the risk of overdosing (Akiyama et al., 2010).

The scientific goal of the research is to develop the foliar application which potassium fertilizer was microencapsulated into biodegradable polylactic acid polymer for controlling nutrient release and their effects on yield and fruit quality of Washington Navel orange.

2 Materials and methods

2.1 Plant material

Six treatments with three replicates and two trees per each, was carried out in randomized complete black design on 36 trees (20 years old) of Washington Navel orange (*Citrus sinensis* L. Osbeck) during two seasons (2015 & 2016) in private orchard located at El-Kalubia Governorate Egypt. Healthy trees, nearly uniform in growth vigor and fruiting were chosen which planted 5×5 meter under basin irrigation system received the same horticultural practices as usual. The soil texture of the experimental site was loamy with organic matter 2.04%; pH 8.4; E.C. 0.32 dsn^{-1}; $CaCO_3$ 1.6%; available macroelements (%): P 2.8, K 47.2, Ca 1000 and Mg 114; available microelements (ppm): Fe 7.6, Mn 3.4, Zn 1.4 and Cu 1.7.

The selected trees were sprayed with specified solutions by the recommended dose of liquid commercial potassium (38% K_2O) which is 2 ml/liter water according to ministry of agriculture Egypt in three times all over the season. The same amount of potassium sprayed as potassium encapsulated in polylactic acid (K-PLA), and combination with each other.

The treatments were as follows:

T_1. (Control) with tap water

T_2. (100% K_2O)

T_3. (100% K-PLA)

T_4. (75% K_2O + 25% K-PLA)

T_5. (50% K_2O + 50% K-PLA)

T_6. (25% K_2O + 75% K-PLA)

Times of spraying were at the beginning of March, the mid of May and Mid of July (Aly et al., 2015). The fruits were harvested at the third week of December in both seasons.

2.2 Potassium encapsulated in polylactic acid

2.2.1 Material

L-lactic acid (LLA) as a 90 wt% aqueous solution was purchased from PURAC bioquimica (Barcelona, Spain) and was purified using a molecular distillation method to further reduce the water content before used. Stannous octoate (tin (II) 2-ethylhexanoate) ($Sn(Oct)_2$) was purchased from Aldrich Chemical Company (Germany). Chloroform and methanol are used without any further purification. Commercial grade of K_2O 38%, aqueous (Misr Eldawly, Egypt) solution was used as received.

2.2.2 Synthesis of polylactic acid

L-lactic acid (1.03 g) was polymerized by using p-toluenesulfonic acid and stannous octoate (0.6 Wt %) as catalysts were stirred for 12 h at 150°C. Acetone (20 mL) was then added. An insoluble white precipitate (1.41 g) was recovered by filtration and dried under vacuum at 40°C over several days (Mirian et al., 2013).

2.2.3 Encapsulated of K_2O in PLA shell

12.5 ml of liquid potassium (K_2O 38%) was mixed with emulsified solution of PLA. The mixture was homogenized with ultrasonic waves for 7 min at 90% amplitude (Branson ultrasonic, UK). Encapsulated K-PLA was formed in aqueous solution and it was used as 100% stock for further dilutions before applied on trees (Rochmadi et al., 2010).

2.2.4 Characterization of potassium encapsulated polylactic acid (K-PLA)

The (K-PLA) microspheres characteristics were investigated by gel permeation chromatography (GPC) and scanning electron microscope, particle size and zeta potential. Cumulative release was determined by inductive couple plasma-atomic emission spectrometry (ICP-AES).

2.2.5 Size exclusion chromatography (SEC)

SEC was used to determine the molecular weights by Waters equipment with differential refractometer as a detector and quaternary pump controller model 600. Two columns type Waters Styragel HT6E and HR4E were applied for the assignment of the molecular weights of prepared PLA samples. This system was operated at flow rates of 0.6 and 0.4 mL min^{-1}, as optimum column measurement conditions. Calibration curves prepared from polystyrene standards in tetrahydrofurane at 30°C was used to calculate the molecular weights.

2.2.6 Scanning electron microscope (SEM)

The scanning electron microscope using SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., magnification14x up to 1000000 and resolution for Gun.1n).

2.2.7 Particle size and zeta potential

Particle size and zeta potential measurements were performed using NICOMP 380 ZLS particle size analyzer (PSA) instrument (PSS, Santa Barbara, CA, USA), using the 632 nm line of a HeNe laser as the incident light with angel 90° and Zeta potential with external angel 18.9°.

2.2.8 Thermal behavior (TGA and DTA) and encapsulation percentage

The thermal analysis (TGA&DTA) of the samples was studied by using the Perkin Elmer TGA7 Thermo gravimetric Analyzer. The samples were heated from 20°C to 500°C at the heating rate of 10°C/min. The analysis was carried out in nitrogen atmosphere with nitrogen flow rate of 20 mL/min. The weight loss of samples was recorded and plotted as a function of temperature. Encapsulation percentage was determined from TG curve by monitoring weight loss of samples.

2.2.9 Cumulative release profile

The cumulative release percentage of potassium was carried out in deionized water as a release medium without agitation at 50°C. Potassium concentration (mg/L) was monitored by Inductive coupled plasma-atomic emission spectrometry (Agilent 725 ICP-OES, USA).

2.3 The measurements on Washington Navel orange trees

2.3.1 Yield and yield components

At harvest time in both years, numbers of fruit per tree, fruit weight, and yield (ton)/feddan were recorded.

2.3.2 Coloring %

Color was calculated as average five fruits/replicate, as follows: each fruit is considered (100 units), which divided the surface area by two imagination perpendicular axes to have four equal parts (50%). Each part divided in two units (25%) as presented in Figure 1.

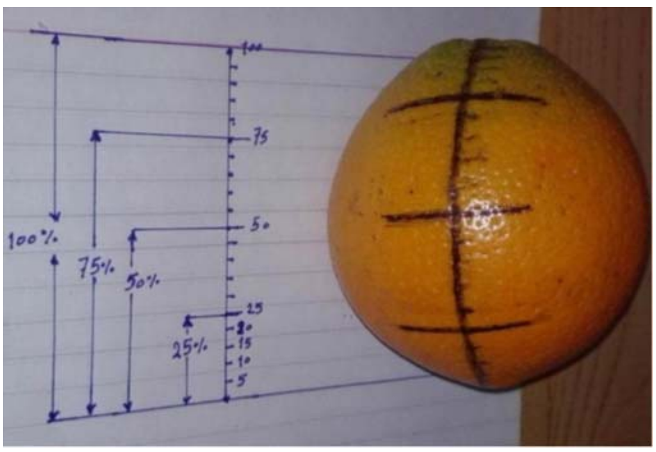

Figure 1 Color Chart "The degradation in color between 100% yellow color and zero% is green color"

2.3.3 Fruit quality

Sample of five fruits per tree from each replicate was collected randomly at harvest time in both seasons to determine some physical properties as average pulp and crust weight/fruit (g) and average fruit dimension (length and diameter “cm”). Also some chemical properties were determined as total soluble solids percentage (TSS%) by using hand refractometer according to (Chen and Mellenthin, 1981), total acidity (TA %) fruit juice was determined according to the (AOAC, 2000) by titration with 0.1N sodium hydroxide using phenolphthalein as an indicator and expressed as citric acid (%) and vitamin C (mg/100ml) juice according to (AOAC, 2000).

2.3.4 Statistical analysis

All data were subjected to computerized statistical analysis using 0.05 according to (Snedecor and Cochran, 1989).

3 Results and discussion

3.1 Size exclusion chromatography (SEC)

SEC was used to investigate the molecular weight of the prepared polymers. The instrument was from Knauer, Berlin, with a RI detector in combination with a PL-GEL 5 mm mixed C column, 300×7.5 mm (Polymer Laboratories, UK) using a flow rate of 1 ml/min and THF as eluent. Calibration was performed with linear polystyrene (PS) standards.

SEC chromatograph was uni-model without humps or shoulder. This is indicated to smooth molar distribution of PLA chains. Mn = 54 KDa, Mw = 156 KDa and PDI is 2.8 as molar indices of PLA. Complete conversion polymerization can be indicated to relatively high weight average molecular weight than number average with related polydispersity index.

3.2 Scanning electron microscope (SEM)

The morphology of K-PLA microcapsule could be observed directly by means of SEM, as shown in Figure 2. Topographic images were found that PLA was a kind of homogenous morphology. The roughness of the film surface increased with K-PLA films. This indicated that the interaction between the potassium oxides was mostly homogenized with PLA polymer.

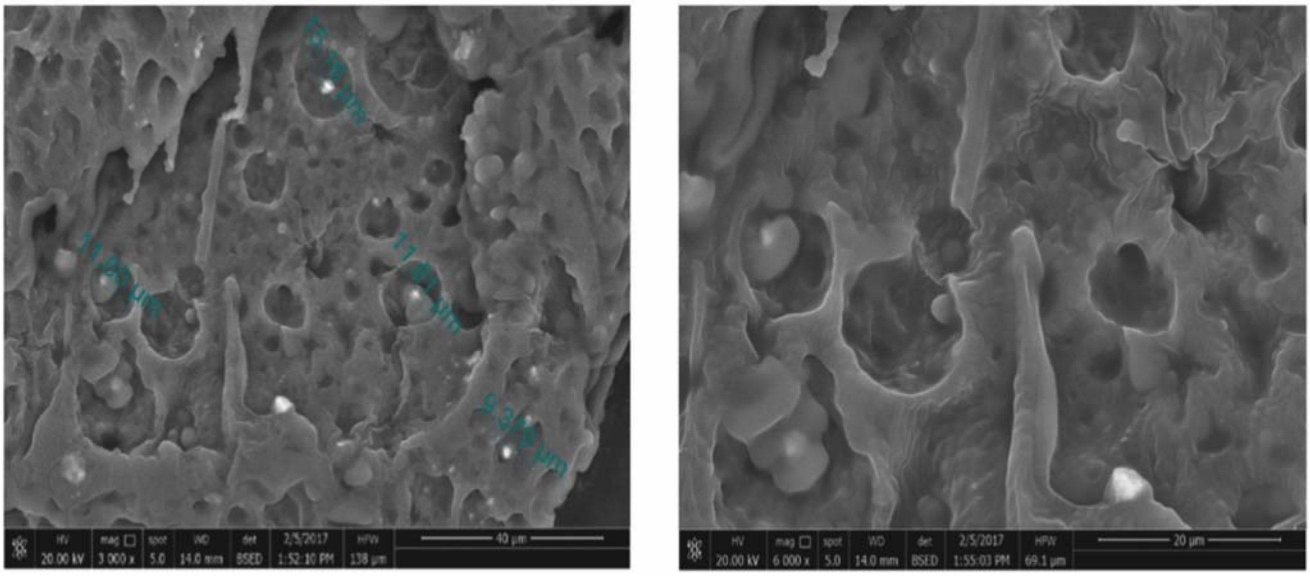

Figure 2 Shows topographic images of K-PLA microspheres

In order to analyze the dependence of the properties of combined polymer films on both structures and morphology, SEM measurements were employed in this study. The morphology of the surfaces of the fractured impact specimens was investigated by SEM, as shown in Figure 2. Combined PLA with dispersed K_2O based on weight percent. The fracture surface of the K-PLA was rougher and more detailed surface features, which displayed the part toughness. Continuous phase morphology consisting of the modified PLA and potassium oxides was obviously obtained in K-PLA biodegradable microspheres.

3.3 Particle size analyzer (PSA)

PSA can be considered a main tool to understand and verify models pertaining to the dynamics of polymers in dilute solution. It allows determining the size and hydrodynamic radius of polymer molecules in solution.

As shown in Figure 3, particle size distribution of PLA which dispersed in aqueous medium presence relative particle diameter measurement distribution over narrow range from 0.3-20 µm of particles by volume distribution as shown in (Table 1).

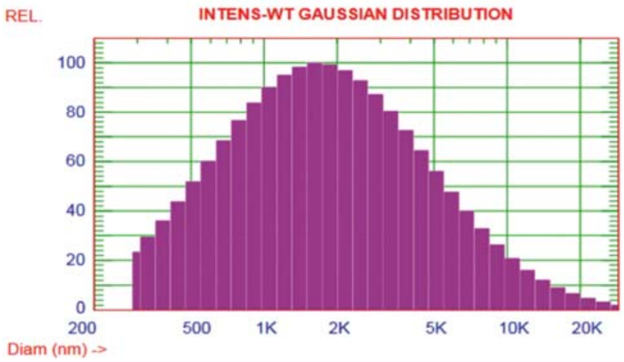

Figure 3 Shows particle size distribution of K-PLA microspheres

Table 1 Illustrated the mean diameter and related parameters

Mean Diameter, nm	Variance P. I.	Norm. Std. Dev.	80% of distribution
2881.4	1.082	1.040	5608.0

Low polydispersity, narrow distribution of particle size, of PLA indicated to homogenized distribution of K_2O. These confirm continuous film with 9-15 µm for K-PLA scanning image and 2.88-20 µm for PSA graph. The stomata pore of Washington Navel orange leaves is elliptical in shape. The average stomata pore lengths and widths for medium-sized leaves of Washington Navel orange, 4.78×2.3 µm (Turrell, 1947). Particle size behaviors give K-PLA microspheres laid in range of application from few µm as leaves coater.

3.4 Thermal behavior and encapsulation percentage

Thermo gravimetric analysis (TGA) contributes evidence on the weight loss due to degradation as a function of temperature. Figure 4 represent the (TG) and its derivative weight% (DTA) of K-PLA. For comparison purposes, the TG and DTA profiles of the pure PLA is also included in Figure 4.

The characteristic thermal parameters selected were onset temperature, which is the initial weight loss temperature, and maximum degradation temperature (T max), which is the highest thermal degradation rate temperature. Thermal degradation of neat PLA takes place in a single weight loss step, which can be an evidence from the DTA curves. The onset degradation peak of pure PLA was 339.60°C, the maximum degradation temperature was 362.60°C and it was completely decomposed at 409.20°C with weight loss percentage 99.85% and ash percentage was 0.15%. However, the onset degradation step of K-PLA starts at 330.33°C and maximum degradation temperature was 399.05°C and continue to complete decomposition at 438.38°C with weight loss percentage 95.35% and ash percentage was 4.65%. The actual encapsulated potassium percentage into PLA microspheres was 4.5 W%.

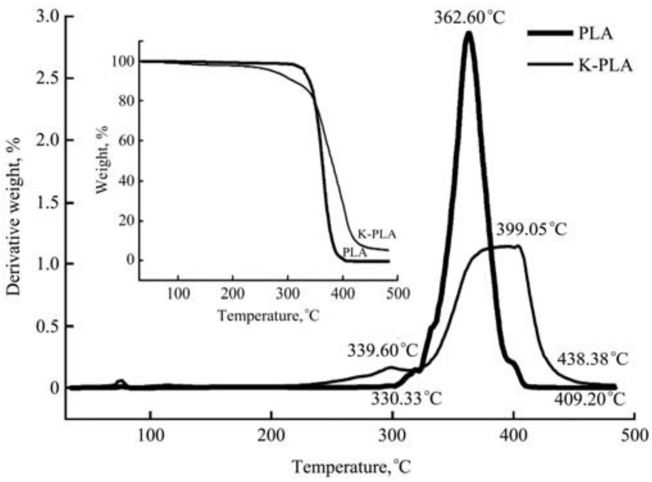

Figure 4 TGA and DTA curves of PLA and K-PLA

3.5 Cumulative release

The cumulative release percentage was shown in Figure 5. As it would be predictable, the release percentages of water soluble potassium fertilizer increase with the extending of releasing times. The polymer will have to release the desired molecules for prolonged periods of time while maintaining polymer form. The maximum release percentage after 12 hours was approximately 3.74 %.

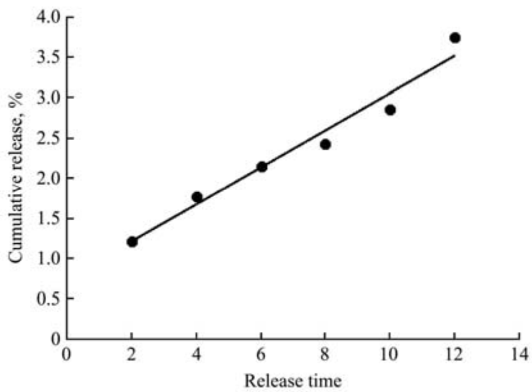

Figure 5 Cumulative release % of potassium fertilizer from K-PLA microspheres

According to encapsulation definition, it should let the core to be isolated from the external environment until release occurred. Therefore, the release at the applicable time is an extremely important property in the encapsulation process, reducing the required dose of compounds of interest and expanding the applications of fertilizers, thus to improve the efficiency. The leading aspects affecting the release rates are associated with interactions between core material and the wall material. Furthermore, further factors influence the release, for example, ratio between the core and wall material, the volatility of the core, viscosity of the wall material, and particle size. The key release mechanisms are degradation, diffusion, pH, temperature -pressure, and use of solvent. Experimentally, more than one mechanism is involved. Diffusion mechanism occurs when the microspheres wall is intact. Temperature variation can stimulate to release. The temperature-responsive release involved two mechanism categories, temperature-sensitive release is remarkably specifically for materials that collapse or expand when a critical temperature is reached, fusion-activated release, in which wall material melts upon temperature increasing. The release mechanism of K-PLA acid microspheres may follow two temperature dependent release mechanism (Gouin, 2004; Desai and Park, 2006; Silva et al., 2014).

3.6 Effect of foliar application with uploaded potassium (K_2O) and loaded potassium (K-PLA) alone or in combination on

3.6.1 Yield and yield components of Washington Navel orange trees

Data in Table 2 showed that all treatments significantly increased average fruit weight, number of fruits/tree, yield (kg)/tree and yield (ton)/feddan than the control.

Table 2 Effect of foliar application with uploaded potassium (K_2O) and loaded potassium encapsulated in polylactic acid (K-PLA) alone or in combination on yield and yield components of Washington Navel orange during 2015 and 2016 seasons

Treatments	Fruit weight, g		No. fruits/tree		Yield /tree, kg		Yield /fed., ton	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	260.0	255.3	269.9	273.3	70.2	69.8	11.2	11.2
100% K_2O	277.5	270.0	289.2	301.8	80.3	81.5	12.9	13.0
100% K-PLA	338.6	332.5	349.9	369.1	118.5	122.7	19.0	19.6
75% K_2O + 25% K-PLA	275.9	273.8	293.6	299.0	81.0	81.9	13.0	13.1
50% K_2O + 50% K-PLA	283.1	279.9	303.0	340.8	85.8	95.4	13.7	15.3
25% K_2O + 75% K-PLA	332.0	330.0	322.6	352.4	107.4	116.3	17.2	18.6
$LSD_{0.05}$	4.9	5.8	3.4	2.7	0.61	0.42	0.53	0.32

The improved yield is due in part to improved fruit set but more commonly as results of an increased number of fruits and fruit weight. The best results regard to all previous parameters was significantly obtained due to spraying Washington Navel orange trees by the sole treatment of loaded potassium (K-PLA 100%) followed in descending order by combined treatments (K_2O 25% + K-PLA 75%), (K_2O 50% + K-PLA 50%) and (K_2O 75% + K-PLA 25%) respectively. However, no significant differences between (K_2O 100%) and (K_2O 75% + KPLA 25%) treatments. In addition, the yield increased by 69.6 and 75% than the control respectively in both seasons with loaded K (K-PLA 100%). While, uploaded (K_2O 100%) were increased by 16.1 and 17 %, consecutively in this respect. Other vise, the lowest statistical value of yield (ton)/feddan was recorded with the untreated trees.

Our results may be due to encapsulation technology which controlled nutrient release from coated fertilizers like (K-PLA). The slow releasing which enhancement the critical role of K_2O in tree productivity as a result to extend the longevity of treatments without any losses by volatization. These results are in agreement with the finding of Rochmadi et al. (2010) who reported that, microencapsulate application is to enclave active one of the chemical solution in which this active compound can be slowly released through the shell of microcapsules. This commonly known as controlled release. Aly et al. (2015) mentioned that spraying Washington Navel orange trees with 2 and 3% potassium sulphate treatments were very effective in improving yield as well as average fruit weight. Average sweet orange production increased after four harvest seasons from 35 to 50 t ha^{-1}/year with an increase in K_2O rate from 0 to 300 kg ha^{-1} per year José et al. (2011). In addition, Maksoud et al. (2003) noticed that foliar application of potassium, calcium and magnesium on Washington Navel orange trees was found to increase yield and improve fruit properties, especially when sprayed during the proper period of growth. Furthermore, nutritional is needs for potassium on four physiological anion neutralization and somatic potential (Clarkson and Hanson, 1980). It is also important information and functioning of proteins, fats carbohydrates and chlorophyll and in maintaining the balance of salt and water in plant cells (Achilea, 1998). Microencapsulation has been widely applied in various areas. One of the microcapsule, application is to enclave active chemical solution in which this active compound can be slowly released through the shell of release (Rochmadi et al., 2010).

From Table 3, data revealed that average fruit weight (pulp and crust) and average fruit dimension (length and diameter) have tacked the same trend in Table 2. As for crust weight, there is a negative effect with all treatments by increasing this parameter than the control. This result may be due to the high level of K. These results are in agreement with José et al. (2011), who reported that the effect K presented on fruit mass, which was primarily associated to an increase in fruit peel thickness. Hafez-Omaima and El-Metwally (2007) on Washington Navel orange who mentioned that, high levels of K caused thick and coarse peel. In contrast K deficiency produced small fruit with thin peel (Aly et al., 2015). It is clearly noticed that the slow release of an active dose of K-PLA 100% was more effective on fruit diameter and length than the control, which was considered the promising treatment. Aly et al. (2015) reported that, 3% K_2SO_4 gave the highest value of average fruit diameter and length in both seasons. Simulation results suggest that the coating lager imperfection lend to earlier and faster nitrogen release than an ideal one Thanh et al. (2015).

Table 3 Effect of foliar application with uploaded potassium (K_2O) and loaded potassium encapsulated in polylactic acid (K-PLA) alone or in combination on fruit weight (pulp and crust) and fruit dimension (length and diameter) of Washington Navel orange during 2015 and 2016 seasons

Treatments	Pulp weight, g		Crust weight, g		Fruit length, cm		Fruit diameter, cm	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	198.0	192.4	62.0	62.9	6.90	6.93	6.79	7.05
100% K_2O	210.3	206.5	65.6	67.3	7.62	7.60	7.47	7.60
100% K-PLA	259.3	253.3	79.3	79.0	8.25	8.22	8.16	8.11
75% K_2O + 25% K-PLA	206.7	199.0	70.8	71.0	7.61	7.59	7.40	7.52
50% K_2O + 50% K-PLA	211.1	207.0	72.0	72.9	7.70	7.69	7.35	7.75
25% K_2O + 75% K-PLA	255.0	252.1	77.9	77.9	7.79	7.96	7.90	8.09
$LSD_{0.05}$	3.4	2.3	1.3	1.4	0.09	0.07	0.08	0.06

3.6.2 Fruit quality

The most serious advantage of k encapsulated is a direct and strong link by fruit quality; Table 4 achieved that foliar application spraying uploaded K (K_2O) and loaded K (K-PLA) alone or in combination three times all over the year was led to increase in fruit color than the control. Markedly and highly percentage of fruit color has been correlated to potassium encapsulated in polylactic acid by 100, 75, 50 and 25%, respectively in the two seasons (Figure 6). There were no significant differences between (K_2O 100%) and (K_2O 75% + K-PLA 25%) treatments on break color. The obtained results may be due to the effect of the slow release of potassium on carotene pigments. These results are in agreement with the finding of Gene et al. (2005) who mentioned that, fruit in plants receiving supplemental foliar K applications were more intensely orange colored than those from control. The intense orange color of potassium treatment fruit was also accompanied by significantly higher beta carotene contents compared to the control.

Also, data in Table 4 revealed that TSS and VC significantly increased but acidity % (TA) decreased. When the level of K-PLA is the optimum 100%, it has the highest effect on this respect than K 100% alone and the control. These results may be due to the major factor by controlled nutrient release (slowly and longevity from polymer coated fertilizers such as potassium encapsulated in polylactic acid.

Table 4 Effect of foliar application with uploaded potassium (K_2O) and loaded potassium encapsulated in polylactic acid (K-PLA) alone or in combination on fruit quality of Washington Navel orange during 2015 and 2016 seasons

Treatments	Coloring, %		Total soluble solids, %		Total acidity, %		Vitamin C, mg/100 mL	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	33.4	35.4	9.8	10.0	0.77	0.79	39.3	40.9
100% K_2O	74.9	79.8	10.9	11.2	0.70	0.63	46.2	43.0
100% K-PLA	98.5	96.9	13.0	13.4	0.59	0.60	51.5	52.9
75% K_2O + 25% K-PLA	77.8	80.0	10.9	11.2	0.69	0.64	46.0	46.2
50% K_2O + 50% K-PLA	85.6	87.2	11.8	12.0	0.65	0.64	47.5	47.3
25% K_2O + 75% K-PLA	91.5	92.8	12.3	12.8	0.64	0.63	47.9	47.3
$LSD_{0.05}$	2.3	0.12	0.13	0.21	0.01	0.02	0.74	0.92

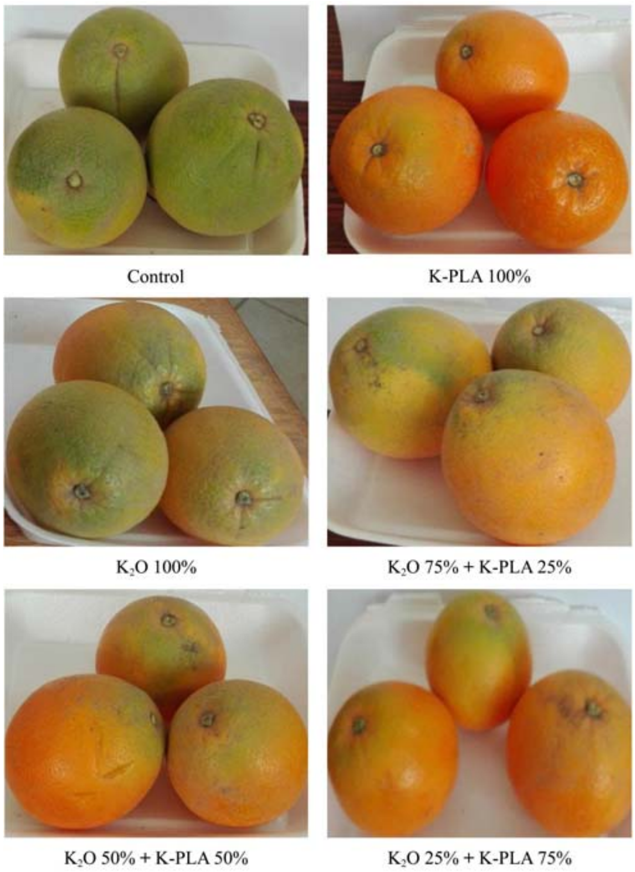

Figure 6 Effect of foliar application with uploaded potassium (K_2O) and loaded potassium encapsulated in polylactic acid (K-PLA) alone or in combination on fruits coloring

These results are in agreements with the finding of Tiwari (2005) and Ashraf et al. (2010), who reported that potassium improves fruit quality by enhancing fruit size, juice contents, color and juice flavor. Aly et al. (2015) noticed that the data indicated that 2 and 3% K_2SO_4 treatments were more effective in increasing vitamin C content and TSS % than other treatments. Gene et al. (2005), Gill et al. (2005) and Rattanpal et al. (2008) reported that foliar application of K increased VC content of citrus fruits. In contrast, Quaggio et al. (2002) found that K rates decreased the soluble solids content of juice because of the increase of peel thickness. In addition, all potassium treatments decreased fruit juice acidity compared with the control treatment. The same trend was obtained by Gene et al. (2005) and Alva et al. (2006). On the other hand, increasing acidity of citrus fruits due to foliar application with K was reported by Gill et al. (2005) and Rattanpal et al. (2008).

4 Conclusion

From our results found that the applied improvement by using foliar sprays of orange trees with encapsulated potassium element into biodegradable polymer (K-PLA). It can significantly increase yield and yield components. In addition, the enhancement of fruit quality due to fruit increment of TSS content, VC and coloring as well as losing in TA % were observed. This is due to the control release of the potassium nutrient (Enhanced to benefit from the potassium element is periodically during the growing stages). It can be recommendation, foliar spraying of Washington Navel orange orchards by loaded potassium formulation is promising to improve the dual benefit, providing fertilizers and environmentally safe.

Acknowledgments

We hereby wish to thank the late Dr/Mamdouh Mohamed Nageib, Pomology Professor, National Research Center (NRC), for providing support and was supplying us the his private farm.

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