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Effect of Gibberellic Acid and Waxing on Quality and Shelf Life of Guava (*Psidium guajava* L.) Fruits

Abu-Bakr A. Abu-Goukh and Ibtissam A. Mohamed-Nour

Department of Horticulture, Faculty of Agriculture, University of Khartoum, Shambat 13314, Sudan.

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Abstract: The effect of post-harvest treatment by gibberellic acid (GA_3) concentrations at 100 and 200 ppm, and waxing on ripening and quality of white- and pink-fleshed guava fruits was evaluated at 20±1 ^{O}C and 85%-90% relative humidity. Gibberellic acid at 100 and 200 ppm without waxing delayed fruit ripening by 3-5 days in both guava types, compared to untreated fruits. The delay was more with the increase in GA_3 concentration. Waxing in addition to GA_3 treatment resulted in 3 days more delay in fruit ripening, compared to GA_3 treatment alone. The effect of GA_3 and wax treatments was indicated by retarded climacteric peak of respiration, delayed peel color development, reduced total soluble solids accumulation and decreased fruit flesh softening.

Key words: Guava fruit; gibberellic acid (GA_3); waxing; fruit quality; shelf life

INTRODUCTION

Guava (*Psidium guajava* L.) is a popular fruit crop in Sudan and is commercially grown in every state in the country. Total production is estimated as 145 thousand tons (HSA, 2017). It gained popularity for its excellent flavor, attractive fragrance, beautiful color, delicious taste and high nutritive value. Although Sudan has great potential to produce and export high quality guava fruits, its marketability is limited to local markets, due to the delicate nature of the fruit, poor handling practices and inadequate refrigerated transportation and storage facilities (Mohamed-Nour and Abu-Goukh 2013). Therefore, proper handling techniques and control of the ripening process are crucial for the development of a sound guava industry in Sudan.

Gibberellins are a group of growth substances, which are known to retard ripening and senescence of fruits. They are synthesized in the young fruit

by the developing seeds and are believed to participate in promoting early fruit growth (Leopold and Kriedemann 1975). Gibberellins have been reported to be involved in many physiological steps leading to ripening and senescence. Several workers have shown that dipping of mango fruits in GA_3 delayed fruit ripening in many cultivars (Khader 1992). Murthy and Rao (1982) reported that ripening of mango fruit can be controlled chemically without lowering the quality of the fruit. The effect of GA_3 seems to be mainly on color development, although other aspects of ripening are also affected. GA_3 delayed chlorophyll degradation and fruit softening in mango (Khader 1992) and lime (Abdallah and Abu-Goukh 2010), decreased sugar accumulation, TSS and sugar/acid ratio in mango (Murthy and Rao 1982), banana (Ahmed and Tingwa 1995) and lime (Abdallah and Abu-Goukh 2010),

Waxing and surface coating materials significantly alter permeability of the skin of horticultural commodities to gases. The commodity, through respiration, is used to reduce oxygen and increase carbon dioxide, and a modified atmospheric condition may be generated; consequently some of the benefits of the modified atmosphere may be achieved (Kader 2002). Waxing was reported to delay fruit ripening, reduce water loss, maintain quality and to extend shelf life of guava (Mohamed-Nour and Abu-Goukh 2013), mango (Mohamed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elshiekh 2008), lime (Abdallah and Abu-Goukh 2010) and papaya (Abu-Goukh and Shattir 2012).

This study was carried out to evaluate the effect of gibberellic acid and waxing on ripening and quality of white and pink-fleshed guava fruits.

MATERIALS AND METHODS

Experimental material

Mature-green fruits of white and pink-fleshed guava fruits were obtained from an orchard at Al-Kadaro, Khartoum North (15^O 40' N, 32^O 22' E). Fruits were selected for uniformity of size, color and freedom from blemishes. The fruits were washed, air dried and transported in plastic baskets lined with perforated polyethylene sheets to the experimental

laboratory at the Department of Horticulture, Faculty of Agriculture, University of Khartoum.

Fruit treatment

The fruits of each guava type were distributed among five treatments in a completely randomized design with four replicates. The treatments were; (i) Untreated fruits (control), (ii) 100 ppm gibberellic acid (GA_3), (iii) 200 ppm GA_3, (iv) 100 ppm GA_3 with wax, and (v) 200 ppm GA_3 with wax. Gibberellic acid (Sigma Chemical Company) was applied by dipping the fruits for three minutes in GA_3 solutions of 100 and 200 ppm and air dried. Food-grade wax (Flucka AG, CH-9470 Buchs) was used for wax treatments. The wax was applied in a thin layer by brushing over the surface of the fruits. Untreated fruits (control) were dipped in distilled water and air dried. The fruits were stored at 20 ± 1 ^{O}C and 85%-90% relative humidity.

Parameters studied

Respiration rate and peel color changes were determined daily during the ripening period in 15 fruits in each treatment. Respiration rate was determined by the total absorption method of Charlimers (1956), as modified by Mohamed-Nour and Abu-Goukh (2010), and expressed in mg CO_2 per kg-hr. Peel color changes were determined using a color score of; mature-green (= 0), trace yellow on skin (=1), 20 % yellow (=2), 40 % yellow (=3), 60 % yellow (=4), 80 % yellow (= 5) and 100 % yellow (= 6).

Fruit flesh firmness and total soluble solid (TSS) were determined on three fruits picked randomly from each treatment, other than those used for respiration rate and color changes, at two-day intervals during ripening. Flesh firmness was measured by Magness and Taylor Firmness Tester (D. Ballauf Meg. Co.), equipped with 8 mm diameter plunger tip. Two readings were taken from opposite sides on each fruit after the peel was removed. Flesh firmness was expressed in kilograms per square centimeters. Total soluble solids (TSS) were determined directly on fruit juice extracted by pressing the fruit pulp in a garlic press, using 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.

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 delayed fruit ripening in white- and pink-fleshed guava fruits. The 200 ppm treatment was more effective than 100 ppm in delaying fruit ripening. Similar results were reported for mango (Khader 1992). Gibberellic acid delayed yellowing and senescence, maintained quality and extended storage life of orange (Coggins and Lewis 1962) and lime (Abdallah and Abu-Goukh 2010). The effect of GA_3 seems to be mainly on color development, although other aspects of ripening were also affected (Murthy and Rao 1982; Khader 1992; Ahmed and Tingwa 1995).

The effects of gibberellin in the regulation of ripening deserve special attention. The mechanism by which GA retards ripening has not been clearly elucidated, but may be supposed to act at the gene level, or through modifying the effect of other hormones. Evidence by Valdorino *et al*. (1967) suggested that GA significantly influenced the level of auxins, in plant tissues. Its effectiveness in blocking the pigment changes with ripening (Coggins and Lewis 1962) has led to commercial use of gibberellin in citrus culture. Its effectiveness in delaying ripening of other fruits (banana, mango, pear, apricot, and tomato) suggests the possible interpretation that gibberellins act in fruits in indirect opposition to ethylene. It has already been mentioned that gibberellin can alter pigment changes without altering the respiratory climacteric. The gibberellin delay of ripening can be overcome by application of ethylene (Russo *et al*. 1968). Wade and Brady (1971) asserted that the delay of the pigment changes in ripening bananas can be achieved with application of gibberellin or auxin or cytokinin.

Waxing in addition to GA treatment resulted in more delay in guava fruit ripening. Waxing was reported to delay fruit ripening and senescence, reduce water loss, improve quality and extend shelf life of guava

(Mohamed-Nour and Abu-Goukh 2013) and mango (Mohamed and Abu-Goukh 2003). The delay in fruit ripening due to GA and wax treatments

was reflected in changes in respiration rate, peel color, flesh firmness and total soluble solids.

Effect on respiration rate

The respiration curves of both guava types exhibited a typical climacteric pattern. Respiration was higher in the pink guava fruits with a climacteric peak at 41.5 mg CO_2/ kg-hr. than in the white guavas, with a peak at 36.8 mg CO_2/ kg-hr. (Fig. 1). Similar climacteric maxima for guava fruits was reported (Mohamed-Nour and Abu-Goukh 2013).

The untreated fruits reached the climacteric peak after 14 and 16 days in the white and pink guavas, respectively. Gibberellic acid (GA_3) treatment, with or without waxing, delayed the onset of the climacteric peak in the two guava types. Fruits treated with GA_3 at 100 and 200 ppm without waxing, reached the climacteric peak three and five days later respectively compared to the untreated fruits. in both guava types. While the fruits treated with GA_3 at 100 and 200 ppm with waxing, reached the climacteric peak six and eight days later respectively, compared to the control in both types, (Fig.1). This agrees with previous reports that GA delayed the onset of the climacteric peak in banana (Ahmed and Tingwa 1995) and decreased respiration rate in limes treated with 50 and 100 ppm GA_3 (Abdallah and Abu-Goukh 2010). Lewis *et al*. (1967) reported that GA had lowered the rate of oxygen uptake and 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.

Waxing in addition to GA_3 treatment resulted in three more days delay in climacteric peak of respiration, compared to GA_3 treatment alone (Fig. 1). Similar results were reported for guava (Mohamed-Nour and Abu-Goukh 2013) and mango (Mohamed and Abu-Goukh, 2003). Waxing was reported to influence respiration rate by decreasing oxygen (O_2) and increasing carbon dioxide (CO_2) content in the internal atmosphere of the fruit (Irving and Warren 1960).

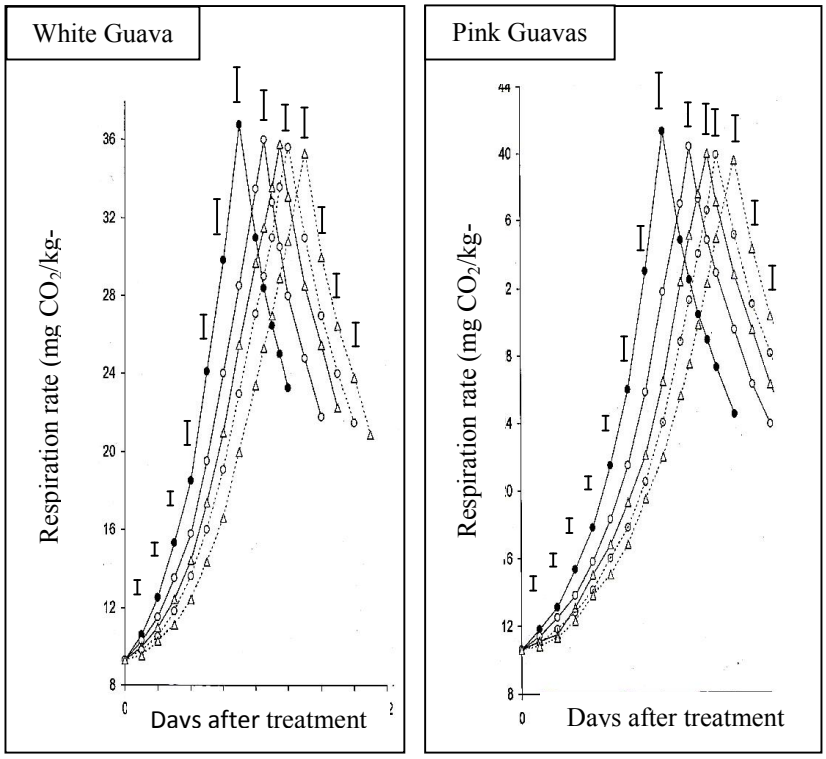

Fig. 1: Changes in respiration rate during ripening of white and pink guava fruits treated with gibberellic acid at 100 (o) and 200 ppm (Δ) without waxing (——) or with waxing (- - - - -), compared to untreated fruits (●) at 20 ± 1° and 85-90 % relative humidity. Vertical bars represent LSD (5 %).

Effect on peel color

Peel color score progressively increased during ripening of the white and pink guava types (Fig. 2). The untreated fruits reached the full yellow stage (color score 6) after 16 days in the white and 18 days in the pink guava. Gibberellic acid (GA_3) and wax treatments differentially delayed color development in both guava types. Fruits treated with GA_3 at 100 and 200 ppm without waxing, reached the full yellow stage three and five days later, respectively, compared to the untreated fruits. While the fruits treated with 100 and 200 ppm GA_3 with waxing, reached the full

yellow color six and eight days later, respectively, compared to the control (Fig. 2). These results are in agreement with previous reports that GA_3 retards color development in orange (Coggins and Lewis 1962) and lime (Abdallah and Abu-Goukh 2010). Moreover, GA_3 delayed chlorophyll degradation in mango (Khader *et al*. 1988) and inhibited degreening in cultured citrus peel segments (Garray 1990, Mohamed and Abu-Goukh 2003). Indeed GA_3 treatment with waxing was more effective in delaying color development. This is in line with the reported that waxing delayed chlorophyll degradation in mango (Mohamed and Abu-Goukh, 2003) and lime (Abdallah and Abu-Goukh 2010).

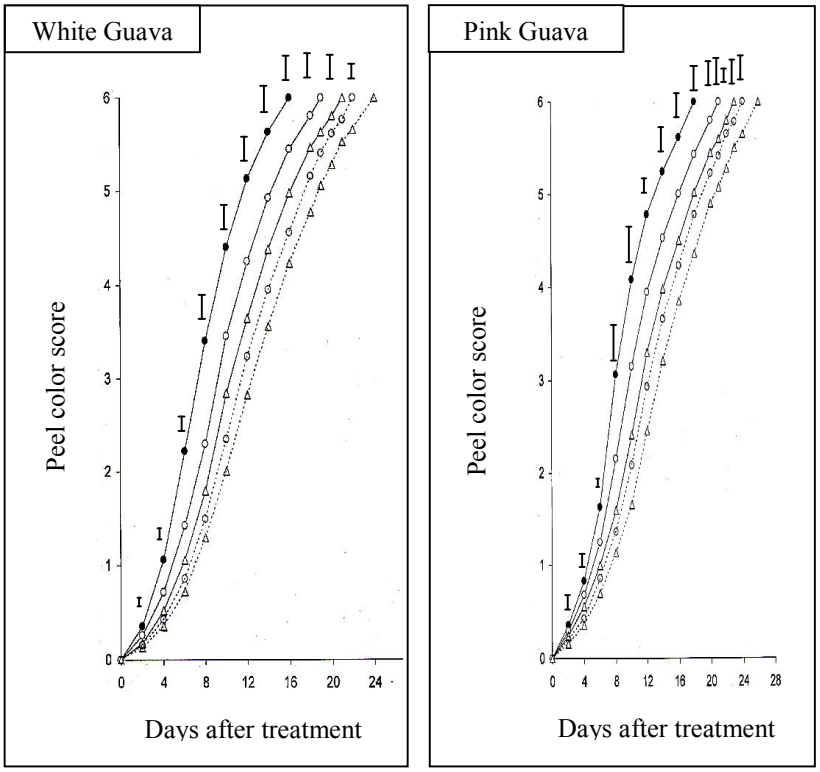

Fig. 2: Changes in peel color score during ripening of white and pink guava fruits treated with gibberellic acid at 100 (o) and 200 ppm (Δ) without waxing (——) or with waxing (- - - - -), compared to untreated fruits (●) at 20 ± 1° and 85-90 % relative humidity. Vertical bars represent LSD (5 %).

Fruit flesh firmness progressively declined during ripening of both guava types. The untreated fruits reached the final soft stage (0.08 kg/cm^2) after 18 and 20 days in the white and pink guava respectively (Fig. 3). Gibberellic acid and wax treatments delayed the drop in flesh firmness in both guava types. Fruits treated with 100 and 200 ppm GA_3 without waxing, had reached the final soft stage three and five days later, respectively, compared to the control. While those treated with 100 and 200 ppm GA_3 with waxing, had reached the final soft stage six and eight days later, respectively, compared to the untreated fruits (Fig. 3). This

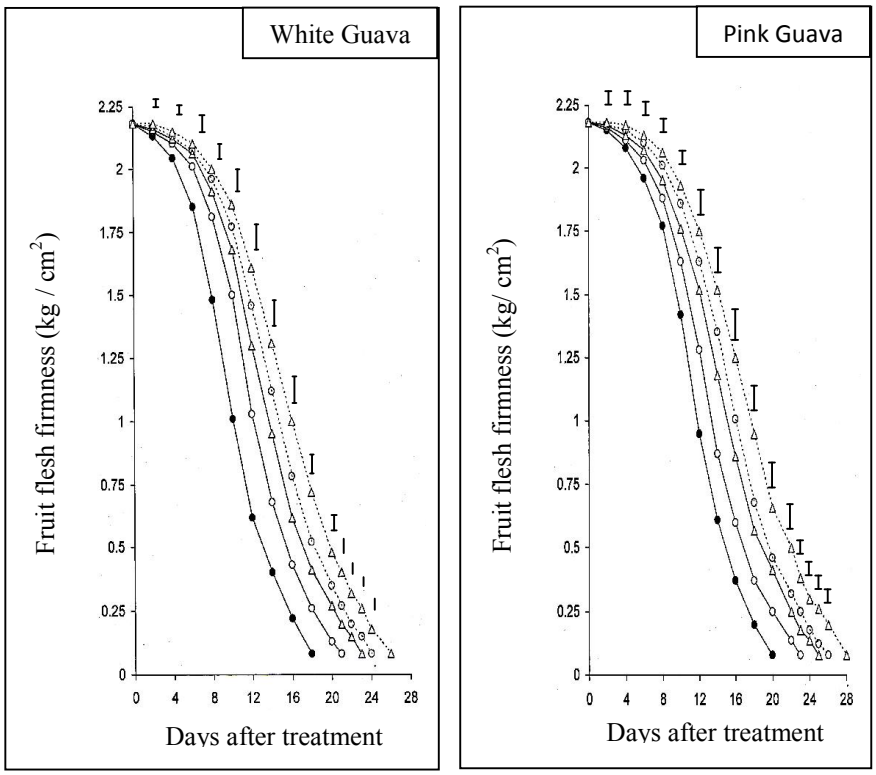

Fig. 3: Changes in fruit flesh firmness during the ripening of white and pink guava fruits treated with gibberellic acid at 100 (o) and 200 ppm (Δ) without waxing (——) or with waxing (- - - - -), compared to untreated fruits (●) at 20 ± 1° and 85-90 % relative humidity. Vertical bars represent LSD (5 %).

agrees with the findings of Khader (1992), who observed a decrease in flesh firmness in mango fruits treated with GA_3. In both guava types, treatment of GA_3 with waxing was more effective in delaying fruit flesh softening, compared to GA_3 treatment alone. Waxing was reported to delay fruit softening in guava (Mohamed-Nour and Abu-Goukh 2013), mango (Mohamed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

Effect on total soluble solids

Total soluble solids (TSS) progressively increased during ripening of the two guava types. The maximum TSS value reached by the untreated fruits was 14.5% in the white and 13.0% in the pink guava. That is, maximum TSS value was reached after 16 and 18 days for the white and pink guavas, respectively (Fig. 4). Gibberellic acid treated fruits at 100 and 200 ppm without waxing, reached the maximum TSS value three and five days later, respectively, compared to the untreated fruits. On the other hand fruits treated with 100 and 200 ppm GA_3 with waxing, reached the maximum TSS value six and eight days later, respectively, compared to the control (Fig. 4). This is in line with previous reports that GA_3 decreased sugar accumulation, TSS and sugar/acid ratio in orange (Lewis *et al.* 1967), banana (Ahmed and Tingwa 1995), and mango (Murthy and Rao, 1982). The wax treatment added to the delay of ripening and accumulation of TSS. This is in support to earlier reports that waxing decreased TSS during ripening and storage of guava (Mohamed-Nour and Abu-Goukh 2013), mango (Mohamed and Abu-Goukh, 2003), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

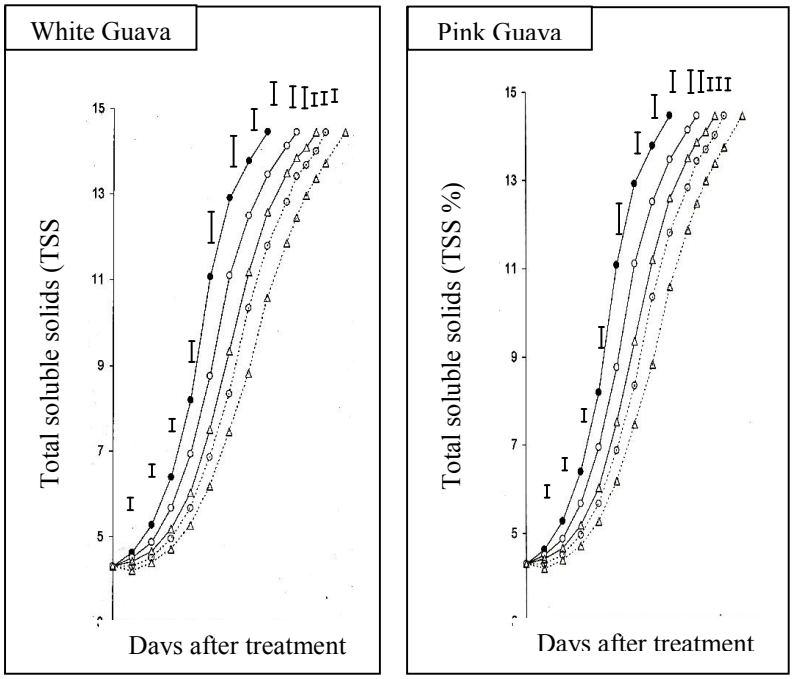

Fig. 4: Changes in total soluble solids (TSS) during ripening of white and pink guava fruits treated with gibberellic acid at 100 (o) and 200 ppm (Δ) without waxing (——) or with waxing (- - - - -), compared to untreated fruits (●) at 20 ± 1° and 85-90 % relative humidity. Vertical bars represent LSD (5 %).

CONCLUSION

- Postharvest treatment of gibberellic acid (GA_3) at 100 and 200 ppm, delayed ripening of white and pink-fleshed guava fruits.
- Waxing in addition to GA_3 treatment resulted in more delay in fruit ripening.
- The effect on fruit ripening was indicated by retarded respiratory climacteric, delayed color development, lowered (TSS) and decreased fruit softening.

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تأثير المعاملة بحمض الجبرلين والتشميع على الجودة والعمر التخزيني لثمار الجوافة (*Psidium guajava* L.)

أبوبكر علي أبوجوخ وإبتسام عبد الله محمد نور

قسم البساتين – كلية الزراعة – جامعة الخرطوم. شمبات 13314 – السودان

المستخلص: تم تقويم تأثر معاملة ثمار الجوافة البيضاء والحمراء بعد الحصاد بحمض الجبرلين والتشميع على إنضاج وجودة الثمار في درجة حرارة 20 $\pm$ 1^{O}م ورطوبة نسبية 85-90 %. أوضحت النتائج أن معاملة الثمار بحمض الجبرلين بتركيز 100 و 200 جزء في المليون بدون تشميع أدى إلي تأخير النضج بثلاثة إلي خمسة أيام في نوعي الجوافة، مقارنة بالثمار غير المعاملة. يزداد التأخير في النضج بزيادة التركيز في حمض الجبرلين. كان لأثر تشميع الثمار إضافة لمعاملتها بحمض الجبرلين أثراً إضافياً في تأخير نضج الثمار بثلاثة أيام أخرى مقارنة بالثمار المعاملة بالجبرلين فقط. أنعكس أثر المعاملة بالجبرلين والتشميع في تأخير نضج الثمار وفي تأخير وصول الثمار إلي ذروة التنفس وتأخير تلون قشرتها وتجميع المواد الصلبة الذائبة بها وخفض ليونتها.