U. of K. J. Agric. Sci. 24(1), 42-59, 2016

Effect of Maleic Hydrazide and Waxing on Quality and Shelf-life of Mango (*Mangifera indica* 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 'Kitchner' and 'Abu-Samaka' mango fruits at 18 ±1°C and 85% - 90% relative humidity was studied. Maleic hydrazide and wax treatments delayed fruit ripening, reduced losses, maintained quality and extended shelf-life of mango fruits. MH at 500 and 1000 ppm significantly delayed fruit ripening by two and four days in both mango cultivars, respectively, compared with the untreated fruits. The higher the concentration of MH, the more delay in fruit ripening. Waxing in addition to MH treatment resulted in ripening delay of six days in fruit ripening than treatment with MH alone. The effect of MH and waxing treatments in delaying mango fruit ripening, was indicated in retarded respiratory climacteric, reduced water loss, delayed peel colour development, fruit softening and total soluble solids accumulation and retained ascorbic acid content.

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

INTRODUCTION

Mango (*Mangifera indica* L.) is an important fruit crop grown in tropical and sub-tropical countries. About 90 percent of tropical fruits produced globally are consumed in the producing countries themselves, while only 10 percent are traded internationally. According to FAO's 2009 food market analysis, mangoes dominated world production of tropical fruits at 31.5 million metric tons, comprising a full 40 percent of global tropical fruits' output (TAPP 2010). Mango is considered one of the best fruits in the world market due to its excellent flavour, attractive fragrance, beautiful colour, delicious taste, and health giving properties (Salunkhe and Desai 1984). In Sudan, mango is the second most important fruit crop after banana, and it is commercially grown in every State. Its annual

Production is about 803,000 tons, which represents about 60% of total Sudan exports of horticultural commodities (AOAD 2010).

Mango is a typical climacteric fruit that exhibits characteristic rise in ethylene production and respiration rate during ripening (Kader 2002). The high rate of respiration which is usually associated with short shelf-life, soft texture and high moisture content, make mango a very perishable fruit that requires absolute care during handling and transportation. Therefore, proper handling, reduction of post-harvest losses, delaying of fruit ripening and extending the shelf-life are crucial techniques for the development of a sound mango industry in Sudan.

Maleic hydrazide is known as a growth regulator that inhibits some processes in fruits and vegetables (Faust 1973). Some investigators reported that MH inhibited sprouting and reduced total loss of potato (Lekan 1965) and onion (Fadl *et al.* 2005) during storage. The effect of MH on the ripening process varies with different types of fruits. Harvested mango fruits dipped in 1000 and 2000 ppm MH showed delayed ripening (Krishnamurthy and Subramanyam 1970). Similar delaying effects of MH on ripening were reported in tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013). Maleic hydrazide applied on Sapota fruits (*Achras sapota* L.), however, hastened the ripening process (Lakshiminarayana and Subramanyam 1967). Crandall (1955) failed to influence the ripening of apples treated with MH as foliar spray 1 to 6 weeks prior to harvest, but the treatment increased flesh firmness of the fruits during storage.

Maleic hydrazide is of low acute toxicity. It has been shown to cause genotoxic effects in some mutagenicity studies. However, in view of several negative cancer studies, its genotoxic hazards is considered negligible. Maleic hydrazide was not found to be carcinogenic and has been classified as a "Group E" carcinogenic – a chemical that is not considered to be a human carcinogenic, and the actual chronic dietary risk posed by MH is minimal (EPA 1994).

Waxing and surface coating materials significantly alter permeability of the skin to gases. The commodity oxygen, through respiration, is reduced and carbon dioxide is increased. Under such restricted air-exchange conditions, a modified atmospheric condition may be generated and some of the benefits of the modified atmosphere may be achieved (Kader 2002). Waxing was reported to delay fruit ripening and senescence, reduce water loss, maintain quality and extend shelf-life of orange (Salih and Thompson 1975), mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh, 2003), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

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

MATERIALS AND METHODS

Experimental material

Mature-green mango fruits of 'Kitchner' and 'Abu Samaka' cultivars were harvested carefully by hand from an orchard at El-Faki Hashim, Khartoum North (15° 40′ N, 32° 22′ E). The fruits were selected for uniformity of size, maturity, and freedom from blemishes. Immediately after harvesting, the fruits were washed with tap water to remove latex and dust, air dried to remove water from the surface, and transported in carton boxes to the Laboratory of the Department of Horticulture, Faculty of Agriculture, University of Khartoum, for further treatments.

Fruit treatment

About 700 fruits from each mango cultivar were distributed among six treatments in a completely randomized design, with four replications. The treatments were: 0, 500 and 1000 ppm MH, with and without waxing. Maleic hydrazide was applied by dipping the fruits for three minutes in MH (Citrashine N-IMZ 'Deco-Pennwalt') solutions at 500 and 1000 ppm and then air dried. Untreated fruits (control) of both cultivars were dipped in distilled water for the same period and air dried. Food-grade wax (Fluck AG, CH-9470 Bucshs) was applied in a thin layer by brushing over the surface of the fruits and left to dry out. The treated fruits were packed in carton boxes and kept in the cold room at 18±1°C and 85% - 90% relative humidity.

Studied parameters

Respiration rate, colour changes and fruits weight loss were determined using the same 10 fruits of 'Kitchner' and 15 fruits of 'Abu Samaka', from each treatment, every two days during the storage period. Respiration rate (in mg CO_2 / kg-hr.) was determined using the total absorption method of Chalmers (1956) as modified by Mohamed-Nour and Abu-Goukh (2010). The colour score used was: mature-green (=0), trace yellow on the peel (=1), 20% yellow (=2), 40% yellow (=3), 60% yellow (=4), 80% yellow (=5) and 100% yellow (=6). Fruit weight loss was determined 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 using two fruits picked randomly from each replication other than those used for determination of respiration rate, colour changes and weight loss. 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.

Ascorbic acid content was determined, using the 2, 6-dichlorophenol-indophenol titration method of Ruck (1963). Thirty grammes of fruit pulp were homogenized in 100 ml of oxalic acid 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 supernatant was topped to 250 ml oxalic acid. Ascorbic acid content was expressed in mg /100 g fresh weight.

Statistical analysis

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

RESULTS AND DISCUSSION

Maleic hydrazide treatments delayed fruit ripening in 'Kitchner' and 'Abu-Samaka' mango cultivars. The higher the concentration, the more delay in the ripening process. Similar result was reported in banana (El- Rayah *et al.* 1980), mango (Parmar and Chandawat 1989), tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013). The wax treatment resulted in more delay in mango fruit ripening. Waxing was reported to delay fruit ripening, reduce water loss, maintain quality, and extend shelf-life of orange (Salih and Thompson 1975), mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elshiekh 2008), lime (Abdallah and Abu-Goukh 2010) and papaya (Abu-Goukh and Shattir 2012). This delay in fruit ripening was reflected in changes in respiration rate, peel colour, flesh firmness, TSS, water loss and ascorbic acid content.

Effect on respiration rate

The respiration curves of the two mango cultivars exhibited a typical climacteric pattern with climacteric peak at 252 and 143mg CO_2/kg-hr. in 'Kitchner' and 'Abu-Samaka' cultivars, respectively (Fig. 1). The untreated fruits reached the climacteric peak after six days in 'Kitchner' and ten days in ‘Abu-Samaka’. Fruits treated with MH at 500 and 1000 ppm, without waxing, reached the climacteric peak two days and four days later, respectively, compared to the untreated fruits (Fig. 1). This is in agreement with previous reports that MH delayed the onset of the climacteric peak of respiration in mango (Krishnamurthy and Subramanyam 1970), tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013). Mango fruits treated with MH at 0, 500 and 1000 ppm with waxing, reached the climacteric peak six, eight and ten days later, respectively, compared with the control (Fig. 1). Similar results were reported for mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013). 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 was continuously increased during storage of mango fruits. The untreated fruits reached the full yellow stage (colour score 6) in 12 and 14 days in 'Kitchner' and 'Abu-Samaka' cultivars, respectively (Fig. 2).

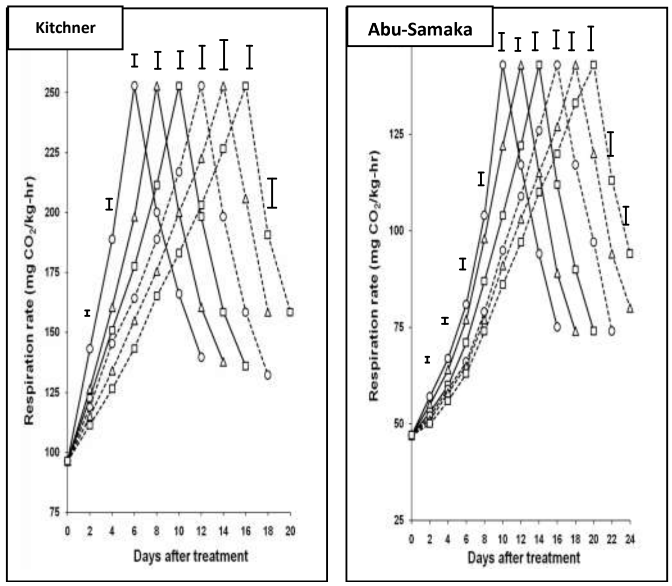

Fig. 1. Changes in respiration rate during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (———) or with waxing (– – – – – –) at 18±1 ºC and 85 % -90 % relative humidity.

Mango fruits treated with MH at 500 and 1000 ppm without waxing, reached the full yellow stage (colour score 7) two and four days later, respectively, compared to the control. These results are in line with the findings that MH treatment delayed colour development in mango (Parmar and Chandawat 1989), tomato (Ahmed and Abu-Goukh 2003) and guava (Mohamed-Nour and Abu-Goukh 2013). Maleic hydrazide with waxing was more effective in delaying colour development. Fruits treated with MH at 0, 500 and 1000 ppm with waxing reached the full yellow stage six, eight and ten days later, respectively, compared with the control (Fig. 2). This agrees with reports that waxing delayed chlorophyll degradation and peel colour development in orange (Martinez *et al*. 1991), mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), lime (Abdallah and Abu-Goukh 2010), grapefruit (Abu-Goukh and Elshiekh 2008) and guava (Mohamed-Nour and Abu-Goukh 2013).

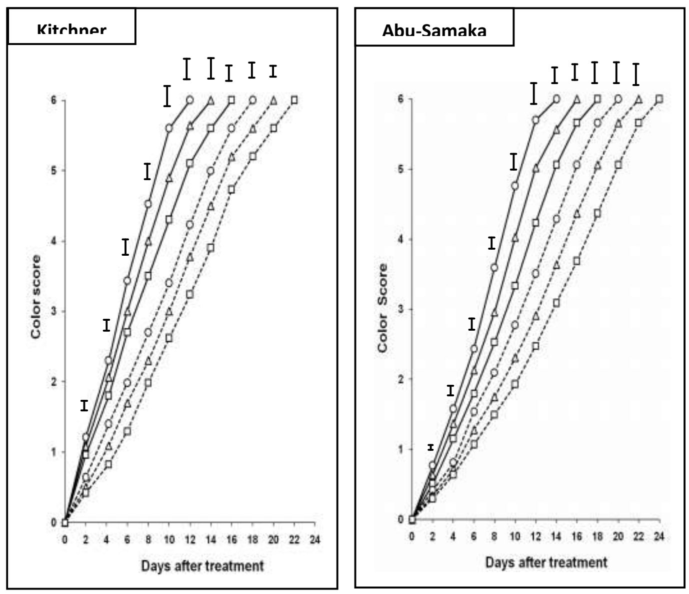

Fig. 2. Changes in peel colour during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (———) or with waxing (– – – – – –) at 18±1 ºC and 85 %-90 % relative humidity. Vertical bars represent LSD (5 %).

Effect on fruit flesh firmness

Fruit flesh firmness decreased steadily during the storage of both mango cultivars. The untreated fruits reached the final soft stage (0.27 and 0.36 kg/cm^2 shear resistance) after 12 and 14 days in 'Kitchner' and 'Abu-Samaka' cultivars, respectively (Fig. 3). Maleic hydrazide, with or without waxing, delayed the drop in flesh firmness at all concentrations, the higher the concentration, the more delay in fruit softening. The fruit treated with MH at 500 and 1000 ppm without waxing, reached the final soft stage two and four days later, respectively, compared with the untreated fruits in both cultivars (Fig. 3). This is in agreement with previous reports that MH delayed fruit softening during ripening and storage banana (El- Rayah *et al.* 1980), mango (Kaushik *et al.* 1991), tomato (Ahmed and Abu-Goukh 2003) and papaya (Abu-Goukh and Shattir 2012). Although Crandall (1955) failed to influence the ripening of apple treated with MH as foliar spray before harvest, the treatment increased flesh firmness of the fruits during storage.

Waxing with MH treatment was more effective in delaying flesh softening of mango fruits. The fruits treated with 500 and 1000 ppm MH with wax, reached the final soft stage eight and ten days later, respectively, compared with the untreated fruits. Wax treatment delayed fruit softening in mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elshiekh 2008), lime (Abdallah and Abu-Goukh 2010), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013).

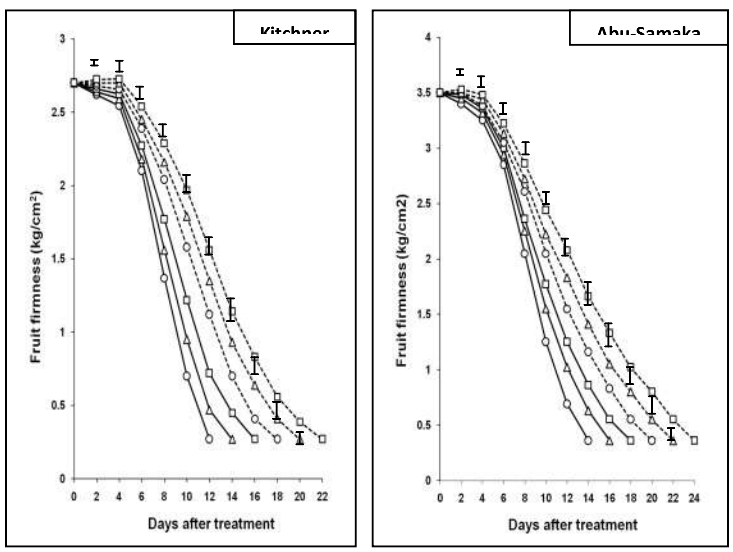

Fig. 3. Changes in fruit flesh firmness during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (———) or with waxing (– – – – –) at 18±1 ºC and 85 %-90 % relative humidity. Vertical bars represent LSD (5 %).

Effect on total soluble solids

Total soluble solids (TSS) progressively increased during storage of both mango cultivars. The maximum TSS value reached by the untreated fruit was 15.3% in ‘Kitchner’ and 19.6% in 'Abu-Samaka' (Fig. 4). That value was reached after 12 days in the untreated fruits of ‘Kitchner’ and 14 days in 'Abu-Samaka'. Maleic hydrazide treated fruits at 500 and 1000 ppm without waxing, reached the maximum TSS value two and four days later in 'Kitchner' and 'Abu-Samaka', respectively, than the untreated fruits.

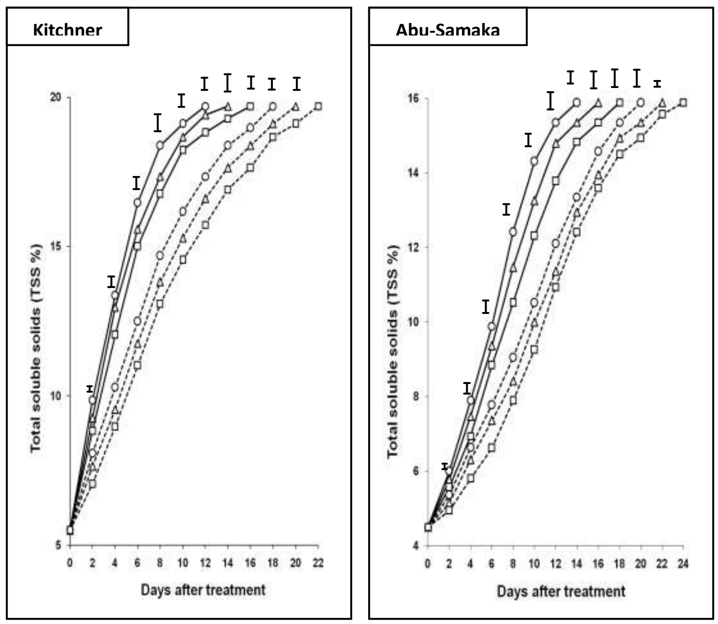

Fig. 4. Changes in total soluble solids (TSS) during storage of ‘Kitchner’ and ‘Abu-Samaka’ mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (——) or with waxing (– – – –) at 18±1 ºC and 85 %-90 % relative humidity. Vertical bars represent LSD (5 %).

This is in agreement with previous reports that MH decreased TSS accumulation during ripening of banana (El-Rayah *et al.* 1980), mango (Parmar and Chandawat 1989), tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013). The wax treatment added to the delay in accumulation of TSS. The maximum TSS was reached in the fruits treated with 0, 500 and 1000 ppm with waxing after six, eight and ten days later, respectively, compared with the control in both cultivars (Fig. 4). Mohamed and Abu-Goukh (2003) reported that waxing decreased TSS accumulation during ripening of ‘Dr. Knight’ and ‘Abu-Samaka’ mango fruits. Similar results were reported during ripening of tomato (Ahmed and Abu-Goukh 2003), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013) and during storage of orange (Martinez *et al*. 1991), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010).

Effect on fruit weight loss

Weight loss progressively increased during storage of the two mango cultivars. Maleic hydrazine, with or without waxing, reduced weight loss at all concentrations used. The higher the concentration, the more reduction in weight loss. Maleic hydrazide with waxing was more effective in reducing weight loss than MH treatment alone (Fig. 5). When the untreated fruits reached the full ripe stage, after 12 days in 'Kitchner' and 14 days in 'Abu-Samaka' cultivars, the weight loss was 16.5% and 14.7% in the two cultivars, respectively (Fig. 5). At that time, the weight loss was reduced by an average of 7.1% and 12.7% in fruits treated with 500 and 1000 ppm MH without waxing and by 22.3%, 27.9% and 33.6% in fruits treated with 0, 500 and 1000 ppm MH with waxing, respectively (Fig. 5). This is in line with previous reports that waxing decreased water loss in orange (Salih and Thompson 1975), mango (Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elsheikh, 2008), lime (Abdallah and Abu-Goukh 2010), papaya (Abu-Goukh and Shattir 2012) and guava (Mohamed-Nour and Abu-Goukh 2013).

Effect on ascorbic acid content

The initial ascorbic acid content was 39.0 and 32.0 mg/100g fresh weight in 'Kitchner' and 'Abu-Samaka' cultivars, respectively. It progressively decreased during ripening and storage of both cultivars (Fig. 6). The amount of ascorbic acid retained in the untreated fruits at the final ripe stage (12 days in 'Kitchner' and 14 days in 'Abu-Samaka') was only 44.0%

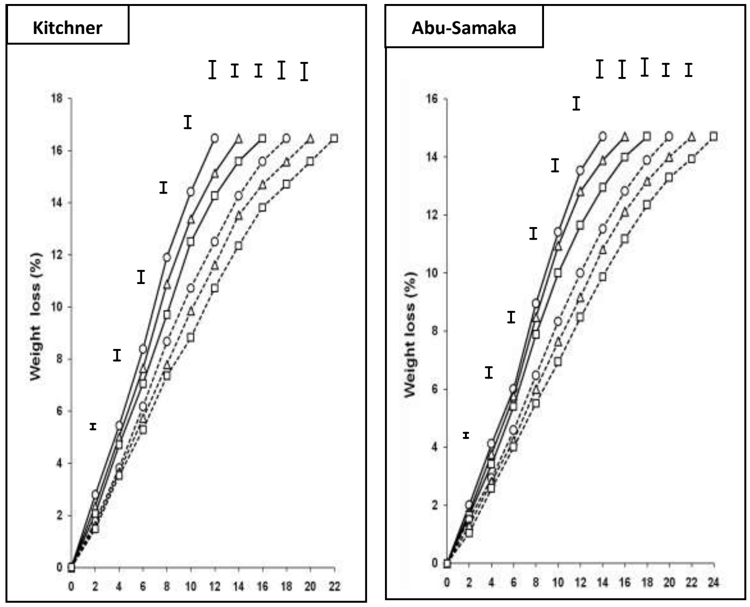

Fig. 5. Changes in fruit weight loss during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (——) or with waxing (----) at 18±1 ºC and 85 %-90 % relative humidity. Vertical bars represent LSD (5 %).

And 52.6% in the two cultivars, respectively. This is in agreement with earlier reports in mango (Abu-Goukh and Abu-Sarra 1993; Mohamed and Abu-Goukh 2003), tomato (Ahmed and Abu-Goukh 2003), orange and pineapple (Adisa 1986).

Maleic hydrazide, with or without waxing, retained ascorbic acid during ripening and storage of both mango cultivars. When the untreated fruits reached the final ripe stage (12 days in 'Kitchner' and 14 days in 'Abu-Samaka'), the average amount of ascorbic acid retained was 50.3% and 54.1% in fruits treated with 500 and 1000 ppm MH without waxing and 60.7% and 63.6% with waxing, respectively, compared with 48.3% in untreated fruits (Fig. 6). Maleic hydrazide delayed fruit ripening in both mango cultivars and it would be expected that ascorbic acid losses to be reduced.

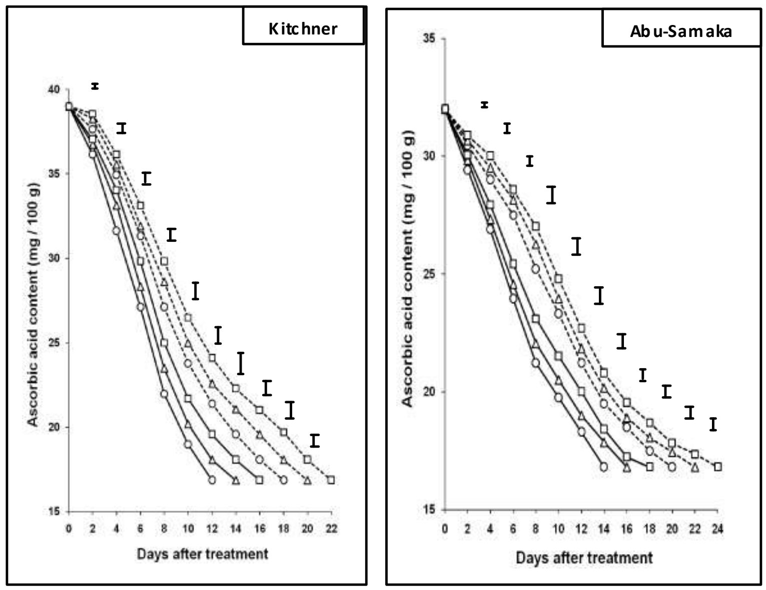

Fig. 6. Changes in ascorbic acid content during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with maleic hydrazide at 0 (o), 500 (Δ) and 1000 ppm (□) without waxing (——) or with waxing (– – – –) at 18±1 ºC and 85 %-90 % relative humidity. Vertical bars represent LSD (5 %).

Maleic hydrazide with waxing was more effective in retaining ascorbic acid than MH alone. When the untreated fruits reached the final ripe stage (12 days in 'Kitchner' and 14 days in 'Abu-Samaka'), the average amount of ascorbic acid retained was 58.1%, 60.7% and 63.6% in fruits treated with 0, 500 and 1000 ppm MH with waxing, respectively, compared with 48.3%, 50.3% and 54.1% in fruits treated with 0, 500 and 1000 ppm MH without waxing (Fig. 6). Similar results were reported for tomato (Ahmed and Abu-Goukh 2003). Ascorbic acid content was significantly higher in waxed fruits than the control in mango (Mohamed and Abu-Goukh 2003), grapefruit (Abu-Goukh and Elshiekh 2008) and lime (Abdallah and Abu-Goukh 2010). Conditions favourable to wilting resulted in more rapid loss of vitamin C (Ezell and Wilcox 1959). Waxing reduced water loss during storage of both mango cultivars (Fig. 5), and consequently reduced ascorbic acid losses in the waxed fruits (Fig. 6). Wrapping, which prevented water loss, reduced ascorbic acid losses in strawberry (Nunes *et al.* 1998). Waxing has been shown 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). It was reported that loss in ascorbic acid can be reduced by storing apples in a reduced O_2 atmosphere (Delaporte 1971). Wang (1983) noted that reduced O_2 retarded ascorbic acid degradation in Chinese cabbage stored for three months at 0° C. Modified atmosphere packaging of broccoli resulted in better maintenance of ascorbic acid compared to broccoli stored in air (Barth *et al.* 1993).

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تأثيـر المعاملة بالماليـك هيـدرازايد والتشـميع على جـودة ثمـــار المانجـو وطــول عمــرها التســويقي

عايدة عيسى مدثر وأبوبكر علي أبوجوخ

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المستخلص: تمت دراسة تأثير معاملة ثمــار المانجــو من صنفي "كتشنر" و"أبو سمكة" بعد الحصاد بالماليك هيدرزايد والتشميع علي جودة وطول فترة عمرها التسويقي في درجة حرارة 18±1 مئوية و85%-90% رطوبة نسبية. أدت معاملة ثمار المانجو بمحلول الماليك هيدرزايد والتشميع إلي تأخير نضج الثمار وتقليل الفاقد والمحافظة علي الجودة وإطالة العمر التسويقي لثمار المانجو. أدت المعاملة بالماليك هيدرزايد بتركيز 500 و 1000 جزء في المليون لتأخير نضج الثمار ليومين وأربعة أيام علي التوالي، مقارنة بالثمار غير المعاملة من صنفي المانجو، وكلما زاد التركيز كلما تأخر نضج الثمار. كما أدى تشميع الثمار إضافة لمعاملتها بالماليك هيدرزايد إلى تأخير نضج الثمار لمدة ستة أيام إضافية، مقارنة بالثمار المعاملة فقط بالماليك هيدرزايد. إنعكس تأثير المعاملة بالماليك هيدرزايد والتشميع في تأخير نضج الثمار، في إبطاء وصول الثمار إلي ذروة التنفس وتقليل الفقد في الوزن وتأخير تلوين قشرتها الخارجية وتجميع المواد الصلبة الكلية الذائبة وخفض ليونة الثمار، كما كان لها تأثير في المحافظة علي محتوي الثمار من حامض الأسكوربيك.