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Effect of Maleic Hydrazide and Waxing on Quality and Shelf-Life of Papaya (*Carica papaya* L.) Fruits

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Abstract: The effect of post-harvest treatment of Maleic hydrazide (MH) with and without waxing on the quality and shelf-life of 'Baladi' and 'Ekostika I' papaya fruits at 18 ± 1°C and 85% – 90% relative humidity was evaluated**.** Maleic hydrazide at 250 and 500 ppm significantly delayed fruit ripening by two and three days in both papaya cultivars, respectively, compared with untreated fruits. The higher the concentration, the more was the delay in fruit ripening. The results also showed that waxing in addition to MH resulted in a delay of two more days in fruit ripening than treatment with MH alone. The effect of MH and waxing treatments in delaying papaya fruits ripening was manifested in retarded respiratory climacteric, reduced weight loss and delayed fruit softening and increase in total soluble solids and ascorbic acid content.

Key words: Papaya fruits; maleic hydrazide; waxing; fruit quality; shelf-life

INTRODUCTION

Papaya (*Carica papaya* L.) is an important and widely distributed fruit crop throughout the tropics. The ripe fruit is consumed fresh for dessert and in fruit salad or processed. Papaya fruits are highly accepted worldwide and the consumer demand for fresh papaya fruit is increasing for its nutritional and medicinal value (Lobo and Cano 1998).

Although Sudan has great potential to produce high quality papaya fruit for local markets and export, its production is still very low and is consumed locally. This could be due to the delicate and perishable nature of the fruit. Papaya fruits are subject to many postharvest losses due to its thin skin, and it cannot tolerate low temperature that increases the difficulties in handling and long distance transportation (Pimentel and

Walder 2004). Therefore, proper handling techniques to minimize physical damage, reduce water loss and control fruit ripening are crucial for development of a sound papaya industry in Sudan.

Maleic hydrazide (MH) is known as a growth regulator that inhibits some processes in fruits and vegetables. Several workers reported that MH inhibits sprouting and reduces losses during storage of potato (Lekan 1965) and onion (Fadl *et al*. 2005). The effect of MH on the ripening process varies with different types of fruits. It delayed fruit ripening in mango (Krishnamurthy and Subramanyam 1970) and tomato (Ahmed and Abu-Goukh 2003). MH applied on sapota fruit (*Achras sapota* L.), however, hastened the ripening process (Lakshiminarayana and Subramanyam 1967).

Waxing significantly reduces the permeability of the fruit skin to gases. The commodity, through respiration, reduces oxygen (O_2) and increases carbon dioxide (CO_2) in the internal atmosphere. Under such restricted air-exchange, a modified atmospheric condition may be generated, and some of the benefits of the modified atmosphere may be achieved (Kader 2002). Waxing delays fruit ripening and senescence and reduces water loss; thus, it maintains quality and extends shelf-life of mangoes (Mohamed and Abu-Goukh 2003), tomatoes (Ahmed and Abu-Goukh 2003), grapefruits (Abu-Goukh and Elshiekh 2008) and limes (Abdallah and Abu-Goukh 2010).

This study was carried out to evaluate the effect of maleic hydrazide and waxing on the quality and shelf-life of papaya fruits.

MATERIALS AND METHODS

Experimental Material

Mature-green papaya fruits of 'Baladi' and 'Ekostika I' cultivars were harvested from the Demonstration Farm, Faculty of Agriculture, University of Sennar, Abu-Naama (12° 44′ N; 38° 08′ E). The fruits were selected for uniformity of size, maturity and freedom from blemishes; they were then washed, air-dried to remove water from the surface and transported in carton boxes to the laboratory for further treatments.

Fruit Treatment

About 700 fruits from each cultivar were distributed among five treatments in a completely randomized design with four replications. The treatments were 0, 250 and 500 ppm MH without waxing and 250 and 500 ppm MH with waxing. The fruits were dipped for three minutes in maleic hydrazide (Citachine N-IMZ "Deco-Pennwalt") solutions at 250 and 500 ppm and then air-dried. Untreated fruits (control) of both cultivars were dipped in distilled water for the same period and were air-dried. Food–grade wax (Flucka AG, CH-9470 Buchs) was applied in a thin layer by brushing over the surface of the fruit. The fruits were packed in carton boxes (67x35x10 cm) and stored at 18 ±1°C and 85%-90% relative humidity.

Studied Parameters

Respiration rate (in mg CO_2 / kg-hr.) was determined in ten fruits, from each treatment, every two days and later every day during the storage period, using the total absorption method (Mohamed-Nour and Abu-Goukh 2010). Weight loss in fruits was determined at two days intervals and later every day in the same 10 fruits used for determination of respiration rate, according to the formula: $w_1 = [(w_0 - w_t)/w_0] \times 100$, where w_1 is the weight loss percentage 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) and ascorbic acid content were determined at two days intervals and later every day in two fruits picked randomly from each replication. 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 firmness was expressed in kilogrammes per square centimetre. 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. Ascorbic acid content in the pulp extracts was determined, using the 2, 6 -dichlorophenol- indophenol titration method of Ruck (1963), and expressed in mg /100 g 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

Maleic hydrazide (MH) treatments delayed fruit ripening in both papaya cultivars. Similar results were reported in mango (Krishnamurthy and Subramanyam 1970), tomato (Ahmed and Abu-Goukh 2003) and guava (Mohamed-Nour 2007). The wax treatment resulted in more delay in papaya ripening. Waxing was reported to delay fruit ripening, reduce water loss and extend shelf-life of mango (Mohamed and Abu-Goukh 2003) and tomato (Ahmed and Abu-Goukh 2003). Waxing significantly alters permeability of the skin to gases. The commodity, through respiration, reduces oxygen (O_2) and increases carbon dioxide (CO_2) in the internal atmosphere. Under such restricted air-exchange, a modified atmospheric condition may be generated, and some of the benefits of the modified atmosphere may be achieved (Kader 2002). The low O_2 and high CO_2 depress the internal ethylene production (Beyer *et al.* 1984). Ethylene has a stimulation role in the general metabolism of fruit (Gomez *et al*. 1999) and is required to turn on ripening genes that affect colour changes, TSS accumulation, aroma and degradation of cell walls that result in tissue softening (Baldwin 2001). This delay in fruit ripening was reflected in changes in respiration rate, water loss, flesh firmness, TSS and ascorbic acid content.

Effect on Respiration Rate

The respiration curves of the two papaya cultivars exhibited a typical climacteric pattern with climacteric peak at 80.0 and 90.0 mg CO_2/kg-hr for ‘Baladi’ and ‘Ekostika I’ cultivars, respectively (Fig. 1). MH and wax treatments slightly decreased climacteric peak in both cultivars. Duckworth (1966) reported that MH differs from most growth regulators in depressing the rate of respiration.

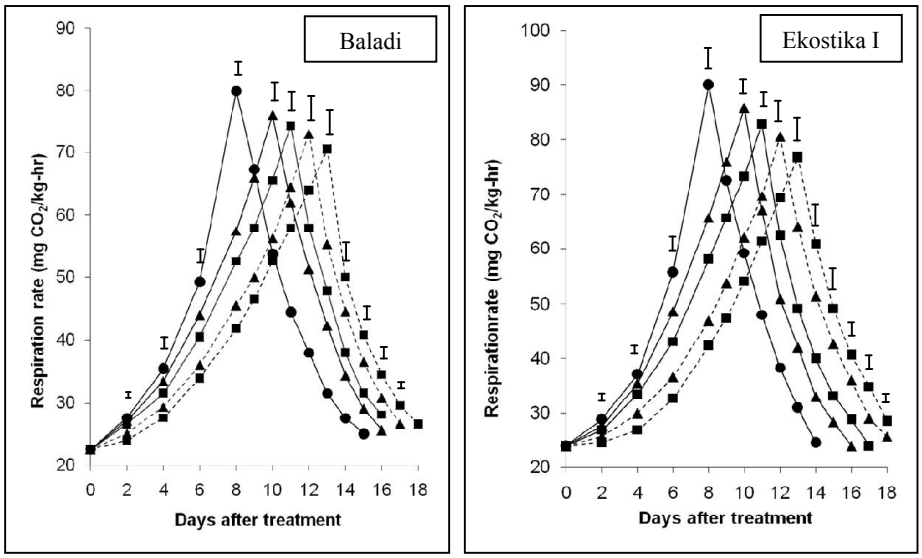

Fig. 1. Changes in respiration rate during storage of 'Baladi' and 'Ekostika I' papaya fruits treated with maleic hydrazide at 250ppm (▲) or 500 ppm (■) without waxing (_____) or with waxing (……), compared with untreated fruits (●) at 18±1^{O}C and 85%-90% relative humidity. Vertical bars represent LSD (5%).

The untreated fruits reached the climacteric peak after eight days in both cultivars. The fruits treated with MH at 250 and 500 ppm without waxing reached the climacteric peak two and three days later, respectively, than the untreated fruits (Fig. 1). This is in agreement with previous reports that MH delayed the onset of the climacteric peak in mango (Krishnamurthy and Subramanyam 1970), tomato (Ahmed and Abu-Goukh 2003) and guava (Mohamed-Nour 2007).

Papaya fruits treated with MH at 250 and 500 ppm with waxing reached the climacteric peak four and five days later in both cultivars, compared with the control (Fig. 1). Similar results were reported for mango (Mohamed and Abu-Goukh 2003) and tomato (Ahmed and Abu-Goukh 2003). Waxing has been shown to influence respiration rate by decreasing O_2 and increasing CO_2 content in the internal atmosphere of the fruit (Irving and Warren 1960).

Effect on Weight Loss

Weight loss progressively increased during the ripening period of the two papaya cultivars irrespective of the treatment applied (Fig. 2-A). MH, with or without waxing, reduced weight loss, and the higher the concentration, the more was the reduction in weight loss. At the end of the storage period (18 days), weight loss was 17.8 % and 18.1 % in the untreated fruits of 'Baladi' and 'Ekostika I' cultivars, respectively. Weight loss was reduced by an average of 6.2 % and 9.2 % in papaya fruits treated with MH at 250 and 500 ppm without waxing, respectively, compared with untreated fruits (Fig. 2-A). Similar results were reported during storage of tomato (Ahmed and Abu-Goukh, 2003) and onion (Fadl *et al*. 2005).

MH with waxing was more effective in reducing weight loss from papaya fruit during storage. At the end of the 18 days storage, the reduction in weight loss was an average of 17.2 % and 20.4 % in fruits treated with 250 and 500 ppm MH with waxing, respectively, compared with the control (Fig, 2-A). This is in line with earlier reports that waxing reduced weight loss in mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), guava (Mohamed-Nour 2007), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

Effect on Fruit Flesh Firmness

Fruit flesh firmness of the two papaya cultivars showed a continuous decline throughout the ripening period irrespective of the treatment (Fig. 2-B). The untreated fruits reached the final soft stage (0.07 kg/cm^2 share resistance) after 14 days. MH, with or without waxing, delayed the drop in flesh firmness during the ripening period. The papaya fruit treated with 250 and 500 ppm without waxing reached the final soft stage (0.07 kg/cm^2 share resistance) one and two days later, respectively, than untreated fruit in both cultivars (Fig. 2-B). After 14 days in storage, when the untreated fruits reached the final soft stage (0.07 kg/cm^2), the fruits treated with MH at 250 and 500 ppm without waxing were 1.6- and 2.1-folds more firm in 'Baladi' and 1.4- and 2.0-folds more firm in 'Ekostika I' cultivars, respectively, compared with the untreated fruits (Fig. 2-B). This is in agreement with previous reports that MH treatment delayed

fruit softening during ripening and storage of banana (Kaushik *et al*. 1991) and tomato (Ahmed and Abu-Goukh 2003). Crandall (1955) failed to influence the ripening of apples treated with MH as foliar spray 1 to 6 weeks before harvest, but the treatment increased flesh firmness of the fruits during storage.

MH with waxing was more effective in retarding fruit softening and keeping fruits firmer. The fruits treated with 250 and 500 ppm MH with waxing reached the final soft stage (0.07 kg/cm^2) three and four days later in both cultivars, than the control, respectively (Fig. 2-B). After 14 days in storage, when the untreated fruits reached the final soft stage (0.07 kg/cm^2), the fruits treated with 250 and 500 ppm MH with waxing were in average of 3.1- and 3.9- folds more firm than the control. Similar results were reported in mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003) and guava (Mohamed-Nour 2007). Park *et al.* (1994) reported that surface coating reduces fruit softening and extends the storage life of stored tomato fruit. Fruit softening is characterized by changes in flesh firmness and has long been associated with ripening (Dostal 1970). These changes in fruit flesh firmness determine the shelf-life and quality of the commodity (Martin-Rodriguez *et al.* 2002).

Effect on Total Soluble Solids

Total soluble solids (TSS) progressively increased in fruits of both papaya cultivars with the advancement of storage period; from 6.8 % to 10.33 % in 'Baladi' and from 7.5 % to 12.32 % in 'Ekostika I' in 13 days (Fig. 3-A). MH-treated fruits at 250 and 500 ppm without waxing reached maximum TSS value after two and three days later, respectively, than the untreated fruits of both cultivars (Fig. 3-A). TSS values in the treated fruits, with or without waxing, were lower throughout the storage period in both cultivars. After 13 days in storage, when the untreated fruits reached maximum TSS, the fruits treated with MH at 250 and 500 ppm without waxing had on average 4.8 % and 8.6 % less TSS, while those treated with 250 and 500 ppm with waxing had 12.3 % and 15.6 % less TSS, respectively, compared with untreated fruits (Fig. 3-A). This is in agreement with previous reports that MH decreased TSS during ripening

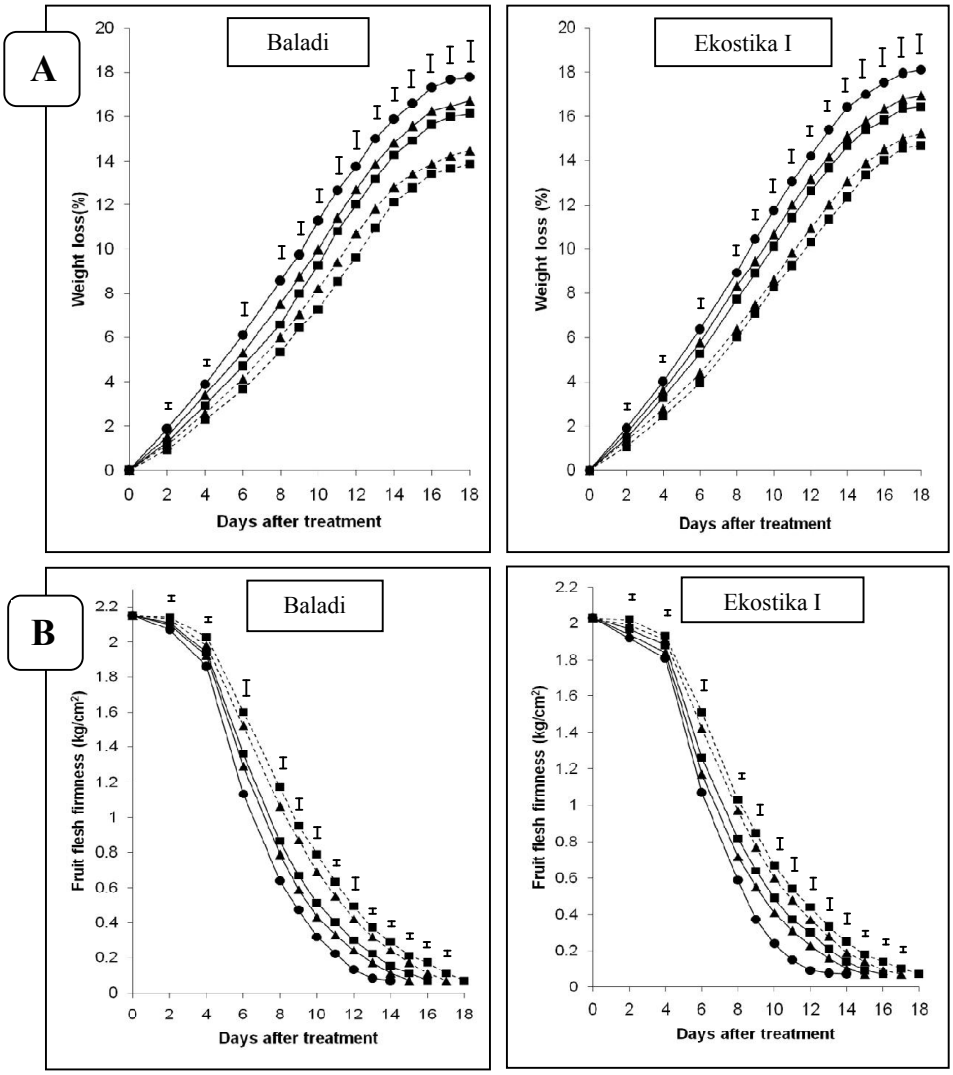

Fig. 2. Changes in weight loss [A] and fruit flesh firmness [B] during storage of 'Baladi' and 'Ekostika I' papaya fruits treated with maleic hydrazide at 250 ppm (▲) or 500 ppm (■) without waxing (_____) or with waxing (…….), compared with untreated fruits (●) at 18±1^{O}C and 85%-90% relative humidity. Vertical bars represent LSD (5%).

of mango (Parmar and Chandawat 1989), tomato (Ahmed and Abu-Goukh, 2003) and guava (Mohamed-Nour 2007). The wax treatment added to the delay of accumulation of TSS. Mohamed and Abu-Goukh (2003) reported that waxing decreased TSS during ripening of 'Dr. Knight' and 'Abu-Samaka' mango fruits. Similar results were reported in tomato (Ahmed and Abu-Goukh 2003), guava (Mohamed-Nour 2007), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

Effect on Ascorbic Acid Content

Ascorbic acid content or vitamin C in papaya fruit steadily increased in both cultivars irrespective of the treatment. The increase was about 50 % in both cultivars (Fig. 3-B). Similar trend was reported during ripening of papayas (Arriola *et al.* 1975; Abu-Goukh *et al.* 2010) and tomatoes (Ahmed and Abu-Goukh, 2003). The untreated fruits reached the maximum value of ascorbic acid (42.8 in 'Baladi' and 43.2 mg/100g fr. wt. in 'Ekostika I') after 13 days in both cultivars. MH delayed accumulation of ascorbic acid. That maximum value of ascorbic acid was reached after two and three days in fruit treated with 250 and 500 ppm MH without waxing and after four and five days in fruit treated with MH with waxing, respectively, compared to the control (Fig. 3-B).

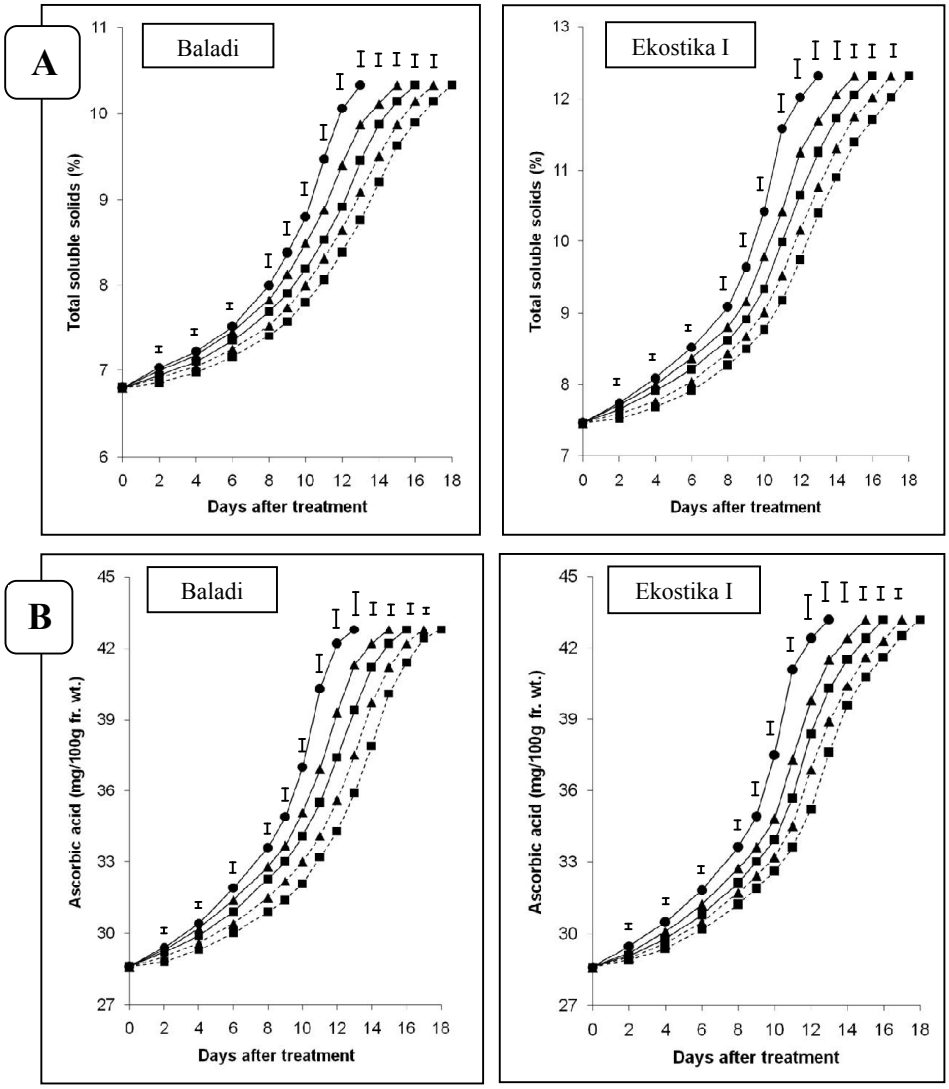

Fig. 3. Changes in total soluble solids (TSS) [A] and ascorbic acid content [B] during storage of 'Baladi' and 'Ekostika I' papaya fruits treated with maleic hydrazide at 250 ppm (▲) or 500 ppm (■) without waxing (_____) or with waxing (…….), compared with untreated fruits (●) at 18±1^{O}C and 85%-90% relative humidity. Vertical bars represent LSD (5%).

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تأثير المعاملة بالماليك هيدرازايد والتشميع على جودة ثمار البالباي وطول عمرها التسويقي

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المستخلص: تمت دراسة تأثير معاملة ثمار البالباي من صنفي 'البلدي' و 'إكوستيكا I' بعد الحصاد بالماليك هيدرزايد والتشميع على جودة وطول فترة عمرها التسويقي في درجة حرارة 18 ± 1 درجة مئوية و 85%-90% رطوبة نسبية. أدت معاملة ثمار البالباي بمحلول الماليك هيدرزايد بتركيز 250 و 500 جزء في المليون إلى تأخير معنوي في نضج الثمار لمدة يومين وثلاثة أيام في صنفي الثمار على التوالي، مقارنة بالثمار غير المعاملة، وكلما زاد التركيز كلما تأخر نضج الثمار. كما أدى تشميع الثمار إضافة إلى المعاملة بالماليك هيدرزايد إلى تأخير نضج الثمار لمدة يومين إضافيين، مقارنة بالثمار المعاملة فقط بالماليك هيدرزايد. وتمثل تأثير المعاملة بالماليك هيدرزايد والتشميع في تأخير نضج الثمار، في تأخير ذروة التنفس وتقليل فقد الوزن من الثمار وتأخير سرعة ليونتها وتراكم المواد الصلبة الكلية الذائبة و حمض الأسكوربيك فيها.