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Effect of Gibberellic Acid and Waxing on Quality and Storability of Lime Fruits

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Abstract: The effect of post-harvest treatment of gibberellic acid (GA_3) and/or waxing on quality and storability of lime fruits at 18 ± 1°C and 85% – 90% relative humidity was evaluated. Treatment with 50 and 100 ppm GA_3 delayed senescence, maintained quality and extended storage life of lime fruits. The higher the concentration of GA_3 the more was the effect. Treatment with GA_3 and waxing was more effective than treatment with GA_3 alone. The effects of GA_3 and/or waxing in delaying senescence, maintaining quality and extending storage life of limes was manifested in reduced respiration rate, weight loss, fruit softening and total soluble solids accumulation, delayed peel colour development (degreening), decreased titratable acidity and increased ascorbic acid retention.

Key words: Lime fruits; gibberellic acid; fruit quality; storability

INTRODUCTION

Lime (*Citrus aurantifolia* L.) is an important subtropical fruit crop. The fruits are used as a condiment, acidulate and beverage. In Sudan, lime is grown in most parts of the country for local consumption and it is gaining importance as export crop, especially to the Gulf States. The seasonality of production, difficulty in storing the fruit and the instability of the juice contribute to the wide fluctuation in prices and quality of limes (Al-Ashwah *et al.* 1981).

Limes should be picked while still green, but after the skin has become smooth and the fruits are mature and somewhat rounded (Hardenburg *et al.*

1986). The market for fresh limes requires the fruit to be dark-green in colour, with minimum yellowing and un-wilted (Stother 1970). It is essential that the fruit should remain firm and lose the minimum amount of water during storage and marketing (Blunden *et al.* 1979)

Plant-growth regulators are a potential means of regulating various aspects of fruit maturity, ripening and senescence. In citrus industry, they proved to be effective in stimulating a number of desirable responses, such as decreasing fruit drop, increasing fruit size, improving fruit set, delaying fruit maturity, ripening and senescence and extending the shelf-life (Coggins and Hield 1989). It has been demonstrated that gibberellic acid (GA_3) delays loss of green rind pigment in limes (Biasi and Zanette 2000), guavas (Mohamed-Nour 2007) and bananas (Osman and Abu-Goukh 2008)

Citrus fruits lose water, shrivel rapidly and lose consumer appeal during marketing and storage. Waxing of fruits retards moisture loss, maintains turgidity and plumpness and covers surface injuries (Wills *et al.* 1998). Waxing was reported to delay fruit ripening and senescence, reduce water loss, maintain quality and extend shelf-life of mangoes (Mohamed and Abu-Goukh 2003), guavas (Mohamed-Nour 2007), grapefruits (Abu-Goukh and Elshiekh 2008) and limes (Ayoub and Abu-Goukh 2009),

This study was carried out to evaluate the effect of gibberellic acid and waxing on quality and storability of lime fruits.

MATERIALS AND METHODS

Experimental Materials

Fruits of ‘Balady’ lime were harvested at the mature-green (full dark-green) stage from Al-Kordi Farm at Soba, south of Khartoum (15^o 40’N, 32^o 22’E). They were selected for uniformity of size, colour and freedom from blemishes and defects. The fruits were transported to the laboratory, washed with tap water to remove dust, dried and treated with 200 ppm sodium hypochlorite (Clorox, 5%) as a disinfectant.

Fruit Treatment

The fruits were distributed among six treatments (600 fruits each) in a randomized complete block design with four replications. The treatments were 0, 50, and 100 ppm GA_3 with or without waxing. The GA_3 treatments were applied by dipping the fruit for three minutes in 50 or 100 ppm GA_3 solution (Sigma Chemical Company) and air dried. The untreated fruits (control) were dipped in distilled water for three minutes and air dried. Food-grade wax (Flucka AG, CH 9470 Buchs) was used for the wax treatment. The wax was applied in a thin layer by brushing over the surface of the fruit. The fruits were stored for six weeks at 18 ± 1°C and 85% – 90% relative humidity.

Parameters Studied

Respiration rate (in mg CO_2 / kg-hr.) was determined in 50 fruits from each replicate at weekly intervals, during the storage period, using the total absorption method (Mohamed-Nour and Abu-Goukh 2010). Peel colour score and weight loss were also determined weekly in the same 50 fruits. The colour score used was mature-green (=0), 25% yellow (=1), 50% yellow (=2), 75% yellow (=3) and 100% yellow (=4). Weight loss was determined according to the formula: $w_l = [(w_0 - w_t)/w_0] \times 100$, where w_l is the percentage weight loss at the designated time, w_0 is the initial weight of fruits, and w_t is the weight of fruits at the designated time.

Firmness of fruit flesh, total soluble solids (TSS), titratable acidity and ascorbic acid content were determined weekly in three fruits selected randomly. Fruit firmness was measured by Magness and Taylor firmness tester (D-Ballautf Meg.Co.) equipped with an 8 mm-diameter plunger tip. Two readings were taken from opposite sides of each fruit after the peel was removed, and the firmness was expressed in kilogrammes per square centimeter. TSS was determined directly from the fruit juice extracted by pressing the fruit pulp in a garlic press, using a Kruss hand refractometer (Model HRN-32). Two readings were taken from each fruit and the mean values were calculated and corrected according to the refractometer chart.

Thirty grammes of fruit pulp were homogenized in 100 ml of distilled water for one minute in a Sanyo Solid State Blender (Model SM 228P) and then centrifuged at 10 000 rpm for 10 minutes using a Gallenkamp portable centrifuge (CF-400). The volume of the supernatant, which constituted the pulp extract, was determined. Titratable acidity in the pulp extracts was determined by the method described by Ranganna (1979) and expressed as percent citric acid. Ascorbic acid content in the pulp extracts was determined, using the 2, 6 -dichlorophenol- indophenol titration method of Ruck (1963), and expressed in milligrammes per 100 grammes fresh weight.

Statistical Analysis

Analysis of variance and Fisher's protected LSD test with a significance level of $P \leq 0.05$ were performed on the data (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Gibberellic acid (GA_3) treatment significantly delayed senescence, maintained quality and extended shelf-life of lime fruits. Similar results were reported for tomatoes (Dostal and Leopold 1967), guavas (Mohamed-Nour 2007) and bananas (Osman and Abu-Goukh 2008).Waxing in addition to GA_3 treatment resulted in more delay in senescence and extension of shelf-life of lime fruits. These effects of GA_3 and waxing on quality and shelf-life of limes were reflected in changes in respiration rate, peel colour, water loss, flesh firmness, TSS, titratable acidity and ascorbic acid content.

Effect on Respiration Rate

The respiration curves of all treatments exhibited a typical non-climacteric pattern (Fig. 1-A). This is in agreement with the findings of Aharoni (1968) who reported that citrus fruits harvested near horticultural maturity show a gradual decline in respiration rate and produce no ethylene. Higher respiration rates during the early stages of storage than later ones were reported in grapefruits (Abu-Goukh and Elshiekh 2008) and limes (Ayoub and Abu-Goukh 2009).

Treatment with the two GA_3 concentrations decreased respiration rate; the higher the concentration the more was the decrease. The respiration rate of the untreated fruits decreased from 18.4 to 15.0 mg CO_2/kg-hr after six weeks of storage. It was 1.3% and 2.0% less in fruits treated with 50 and 100 ppm GA_3, respectively, compared to the control (Fig. 1-A). This agrees with previous reports that GA_3 lowers the respiration rate in guava (Mohamed-Nour 2007) and banana (Osman and Abu-Goukh 2008) fruits. Lewis *et al.* (1967) reported that GA_3 lowered the rate of oxygen uptake in 'Navel' oranges and they found that the treated fruits had a lower ratio of monovalent to divalent cations and a higher phosphorus level than the control. They proposed that the integrity of the mitochondrial membranes was affected by GA_3.

Treatment with GA_3 and waxing was more effective in reducing respiration rate than treatment with GA_3 alone. The decrease in respiration rate was 4.0% and 5.0% in the waxed fruits treated with 50 and 100 ppm GA_3, respectively, compared to the control (Fig. 1-A). Waxing was reported to reduce respiration in oranges (Martinez *et al.* 1991), mangoes (Mohamed and Abu-Goukh 2003), guavas (Mohamed-Nour 2007), grapefruits (Abu-Goukh and Elshiekh 2008), and limes (Ayoub and Abu-Goukh 2009). Waxing has been shown to influence respiration rate by decreasing oxygen and increasing carbon dioxide content in the internal atmosphere of the fruit (Irving and Warren 1960).

Effect on Peel Colour

Peel colour score progressively increased during storage of lime fruits regardless of the treatment. Significant delay in peel colour development was obtained in fruits treated with GA_3 (Fig. 1-B). At the end of the 6-week storage period, the untreated fruits reached the maximum yellow stage (colour score 1.35), while the fruits treated with 50 and 100 ppm GA_3 without waxing only reached 0.87 and 0.72 colour score, respectively. This is in agreement with previous reports that GA_3 delays loss of green rind pigment in tomatoes (Dostal and Leopold 1967), limes (Biasi and Zanette 2000), guavas (Mohamed-Nour 2007) and bananas (Osman and Abu-Goukh 2008). GA_3 delayed chlorophyll degradation in bananas (Vendrell 1970). Fletchner and Osborne (1965) suggested that GA_3 regulates protein and nucleic acid synthesis and thus retains the chlorophyll moiety.

The treatment with GA_3 and waxing was more effective in delaying peel colour development in limes than treatment with GA_3 alone (Fig. 1-B). After 6 weeks of storage, the colour score was 0.94, 0.52 and 0.28 in the waxed fruits compared to 1.35, 0.87 and 0.72 in the unwaxed fruits treated with 0, 50 and 100 ppm GA_3, respectively (Fig. 1-B). This agrees with reports that waxing delays chlorophyll degradation and skin colour development in limes (Blunden *et al*. 1979; Ayoub Abu-Goukh 2009) oranges (Martinez *et al*. 1991), mangoes (Mohamed and Abu-Goukh 2003), and grapefruits (Abu-Goukh and Elshiekh 2008)

Effect on Weight Loss

Weight loss progressively increased during storage of lime fruits regardless of the treatment (Fig. 1-C). The GA_3 with or without waxing significantly reduced weight loss in both concentrations, the higher the concentration the more was the reduction in weight loss. At the end of the 6-week storage period, weight loss was 36% in the untreated fruits. It was reduced by 4.3% and 9.3% in fruits treated with 50 and 100 ppm GA_3 without waxing, respectively, compared to the control (Fig. 1-C). This is in line with previous reports that growth regulators reduce weight loss during storage of fruits. GA_3 was reported to reduce weight loss during storage of bananas (Osman and Abu-Goukh 2008) and 2,4,5-T during storage of limes (Ayoub and Abu-Goukh 2009).

Treatment with GA_3 and waxing was more effective in reducing weight loss than GA_3 treatment alone. Weight loss was reduced by 15.1%, 22.6% and 30.9% in fruits treated with 0, 50 and 100 ppm GA_3 with waxing, respectively, compared to the untreated fruits (Fig. 1-C). This is consistent with the reports that waxing decreases water loss in oranges (Martinez *et al*. 1991), mangoes (Mohamed and Abu-Goukh 2003), guavas (Mohamd-Nour 2007), grapefruits (Abu-Goukh and Elshiekh 2008) and limes (Ayoub and Abu-Goukh 2009).

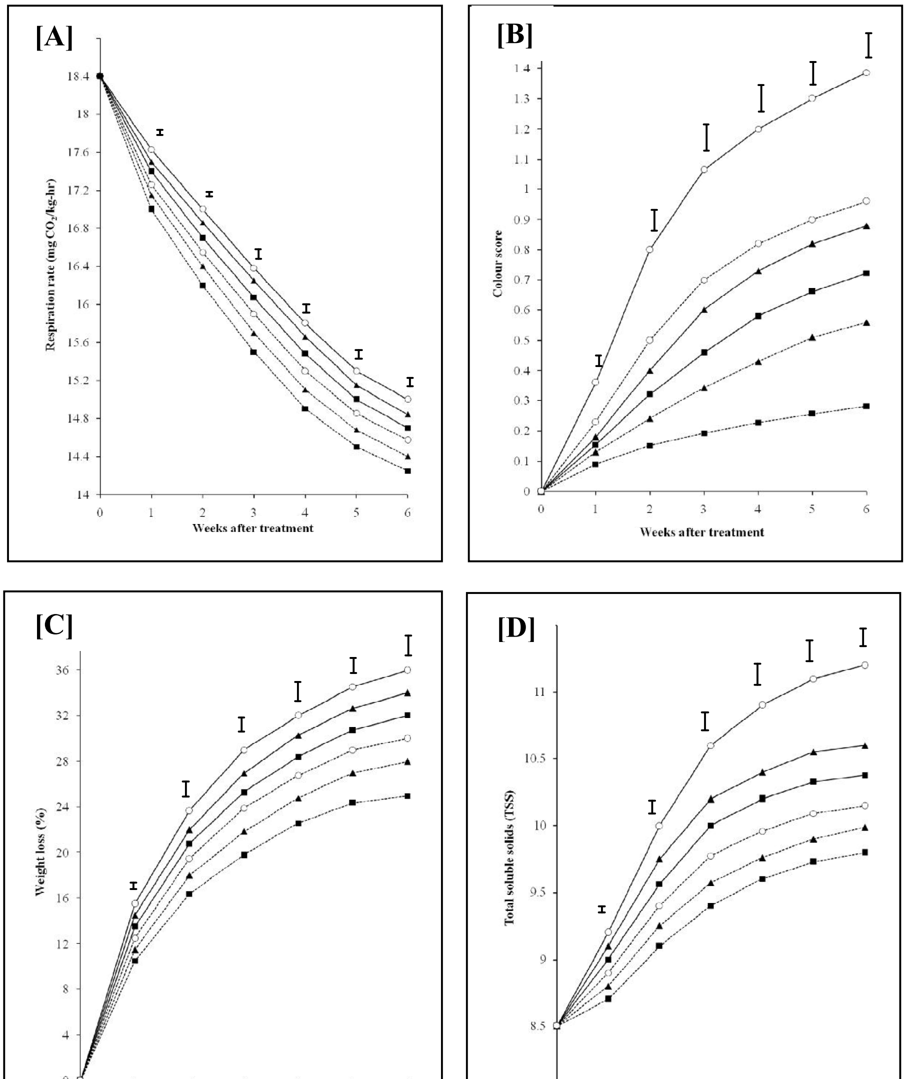

Fig. 1. Changes in respiration rate [A], peel colour score [B], weight loss [C] and total soluble solids (TSS) [D] during storage of lime fruits treated with zero (o), 50 (▲), and 100 ppm GA_3 (■) without waxing (——) or with waxing (…....) at 18 $\pm$ 1^{O}C and 85%-90% R.H. Vertical bars represent LSD (5 %).

Effect on Total Soluble Solids

Total soluble solids (TSS) showed continuous increase during storage of lime fruits in all treatments. It increased in the untreated fruit from 8.5% to 11.2% after six weeks of storage (Fig. 1-D). This is in agreement with earlier reports that TSS increases during storage of grapefruits (Abu-Goukh and Elshiekh 2008) and limes (Ayoub and Abu-Goukh, 2009). The increase in TSS was reduced by 4.7% and 7.3% in fruits treated with 50 and 100 ppm GA_3 without waxing and 11.3% and 13.2% with waxing, respectively, compared to the control (Fig. 1-D). The increase in TSS during storage was attributed to the loss of moisture content, which led to the concentration of TSS (Ayoub and Abu-Goukh 2009). GA_3 and waxing treatments reduced water loss (Fig. 1-C), which was reflected in less increase in TSS during storage (Fig. 1-D), and a positive correlation was found between the increase in TSS and weight loss during storage of limes. This agrees with the findings of Ayoub and Abu-Goukh (2009).

Effect on Fruit Flesh Firmness

Firmness of fruit flesh progressively declined during storage of lime fruits in all treatments (Fig. 2-A). In the untreated fruits, the firmness decreased from 1.88 to 1.15 kg/cm² after 6 weeks in storage. GA_3 and wax treatments delayed the decrease in flesh firmness during storage of the fruits. The treated fruits with GA_3 and/or wax were more firm than the control at any time during the storage period, but the differences diminished with time in storage (Fig.2-A). This agrees with the findings of Mohamed-Nour (2007) who observed a decrease in flesh firmness during storage of guava fruits treated with GA_3. Treatment of GA_3 with waxing was more effective in delaying fruit softening, compared to GA_3 treatment alone. Waxing was reported to delay fruit softening in oranges (Martinez *et al*. 1991), mangoes (Mohamed and Abu-Goukh 2003) guavas (Mohamed-Nour 2007) and grapefruits (Abu-Goukh and Elshiekh 2008).

Effect on Titratable Acidity

Titratable acidity progressively decreased, during storage of lime fruits, from 1.6% to 0.55% after six weeks in storage (Fig. 2-B). This is in agreement with the findings of Biasi and Zanette (2000) who found a decrease in total acidity during storage of limes. Similar results were reported by Attia (1995) in oranges. Abu-Goukh and Elshiekh (2008) reported that titratable acidity increased slightly during the first 15 days of the storage of grapefruits followed by a decrease till the end of storage period.

GA_3 and wax treatments decreased titratable acidity during storage of lime fruits (Fig.2-B). At the end of the storage period the titratable acidity was 0.45% and 0.33% in fruits treated with 50 and 100 ppm GA_3 without waxing, and 0.12% and 0.05% with waxing, respectively, compared to 0.55% in the control (Fig. 2-B). This might be explained in terms of weight loss, which was less in the waxed fruits leading probably to concentration of the acid in the fruit tissues. It was reported that waxing reduces water loss and decreases acidity during storage of oranges (Martinez *et al*. 1991) and grapefruits (Abu-Goukh and Elshiekh 2008).

Effect on Ascorbic Acid Content

Ascorbic acid content showed continuous decline during storage of lime fruits in all treatments. It decreased from 48.50 to 26.14 mg/100g fresh weight in the untreated fruits (Fig. 2-C). This agrees with previous reports that ascorbic acid declines rapidly during storage of mango (Abu-Goukh and Abu-Sarra 1993) and guava fruits (Bashir and Abu- Goukh 2003). The ascorbic acid retained at the end of the storage period of the untreated fruits was 53.9% of the initial amount (Fig. 2-C). GA_3 with or without waxing, resulted in higher ascorbic acid retention. At the end of the 6-week storage period, ascorbic acid was 1.4% and 4.7% higher in the fruits treated with 50 and 100 ppm GA_3 without waxing and 10.2% and 15.1% with waxing, respectively, compared to the untreated fruits (Fig.2-C). This agrees with Abu-Goukh and Elshiekh (2008) who showed that waxing retains ascorbic acid, maintains fruit quality, reduces post-harvest losses and extends the shelf-life of grapefruits. Similar results were reported for oranges (Martinez *et al.* 1991), mangoes (Mohanmed and Abu-Goukh 2003), guavas (Mohamed-Nour 2007) and limes (Ayoub Abu-Goukh 2009).

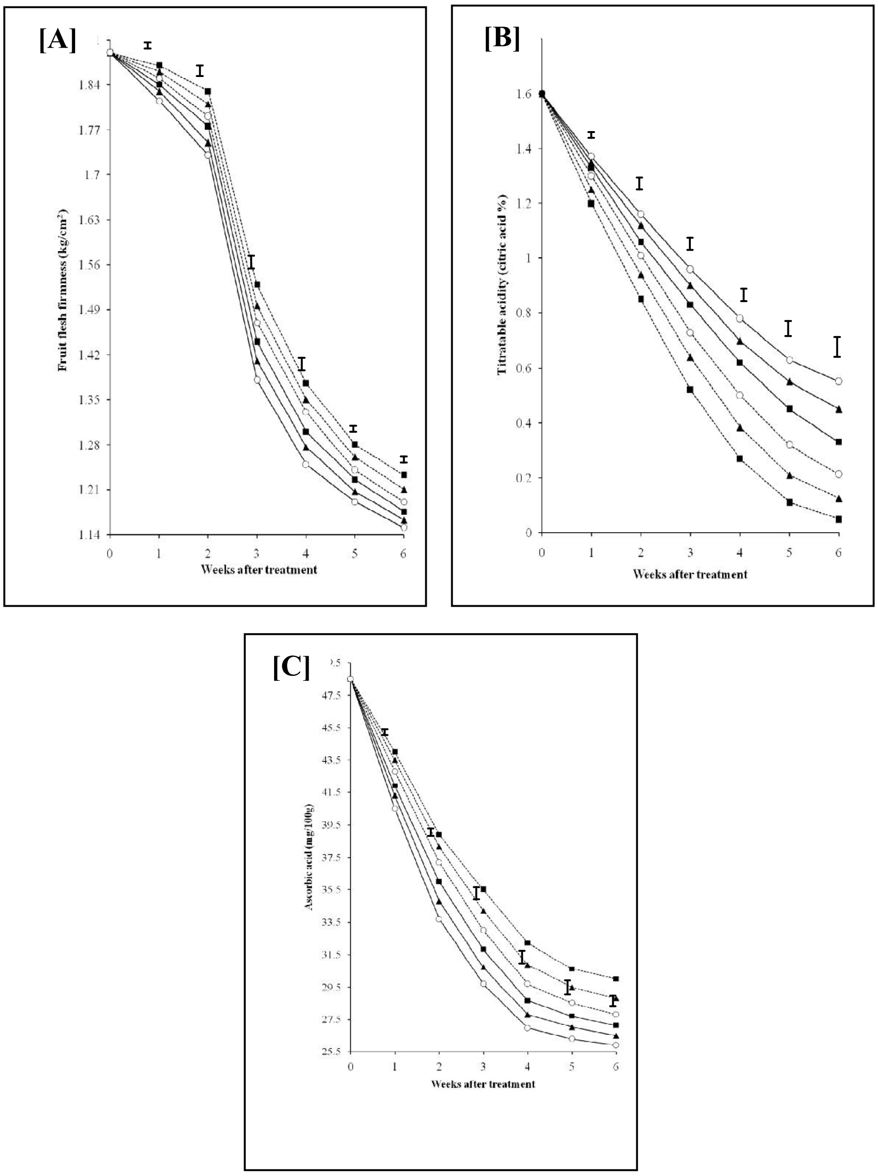

Fig. 2. Changes in fruit flesh firmness [A], titratable acidity [B] and ascorbic acid content [C] during storage of lime fruits treated with zero (o), 50 (▲), and 100 ppm GA_3 (■) without waxing (——) or with waxing (…....) at 18 $\pm$ $1^{O}C$ and 85%-90% R.H. Vertical bars represent LSD (5 %).

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تأثير المعاملة بحمض الجبرلين والتشميع على جودة ثمار الليمون البلدي وطول فترة تخزينها

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المستخلص: تمت دراسه تأثير معاملة ثمار الليمون البلدي بعد الحصاد بحمض الجبرلين (GA_3) والتشميع على جودة وطول فترة تخزينها في درجة حرارة 18 ± 1 درجة مئوية و85% – 90% رطوبة نسبية. أدت معاملة الثمار بحمض الجبرلين (GA_3) بتركيز 50 و100 جزء فى المليون الى تأخير الشيخوخة والمحافظة على الجودة وإطالة فترة التخزين لثمار الليمون البلدي، وكان التركيز الأعلي أكثرفعالية. كما أن معاملة الثمار بحمض الجبرلين مع التشميع كان أكثر فعالية من معاملتها بحمض الجبرلين فقط. تجلى تأثير المعاملة بحمض الجبرلين والتشميع في انخفاض معدل التنفس، وفقد الوزن، وليونة الثمار، وتركيز المواد الصلبة الذائبة الكلية، وتأخير تلون القشرة، وتقليل الحموضة، والمحافظة علي حمض الاسكوربيك فى الثمار.