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Surface Coating and Modified Atmosphere Packaging Enhances Storage Life and Quality of 'Kaghzi lime'

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ABSTRACT

The study was conducted to assess the effect of different wax coating materials and Modified Atmosphere Packaging (MAP) on storage life and quality of 'Kaghzi lime' (*Citrus aurantifolia* Swing.) fruits. The fruits were harvested at light yellow skin color stage and treated with different wax coating materials: T_1= Citrus Wax (wood resins18%, Imazalil 0.3%, Thiabendazloe 0.5%), T_2= PHRC SCM Wax [9% total solids (castor and shellac based wax)]; T_3= Modified Atmosphere Packaging (MAP), and T_0= The fruit without any treatment were used as control. The fruits were stored at 10°C for 45 days and relative humidity was maintained at 90%. Physiochemical, sensory, organoleptic, and quality parameters were measured after 30 and 45 days of harvesting. The coating treatments significantly ($P \leq 0.05$) reduced physiological weight loss, increased shelf life and maintained the quality of fruits. Among all treatments, Citrus Wax proved best because it maintained relatively higher levels of acidity, flavor, vitamin C content and fruit firmness; prevented disease attack; and improved juice recovery of lime fruits compared with control. Thus this treatment can be used to enhance the shelf life and maintain quality of the lime fruits.

Keywords: *Citrus aurantifolia*, Lime, Postharvest treatment, Shelf life, Wax application.

INTRODUCTION

Citrus is the most important fruit crop of Pakistan. Citrus orchards are prevalent over an area of 193,785 hectares with an annual production of 2.17 million tons (AMIS, 2014). Although the area and production of limes are less compared with other commercial citrus cultivars such as mandarins and sweet orange but because of unique culinary uses and medicinal properties this is utilized throughout the year. Lime is a non-climacteric fruit, thus tree ripened fruits are harvested and marketed. Likewise other fruits, limes are perishable; 25-40% harvested fruits are lost before consumption because of poor postharvest handling practices and microbial attack (Mahajan and Singh, 2008). Once the fruit is harvested from plants its quality needs to be maintained, thus it can be transported to distant markets. Although lime has a fairly good shelf life, however, a further enhancement is required to fulfill the

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requirement during the off-season when market demands are higher. In addition to shelf life, maintenance of the fruit quality is also very important to fulfill consumer preferences. The postharvest losses can be minimized by reducing the rate of respiration, transpiration, microbial infection, and protecting membranes from disorganization (Bisen *et al.,* 2012). In a recent report, Bodbodak and Moshfeghifar (2016) reported that postharvest treatments and Modified Atmosphere Packaging (MAP) can extend the shelf life of the product by up to 50-200%. Similarly, a lot of studies have been conducted to enhance the storage life and to maintain the quality of pomegranate (Mirdehghan and Ghotbi, 2014; Banda *et al.,* 2015), broccoli, mushroom and tomato (Tano *et al.,* 2007), apricot (Saba *et al.,* 2016) and citrus fruits such as oranges, mandarins, and grapefruits (Njombolwana *et al.,* 2013; Hassan *et al.,* 2014; Arnon *et al.,* 2014; Wang *et al.,* 2014) but relatively information is available regarding lime fruits. So keeping in view the above said situation,the present study was conducted to assess the effect of surface coating materials and MAP to enhance the storage life and maintain the quality of lime fruits.

MATERIALS AND METHODS

The light yellow, mature and uniform Kaghzi lime (*Citrus aurantifolia* Swing.) fruits were harvested from ten year old lime tress growing at a citrus fruit farm situated at Kot Muhammad Yar, Sargodha, Pakistan. This area belongs to a sub-tropical environment. Average temperature during the month of January remains around 10-11ºC then it gradually rises to 34ºC during June and again gradually decreases (Nawaz *et al.,* 2016). The fruits were washed and manually sorted by size and color. Only water sinker fruits were utilized in this study. Sixty fruits were used for each treatment, divided into groups of 20 fruits for each replicate. A total of four treatments were used in this study, T_0 (control); T_1 [fruits treated with Citrus Wax (wood resins 18%, Imazalil 0.3%, thiabendazle 0.5%)]; T_2 {fruits treated with PHRC SCM Wax [9% total solids (castor and shellac based)]}, T_3 [fruits stored in MAP (Modified Atmosphere Packaging)]. Citrus Wax is a kind of wax that is used by the commercial citrus processing units situated at Sargodha, Punjab, Pakistan, whereas PHRC SCM Wax was developed by Postharvest Research Center, Ayyub Agricultural Research Institute, Faisalabad, Pakistan. After the application of postharvest treatments, fruits were stored in a storage chamber at 10ºC and relative humidity was maintained at 90%. Data for different parameters related with shelf life and quality of fruits were taken after 30 and 45 days of storage using three replications. Five fruits were randomly selected from each treatment for chemical parameters (total soluble solids, juice percentage, titratable acidity, and vitamin C content) and physical and organoleptic analysis (physiological weight loss, taste, flavor, aroma, external color, firmness, and disease incidence) separately and the experiment was repeated three times. The laboratory work was carried out at Postharvest Research and Training Center, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.

The Physiological Weight Loss (PWL) was determined by using the following formula:

Weight loss (%)= [(A−B)/A]×100

Where, *A* indicates the fruit weight at the time of harvest and *B* indicates the fruit weight at specific interval.

Peel color was scored manually according to the scale; 5= Full yellow; 4= 75% yellow; 3= 50% yellow; 2= 25% yellow and 1= green (Ahmed, 2005). Firmness of lime fruits was determined by hand feeling using a numerical rating scale of 1-5, where 1: Hard; 2: Sprung; 3: Slightly soft; 4: Eating soft (ripe), and 5: Over ripe (Malik and Singh, 2005).

Titratable Acidity (TA) was determined by using the method described by Hortzwiz (1960).

$$\textbf{TA (\%)} = \frac{\text{N/10 NaOH used} \times 0.0064 \times 100}{\text{Volume of sample used}}$$

Total Soluble Solids (TSS) were measured by placing one to two drops of fruit juice on the lens of hand refractometer (MASTER-AGRI, ATAGO, USA) and the reading was expressed as %Brix. L-Ascorbic acid (vitamin C) was determined by the method described by Barakat *et al.* (1973). Briefly, 10 ml potassium iodide (5%) was added to each 5 ml of fruit juice and then three drops of starch solution (1%) were added. Subsequently a solution of copper sulfate 0.01M was poured into burette and titration was performed until the appearance of the first symptoms of red color. Volume of consumed copper sulfate was recorded and the amount of vitamin C was calculated according to the following formula:

Ascorbic acid (mg 100 ml^{-1} juice)= 0.88×Volume of copper sulfate used

Where, 0.88 is a coefficient based on the amount of ascorbic acid required to neutralize1 ml copper sulfate (0.1 M). Juice percentage was determined by extracting the juice of fruits by a juice squeezer juice weight was measured by an electric balance and then juice percentage was calculated.

Fruit samples were evaluated for taste, flavor and aroma by a panel of five experts using the Hedonic scale (Larmond, 1977). Similarly, a panel of five experts performed disease scoring by using a disease rating scale, where 1 represents no disease affected fruit surface; 2 represents < 1%; 3 represents 1-5%; 4 represents 6-10%; 5 represents 11-25%; 6 represents 26-50%, and 7 represents over 50% disease affected fruit surface. The experiment was conducted according to factorial with completely randomized design. The collected data was subjected to statistical analysis using Analysis Of Variance (ANOVA) techniques and means were compared by least significant difference test ($P \leq 0.05$, 0.01). The mean squares for different physiochemical and organoleptic characteristics of lime fruits under different postharvest treatments are presented in Table 1.

RESULTS AND DISCUSSION

Physiological Weight Loss (%)

The Physiological Weight Loss (PWL) of fruits was increased with an increase in storage period (Figure 1-A). Highest *PWL* (33.46%) was observed in control treatment after 45 days of storage. However, a minimal *PWL* was observed in lime in response to postharvest treatments during the corresponding period. Fruits stored in MAP showed a minimum *PWL* (1.04%) followed by Citrus Wax (18.35%). The results of this study are similar with the previous findings where MAP and wax treatments helped reduce *PWL* (Sandhya, 2010; Bisen *et al.,* 2012). MAP is associated with physiochemical changes in fruits (Sandhya, 2010) and it improves the shelf life of sweet cherries (Giacalone and Chiabrando, 2013). MAP reduces rate of transpiration from fruit surface by enhancing the humidity around the fruits, within the

Table 1. Mean squares of different physiochemical and organoleptic characteristics under different postharvest treatments and storage period.[a]

SOV [a]	PWL [b]	TSS [c]	TA [d]	VC [e]	Taste	Fl [f]	Ar [g]	EC [h]	J [i]	Ds [j]	Fr [k]
T [l]	1092.36**	0.54**	0.27**	92.10**	0.92*	0.92*	3.03**	1.52**	85.96**	1.00**	1.97**
S [m]	317.84**	0.002NS	0.03*	1279.11**	4.41**	4.41**	0.74**	11.37**	63.27**	2.78**	2.79**
T×S [n]	34.83**	0.11**	0.05*	11.28*	0.36*	0.36*	0.62**		3.93*	0.39**	0.28**

[a] Source of variation, [b] Physiological Weight Loss, [c] Total Soluble Solids, [d] Titrable Acidity; [e] Vitamin C; [f] Flavor; [g] Aroma, [h] External Color, [i] Juice percentage, [j] Disease incidence, [k] and Fr= Firmness, [l] Postharvest Treatments, [m] Storage time, [n] Interaction between postharvest Treatments and Storage time.* $P \leq 0.05$; ** $P \leq 0.01$, NS= Non Significant.

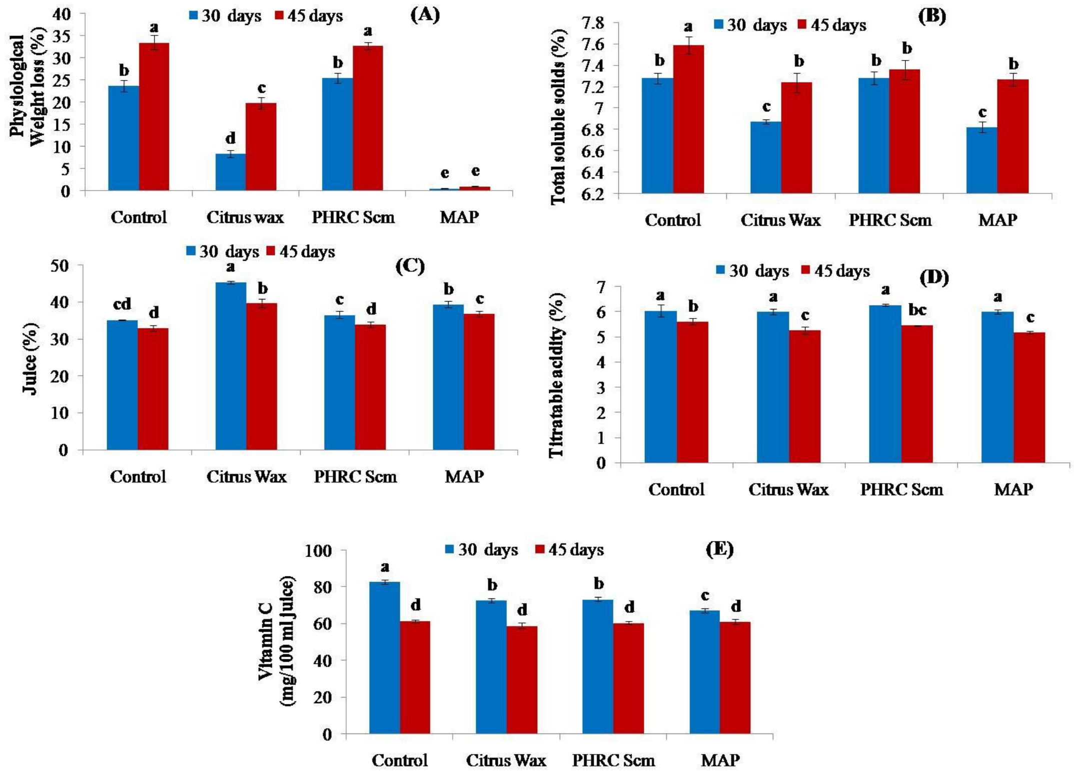

Figure 1. Effect of citrus wax, PHRC SCM, and MAP on physiological weight loss (A), total soluble solids (B), juice percentage (C), titrable acidicity (D), and vitamin C content (E) of lime fruits at $P \leq 0.05$.

packaging material (Mathooko, 2003) that seem the possible reason for reduction in weight loss. The reason of low *PWL* in fruits treated with Citrus Wax may be the anti-senescence property of wax resulting in slow respiratory rate, transpiration rate and lessethylene biosynthesis (Tomas *et al.*, 2005).

Total Soluble Solids

TSS content of lime fruits were increased progressively with an increase in storage period (Figure 1-B). After 30 days of storage highest TSS (7.28%) was found in untreated fruits (control) while lowest TSS (6.82%) was observed in fruits treated with MAP. Similarly after 45 days of storage, highest TSS (7.59%) was observed in untreated fruits while the minimum TSS (7.24%) was observed in fruits treated with Citrus Wax. In some previous reports an increase in TSS content during storage has been observed in several fruits such as orange (Baldwin *et al.*, 1995), guava (Bashir and Abu-Goukh, 2003), and apple (El-Anany *et al.*, 2009). The increase in TSS content of fruits is directly correlated with the hydrolytic activities of starch that indicates fruits are undergoing the ripening process (Hassan *et al.*, 2014). Moreover, as the water loss from untreated fruits was higher compared with other treatments, thus the concentration of sugars was increased leading towards improved TSS content. Limes are utilized particularly to get an acidic taste, if the TSS increases, it adversely affects the lime fruit quality. So maintenance of low TSS is required so that it can be achieved by applying surface coating materials or MAP.

Juice Percentage

The juice percentage of lime fruit is a very important quality parameter. In the present study, juice percentage of lime fruits decreased with an increase in storage period in all treatments (Figure 1-C). The maximum juice 45.36 and 39.70% was obtained from fruits treated with Citrus Wax after 30 and 45 days of storage, respectively, while minimum juice (35.13 and 32.94%) was obtained from untreated fruits (control) after 30 and 45 days of harvesting, respectively. The reason for high juice content in Citrus Wax treatment is the minimum loss of water from the fruit surface. Previously, the highest juice content was also found in citrus fruits coated with different wax emulsions (Bullar,1988)

Titrable Acidity

Titrable Acidity (TA) was decreased with an increase in storage period irrespective of the treatments (Figure 1-D). The highest TA (6.27%) was recorded in PHRC SCM treated fruits followed by untreated fruits (6.04%), after 45 days of storage. However after 30 days of storage, the highest TA (5.61%) was observed in untreated fruits followed by PHRC SCM (5.45%) while the lowest TA (5.17%) was found in fruits stored in MAP. Fruits treated with MAP had the least TA compared with other treatments. Similar results were also found in a previous report where TA of fruits was decreased with extended storage conditions (Bisen *et al.*, 2012); however our results were contrary to the findings of Sharma and Sandhooja (1991). The reduction in acid content of fruits can be attributed to the conversion of organic acids to sugars during the process of respiration (Wills *et al.*,1998).

Vitamin C

Vitamin C is among the most important quality parameters for fruits. In the present investigation, vitamin C content was decreased with an increase in storage time (Figure 1-E). The highest vitamin content (82.73 mg 100 ml^{-1} juice) after 30 days of storage was found in untreated fruits while the minimum (67.16 mg 100 ml^{-1} juice) was found in fruits with MAP. After 45 days, the highest vitamin C (61.53 mg 100 ml^{-1} juice) was also observed in untreated fruits while the lowest amount of vitamin C (58.92 mg 100 ml^{-1} juice) was observed in fruits treated with Citrus Wax, however the differences were non-significant. Our findings are in agreement with some previous studies (Jadhao *et al.,* 2008; Bisen *et al.,* 2012) where vitamin C content was slightly reduced during the storage. The decline in vitamin C content seems to be caused by the oxidation of ascorbic acid by enzymes; surface coating treatments might have triggered the action of the enzymes during storage (Singh and Chauhan, 1993).

Taste

Taste is an imperative attribute towards consumer choice. It is a sensation when any substance entered into the mouth reacts chemically with the taste receptor present on the tongue. In case of lime fruits, the taste is considered a key importance while purchasing fruit. In the present study, the value of fruit taste rating scale decreased with an increasing storage time in all four treatments under observation (Figure 2-A). The highest taste value was recorded in MAP treated fruits after 30 days of storage, but later on a rapid decrease in taste index it was also observed in the same treatment (MAP) during extended storage (45 days). The highest value of taste index after 45 days of storage was observed in fruits treated with Citrus Wax. Previously it was reported that bee wax treated fruits have a better taste compared to MAP (Bisen *et al.,* 2012). The minimum value of taste in MAP treatment after 45 days is supposed to be the result of anaerobic respiration that needs further investigation. Similar concerns have been raised by several other researchers where they highlighted the importance of gaseous concentration and temperature during MAP, otherwise the quality of fruits

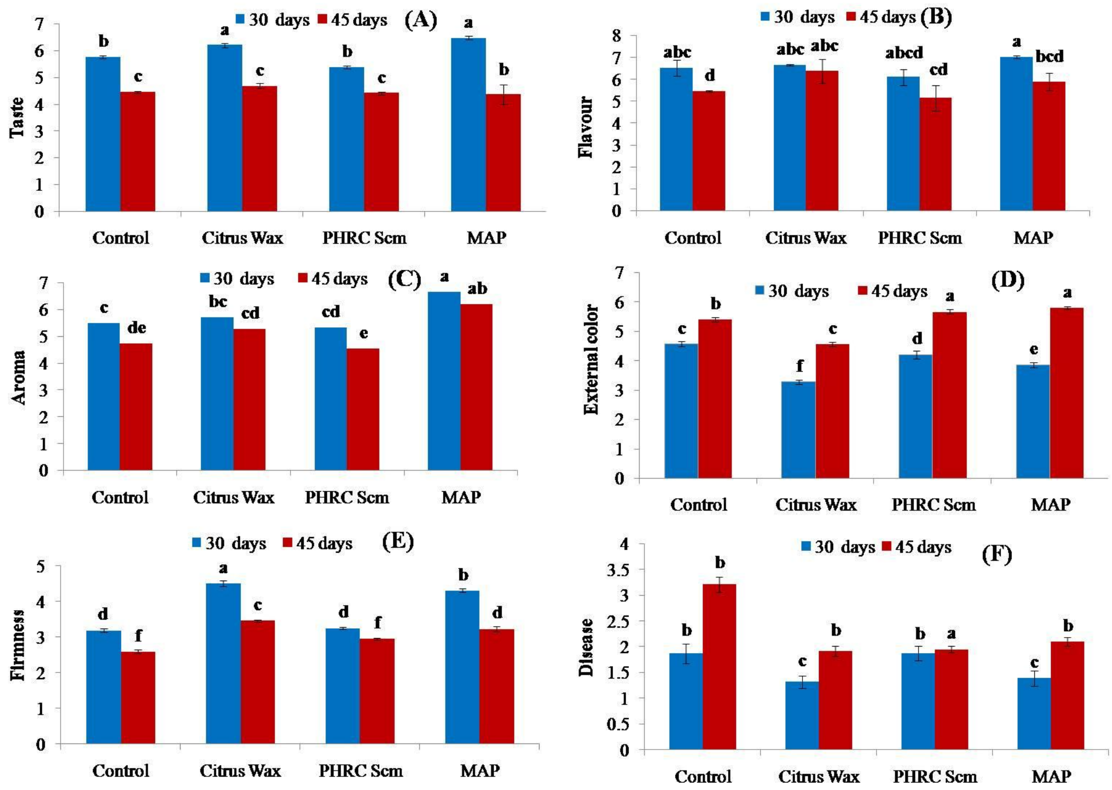

Figure 2. Effect of Citrus Wax, PHRC SCM and MAP on taste (A), flavor (B), aroma (C), external color (D), firmness (E), and disease incidence (F) of lime fruits at $P \leq 0.05$.

and vegetables is compromised (Tano *et al.*, 2007; Banda *et al.*, 2015).

Flavor

Flavor is an important quality parameter that is primarily determined by the taste and smell of fruits. It gains special consideration in case of fruit juices. A reduction in the value of flavor was observed with an increase in storage period in all four treatments (Figure 2-B). However, the reduction in flavor value was minimal in fruits coated with Citrus Wax compared with other treatments under consideration. The maximum value of flavor (6.38) was recorded under Citrus Wax treatment and the minimum value of flavor (5.14) was recorded in the fruits treated with PHRC SCM after 45 days of storage. Previously the decrease in flavor of lime fruits was also reported by Bisen *et al.* (2012). Since the highest value of flavor after 45 days was recorded in fruits treated with Citrus Wax, a minimum decrease in flavor value was observed in this treatment compared with control. Hence the Citrus Wax can be considered the best treatment. Sometimes the wax application disturbs the function of oil glands and triggers postharvest pitting that affects fruit cosmetics and other quality attributes such as flavor (Petracek *et al.*, 1998), this problem may be solved by changing the wax components (Dou and Ismail, 1999). Sharma and Sandhooja (1991) investigated that application of sesame oil has significant effects on the firmness, flavor, and aroma of Kinnow (C*itrus reticulata*) fruits.

Aroma

Aroma is another quality parameter of lime fruits, preferred mainly by consumers in Asia. It is described by the odor of a substance sensed by the nose. It is because of the volatile compounds found in the peel of citrus fruits. The oil glands present on skin of citrus fruits are responsible for aroma. The organoleptic value of aroma was decreased with the passage of time during storage (Figure 2-C). A significant decline in aroma was observed in all four treatments under consideration. The maximum values for aroma 6.64 and 6.18 were recorded in fruits stored in MAP after 30 and 45 days of storage respectively, while minimum value (4.54) was recorded in fruits treated with PHRC SCM after 45 days of storage.

External Color

An obvious improvement in external color of fruits was observed in all four treatments with an increase in storage time (Figure 2-D). Maximum improvement of external color (33.44%) was observed under MAP treatment while minimum improvement of external color (16.66%) was observed in untreated fruits. The minimum value of color (4.56) after 45 days of storage was observed in fruits treated with Citrus Wax that had high acceptability in the market. Our findings are in accordance with previous studies stating that citrus fruits coated with Citrus Wax have better appearance compared with untreated fruits (Dhemre and Wasker, 2003). The minimum color change in Citrus Wax treated fruits seems to be caused by delay in senescence process, slow metabolic, as well as enzymatic activities and less pigment breakdowns.

Firmness

Fruit firmness is an important criterion to assess the quality of lime fruits. The firmness of lime fruits was reduced with an increased storage period in all four treatments (Figure 2-E). However, the treated fruits maintained relatively higher firmness compared with untreated fruits (control). The maximum value of firmness (3.46) was found in fruits treated with Citrus Wax after 30 days and the minimum value (2.59) was recorded in untreated fruits after 45 days of storage. Our results were similar with Hagenmaier and Baker (1995) who reported that wax coating reduces shriveling of citrus fruits. The maintenance of firmness in wax coated fruits may be attributed to slow degradation of insoluble protopectins to additional soluble pectin, and reduced water loss from the fruit surface (Yaman and Bayoindirli, 2002).

Diseases Infestation

Diseases play a major role in the loss of fruits after harvesting, resulting in less profit to farmers because of low market value of the product. Stomata have been described as the first door of entry for pathogens into the fruits (Meeterenand Aliniaeifard, 2016). In the present study, postharvest treatments were used to assess the reduction in disease infestation on lime fruit surface. After 45 days of storage the highest disease score (3.21) was observed in untreated fruits (control) while minimum disease index (1.92) was observed in the fruits treated with Citrus Wax (Figure 2-F). Citrus Wax evidently repressed the growth of fungus and bacteria on fruit surface followed by PHRC SCM treatment. It may be because of sealing stomata and other minor surface injuries with the coatings material (Citrus Wax and PHRC SCM) thereby preventing the entry of pathogens into the fruit. In some previous reports it was found that the application of wax coating on apple and guava fruits reduces disease incidence during storage (Chandra, 1995; Petracek *et al.*, 1998; El-Anany *et al.*, 2009; Meeteren and Aliniaeifard, 2016).

CONCLUSIONS

Keeping in view the overall performance of different treatments, it can be concluded that Citrus Wax proved better compared with all other treatments followed by MAP. Citrus Wax played an important role in improving the shelf life and maintaining the quality of lime fruits. Most of the quality parameters such as physiological weight loss, total soluble solids, juice percentage, titratable acidity, vitamin C content, taste, flavor, external color and firmness remained stable for the lime fruits treated with Citrus Wax. Similarly, disease incidence was also considerably lower compared with untreated lime fruits; therefore Citrus Wax can be utilized on commercial scale to enhance the shelf life and to maintain the quality of lime fruits. We hope this information will be useful for the stakeholders involved in the production, storage and marketing of lime fruits.

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افزایش طول عمر ذخیره سازی و کیفیت "Kaghzi lime" توسط پوشش سطحی و بسته بندی محیطی اصلاح شده

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چکیده

این مطالعه به منظور بررسی اثر مواد مومی مختلف پوشش دهنده و بسته بندی محیطی اصلاح شده (MAP) بر روی عمر انبارداری و کیفیت لیمو ترش (*Citrus aurantifolia* Swing) انجام شد. این میوه ها در زمانی که پوستشان زرد می شود برداشت شدند و با مواد پوششی مختلف تیمار شدند: ۱- واکس مرکبات (wood resins 18%, Imazalil 0.3%, Thiabendazloe 0.5%) ۲- موم PHRC SCM (۹٪ کل مواد جامد (castor and shellac based wax)) ۳- بسته بندی محیطی اصلاح شده (MAP) و میوه بدون هیچ گونه درمان به عنوان شاهد (T_0) میوه ها در دمای ۱۰ درجه سانتیگراد برای ۴۵ روز ذخیره و در رطوبت نسبی ۹۰ درصد نگهداری شدند. بعد از ۳۰ و ۴۵ روز از برداشت، پارامترهای فیزیکی، شیمیایی، حساسیت، ارگانولپتیک و کیفیت اندازه گیری شد. تیمارهای پوششی به طور معنی داری ($p \leq 0.05$) باعث کاهش وزن فیزیولوژیکی، افزایش طول عمر و حفظ کیفیت میوه ها شدند. در میان تمام تیمار ها، موم مرکبات به بهترین شکل ثابت شد، زیرا بالاترین میزان اسیدی ، طعم و مزه، محتوای ویتامین C و استحکام میوه را حفظ کرده بود؛ همچنین مانع از حمله بیماری؛ و بهبود آب میوه ها در مقایسه با میوه های شاهد گشته بود. بنابراین این درمان می تواند برای افزایش عمر مفید و حفظ کیفیت این میوه ها مورد استفاده قرار گیرد.