Effect of 1-methylcyclopropene (1-MCP) and waxing on quality and shelf-life of mango fruits

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ABSTRACT

The effect of 1-methylcyclopropene (1-MCP) and waxing on quality and shelf-life of 'Kitchner' and 'Abu-Samaka' mango fruits was evaluated. The fruits were treated with 250 and 500 ppb of 1-MCP (SmartFresh, 0.14 %) with and without waxing. Food-grade wax was used for wax treatment and was applied in a thin layer by brushing over the surface of the fruits. After treatment, the fruits were packed in carton boxes and stored at 18 ± 1ºC and 80-85 % relative humidity. Treatment by 1-MCP at 250 and 500 ppb significantly delayed fruit ripening and maintained quality of the two mango cultivars. The effect on fruit ripening was indicated by retarded respiratory climacteric, delayed peel color development, TSS accumulation and changes in titratable acidity, decreased fruit softening and weight loss, retained ascorbic acid content and maintained overall quality of the fruits. Fruit ripening was delayed by 4 and 7 days in fruits treated with 1-MCP at 250 and 500 ppb without waxing and by 6 and 9 days with waxing, respectively, compared with untreated fruits. Fruits treated with 1-MCP at 250 and 500 ppb with waxing resulted in 43.1 % and 55.1 % of fruits in the 'very good' quality grade and 21.3 % and 24.1 % in the 'good' grade, respectively, compared with only 22.3 % in the 'very good' grade and 13.6 % in the 'good' grade in the control fruits. On the other hand, only 11.5 % and 4.5 % of fruits were 'unmarketable' and 10.7 % and 6.5 % were in the 'poor' quality grade in fruits treated with 250 and 500 ppb with waxing, respectively, compared with 25.3 % of the fruits 'unmarketable' and 21.3 % in the 'poor' grade in the untreated fruits.

INTRODUCTION

Mango (*Mangifera indica* L.) is an important fruit crop in the Sudan. It is only second to banana, and is commercially grown in every State with a total production of 641,600 metric tons (FAO, 2016). Mango is the leading export fruit crop, representing about 60% of total exports of horticultural commodities (AOAD, 2010). 'Abu-Gebeha' in Southern Kordofan State is one of the most important areas in the Sudan for producing low cost fruit crops, specially mango, guava and citruses, since they are produced under rain-fed conditions.

Mango is a typical climacteric fruit that exhibits characteristic rise in ethylene production and respiration rate during ripening (Kader, 2002). Mangoes are usually harvested mature-green and transported to distant markets and ripened afterwards. During transit, they should remain green and firm for one to two weeks, depending on market distance. The shelf-life of mangoes can be extended by transporting them under optimum conditions of temperature, relative humidity and atmospheric composition, elimination or inhibition of ethylene gas and the use of ripening retardants (Kader, 2002).

Recently, 1-methylcyclopropene (1-MCP) has been employed to increase the shelf-life of some horticultural commodities. By binding to the ethylene receptors, 1-methylcyclopropene acts as an efficient ethylene antagonist and its effects can persist for a long time (Sisler *et al.,* 2003). It can, therefore, slow down the ripening process as well as senescence of fruit (Abu-Goukh, 2013). 1-methylcyclopropene is being described as a breakthrough shipping and storage technology that can maintain the fresh-picked quality of the commodity (Abu-Goukh, 2013). It is marketed as 'SmartFresh' powder from AgroFresh, containing 0.14% 1-MCP active ingredient, distributed commercially as a cyclodextrin-bound formulation. When warm water or diluted base is added, the sugar dissolves and 1-MCP is released as a gas into the surrounding environment. It must be released in an airtight room or chamber (Prange and Delong, 2003).

1-methylcyclopropene delayed fruit ripening, maintained quality and extended shelf-life of apple, avocado, banana, tomato (Blankenship and Dole, 2003; Abu-Goukh, 2013), and mango (Hofman *et al.,* 2001). The response of the fruit to 1-MCP depends upon a number of variables, including cultivar, maturity stage, concentration, temperature, duration, application technique and exposure and storage environment (Abu-Goukh, 2013).

Waxing retards the rate of moisture loss, maintains turgidity and plumpness and covers injuries on the surface of the commodity (Wills and Golding, 2016). Waxing was reported to delay fruit ripening, reduce water loss, maintain quality and extend shelf-life (Mohamed and Abu-Goukh, 2003; Mohamed-Nour and Abu-Goukh, 2013).

This study was conducted to evaluate the effect of 1-MCP and waxing on quality and shelf-life of 'Kitchner' and 'Abu-Samaka' mango fruits.

MATERIALS AND METHODS

Experimental material

Two of the most important mango cultivars grown in Sudan; an early 'Kitchner' and late maturing 'Abu-Samaka' were selected for this study. Mature-green fruits of the two cultivars were harvested from an orchard at Abu-Gebeha, south-east Kordofan (11º 27´ N, 31º 14´ E). Fruits were picked by a hook attached to a long bamboo pole equipped with a long cloth bag held open by a ring. When the pedicle was severed, the fruit dropped into the sleeve, and moved smoothly downwards to be received by the picker (Abu-Goukh and Mohamed, 2004). About 900 fruits of each cultivar were selected for uniformity in size, color and freedom from blemishes and defects. The fruits were packed in carton boxes and transported to the laboratory at the Faculty of Agriculture, University of Khartoum. The fruits were washed with tap water to remove latex and dust, washed by distilled water, treated with 10% sodium hypochlorite (Clorox, 5.2 %) as a disinfectant and air dried.

Fruit treatment

Fruits were distributed among five treatments (50 fruits each) in a completely randomized design with four replicates. Treatments were: (1) control (untreated with 1-MCP and unwaxed), (2) 250 ppb 1-MCP, (3) 500 ppb 1-MCP, (4) 250 ppb 1-MCP and waxed and (5) 500 ppb 1-MCP and waxed. The fruits were treated with 250 and 500 ppb 1-MCP (SmartFresh, 0.14%) for 24 hours at 18 ˚C in hermetically sealed 20-liters plastic chambers, according to the manufacturer recommendations. Information provided by AgroFresh indicates that 1.6 g of SmartFresh powder releases 1 ml of 1-MCP gas at 25 ˚C (Blankenship and Dole, 2003). The required concentrations of 1-MCP were obtained by adding 25 ml of distilled water at 50 ˚C to appropriate amounts of 1-MCP (SmartFresh, 0.14 %) powder, calculated according to the free space volume, in 100 ml flasks. After complete dissolution of 1-MCP powder, the flasks were placed and opened in the treatment chambers which were immediately sealed to avoid gas loss. Control fruits were maintained in identical containers, but without 1-MCP. Following the 24 hours treatment time, the chambers were opened and fruits were removed from the chambers. Food-grade wax (Flucka AG, CH-9470 Buchs) was used for wax treatment, and was applied in a thin layer by brushing over the surface of the fruits. In the composite treatments of 1-MCP and waxing, the wax was applied after 1-MCP treatment. The fruits were then packed in carton boxes (43 x 33 x15 cm) and stored at 18+1 ˚C and 80-85 % relative humidity.

Parameters studied

Respiration rate, peel color and weight loss were determined daily during the storage period on 12 fruits from each replicate. 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 was determined using the following color score: Mature green (0), trace yellow on skin (1), 20% yellow (2), 40% yellow (3), 60% yellow (4), 80% yellow (5), and 100% yellow (6). Weight loss percentage was determined according to the formula: $W_1 (\%) = [(W_o - W_t) / W_o] \times 100$; where W_1 is the percentage weight loss, W_o is the initial weight of fruits at harvest and W_t is the weight of fruits at the designated time. Flesh firmness, total soluble solids (TSS), titratable acidity and ascorbic acid content were determined on three fruits picked randomly from each replicate, other than those used for respiration rate, peel color and weight loss determinations, in 2- day intervals and later daily during storage period. Flesh firmness was measured by Magness and Taylor firmness tester (D. Ballauf 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 expressed in kg/cm. Total soluble solids were measured 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 opposite sides of each fruit and the mean values were calculated and corrected according to the refractometer chart.

Titratable acidity was measured according to the method described by Ranganna (1979). Thirty grams of fruit pulp were homogenized in 100 ml distilled water for one minute in a Sanyo Solid State blender (model SM 228P) and centrifuged at 10,000 rpm for 10 minutes using a Gallenkamp portable centrifuge (CF-400). The volume of supernatant, which constituted the pulp extract, was determined. Titratable acidity was expressed as percent citric acid.

Ascorbic acid content was determined in the pulp extract using 2,6-dichlorophenol-indophenol titration method of Ruck (1963). Thirty grams of pulp were homogenized in 100 ml of oxalic acid for one minute in a Sanyo Solid State blender (model SM 228P) and centrifuged at 10,000 rpm for 10 minutes by a Gallenkamp portable centrifuge (CF-400). The volume of supernatant was topped to 250 ml oxalic acid. Ascorbic acid content was expressed in mg per 100g fresh weight.

At the end of the storage period, the fruits in the different treatments were evaluated for general quality. The fruits were graded according to the general appearance into five categories: very good, good, fair, poor and unmarketable. The percentage of fruits in each category was calculated.

Statistical analysis

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

RESULTS AND DISCUSSION

1-methylcyclopropene (1-MCP) significantly delayed fruit ripening, maintained quality and extended shelf-life of mango fruits. Similar results were reported for apple, avocado, banana and mango (Blankenship and Dole, 2003; Abu-Goukh, 2013). 1-MCP at very low concentration inhibited ethylene action by blocking ethylene receptors (Candan *et al.*, 2006). By binding to ethylene receptors, 1-methylcyclopropene acts as an efficient ethylene antagonist and its effect can persist for a long time (Sisler *et al.*, 2003). It can, therefore, slow down the ripening process as well as senescence of fruit (Abu-Goukh, 2013). Waxing was reported to delay fruit ripening, reduce water loss, maintain quality and extend shelf-life (Mohamed and Abu-Goukh, 2003; Mohamed-Nour and Abu-Goukh, 2013). The effect of 1-MCP in delaying fruit ripening and extension of shelf-life of mango fruits was reflected in changes in respiration rate, weight loss, peel color, flesh firmness, total soluble solids (TSS), titratable acidity and ascorbic acid content.

Effect on respiration rate

The respiration curves of the two mango cultivars in all treatments, exhibited a typical climacteric pattern with a climacteric peak at 250 mg CO_2/kg-hr in 'Kitchner' and 153 mg CO_2/kg-hr in 'Abu-Samaka' untreated fruits (Fig. 1). 1-methylcyclopropene and wax treatments slightly decreased the climacteric peak. The untreated fruits reached the climacteric peak after 8 and 10 days in 'Kitchner' and 'Abu-Samaka' cultivars, respectively. 1-methylcyclopropene treatment significantly delayed the onset of the climacteric peak. Fruits treated with 1-MCP at 250 and 500 ppb without waxing reached the climacteric peak 4 and 7 days later, respectively, compared to the untreated fruits in both cultivars (Fig. 1). This is in agreement with previous reports that 1-MCP reduced or delayed the onset of the climacteric peak in mango (Hofman *et al.,* 2001), apple, avocado, guava and tomato (Blankenship and Dole, 2003; Abu-Goukh, 2013), banana (Saeed and Abu-Goukh, 2013) and plum (Candan *et al.,* 2006).

1-methylcyclopropene with waxing was more effective than 1-MCP alone. Mango fruits treated with 250 and 500 ppb 1-MCP with waxing reached the climacteric peak 6 and 9 days later, respectively, compared with the control in both cultivars (Fig. 1). Waxing delayed the onset of the climacteric peak in mango (Mohamed and Abu-Goukh, 2003) 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 weight loss

Weight loss progressively increased with storage of the two mango cultivars. Weight loss was measured till the untreated fruits reached the full yellow stage (color score 6), which was reached after 11 days in 'Kitchner' and 14 days in 'Abu-Samaka' mango fruits (Fig. 2). At that time weight loss of the untreated fruits was 19.4% in 'Kitchner' and 12.9% in 'Abu-Samaka' mangoes. 1-Methylcyclopropene, with or without waxing, significantly reduced weight loss by an average of 21.0% and 38.2% in mango fruits treated with 1-MCP at 250 and 500 ppb without waxing, respectively, compared with the control. This is in line with previous reports that 1-MCP reduced fruit weight loss in banana (Saeed and Abu-Goukh, 2013), avocado and melon (Blankenship and Dole, 2003; Abu-Goukh, 2013). On the other hand, 1-MCP did not affect weight loss in mango (Hofman *et al.,* 2001). 1-methylcyclopropene with waxing was more effective in reducing weight loss than 1-MCP alone. In mango fruits treated with 1-MCP at 250 and 500 ppb with waxing, weight loss was reduced by an average of 30.2 % and 44.9 %, , respectively, compared with the control (Fig. 2). This agrees with the reports that waxing decreased weight loss in mango (Mohamed and Abu-Goukh, 2003), guava (Mohamed-Nour and Abu-Goukh, 2013), orange (Martinez *et al.,* 1991) and grapefruit (Abu-Goukh and Elshiekh, 2008).

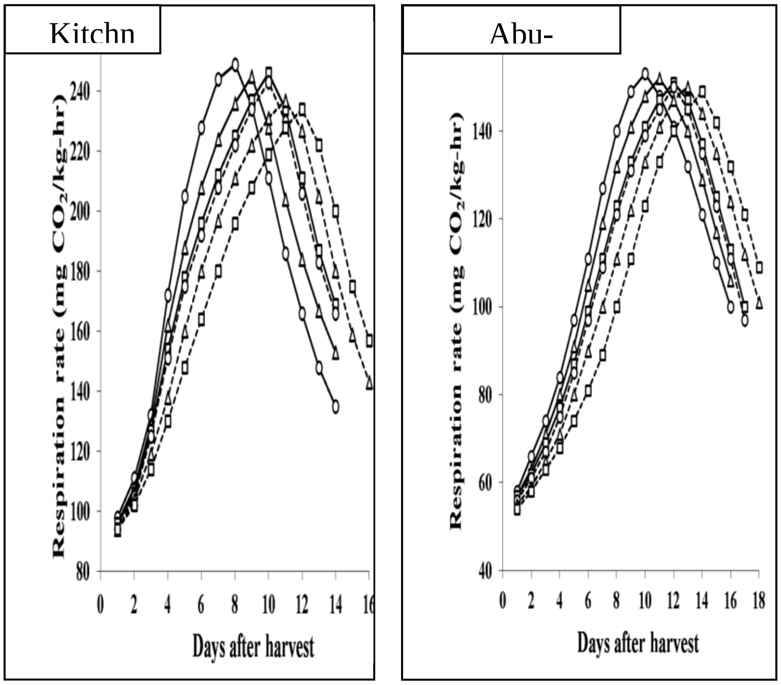

Fig. 1. Changes in respiration rate during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (o) at 18 □ 1 °C and 80% - 85% relative humidity.

Effect on peel color

Peel color score steadily increased during storage of both mango cultivars. The untreated fruits reached the full yellow stage (color score 6) 11 and 14 days in 'Kitchner' and 'Abu-Samaka', respectively (Fig. 3). At that time, the color score was just 4.8 and 5.3 in the fruits treated with 250 ppb and 3.5 and 4.8 in fruits treated with 500 ppb 1-MCP in 'Kitchner' and 'Abu-Samaka' fruits, respectively. Mango fruits treated with 1-MCP at 250 and 500 ppb without waxing reached the full yellow stage 4 and 7 days later, respectively, compared to the control in both cultivars (Fig. 3). 1-methylcyclopropene prevented or delayed chlorophyll degradation

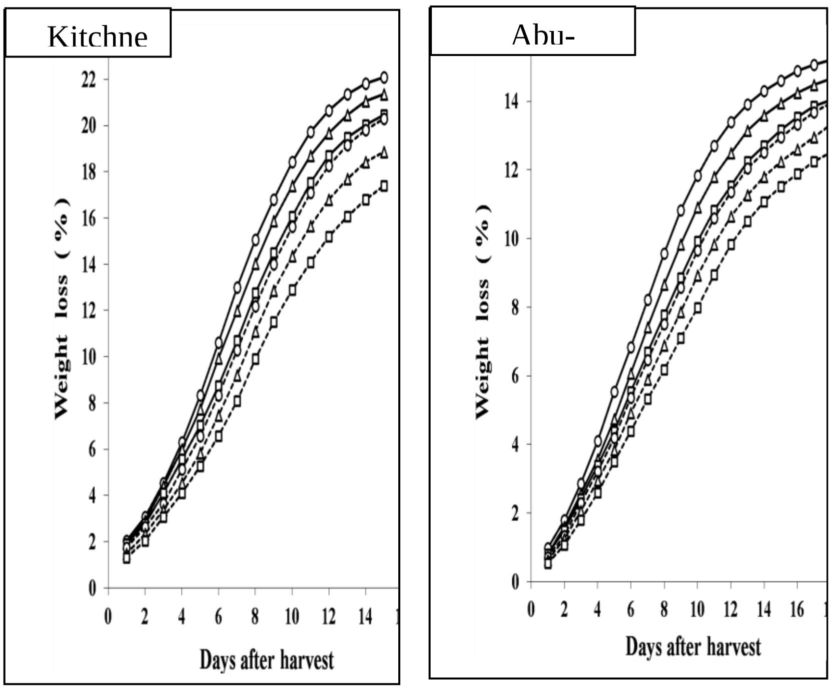

Fig. 2. Changes in weight loss during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1 $^{\circ}$C and 80% - 85% relative humidity.

and various types of color changes in a wide range of crop species. Degreening of 'Fuji' apples was inhibited by 1-MCP (Fan and Mattheis, 1999). In apricots, 1-MCP-treated fruits were greener and exhibited less color changes than the control fruits (Fan *et al.*, 2000). Similar results were reported in banana (Saeed and Abu-Goukh, 2013), avocado, guava and lime (Blankenship and Dole, 2003; Abu-Goukh, 2013).

1-methylcyclopropene with waxing was more effective in delaying color development. Mango fruits treated with 1-MCP at 250 and 500 ppb with waxing reached the full yellow stage (color score 6), 6 and 9 days later, respectively, compared with the control in both cultivars (Fig. 3). This agrees with reports that waxing delayed chlorophyll degradation and peel color development in mango (Mohamed and Abu-Goukh, 2003), guava (Mohamed-Nour and Abu-Goukh, 2013), orange (Martinez *et al.*, 1991) and grapefruit (Abu-Goukh and Elshiekh, 2008). Waxing and surface coating materials significantly alter permeability of skin to gases. The fruit, through respiration is used to reduce O_2 and increase CO_2. Under such restricted air-exchange condition, a modified atmosphere condition may be generated and some of the benefits of the modified atmosphere may be achieved

(Kader, 2002). Modified atmosphere reduces the rates of respiration and ethylene production, ripening and other metabolic processes. Carbon dioxide-enriched atmosphere may also inhibit ethylene action, since CO_2 is a competitive inhibitor of ethylene action (Kader, 2002).

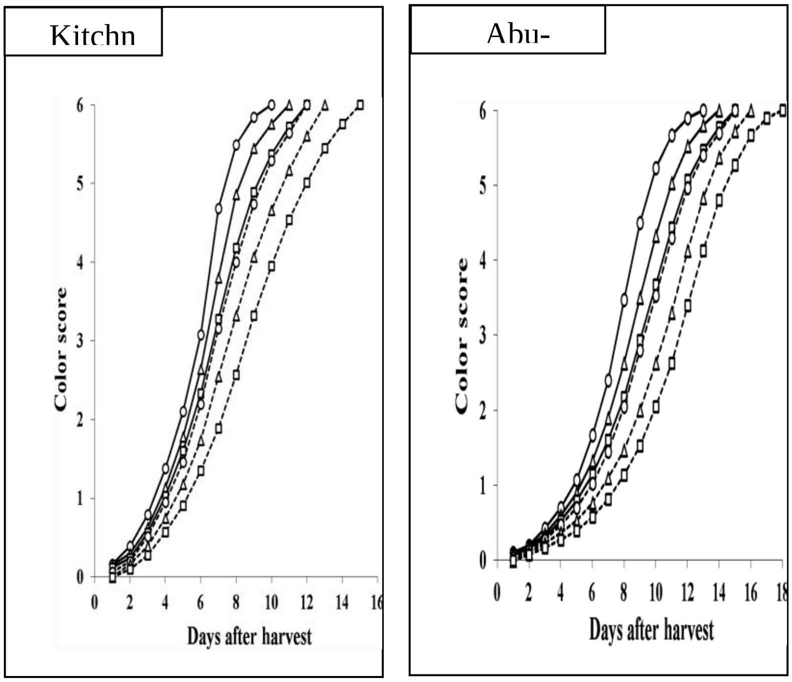

Fig. 3. Changes in peel color during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1 °C and 80% - 85% relative humidity.

Effect on fruit flesh firmness

Fruit flesh firmness progressively decreased with storage of both cultivars in all treatments. The untreated fruits reached the final soft stage (0.14 kg/cm^2 shear resistance) after 16 and 19 days in 'Kitchner' and 'Abu-Samaka' cultivars, respectively (Fig. 4). 1-methylcyclopropene, with or without waxing, significantly delayed the drop in flesh firmness. The treated fruits were firmer than the untreated fruits at any time during the storage period. The fruits treated with 1-MCP at 250 and 500 ppb without waxing reached the final soft stage (0.14 kg/cm^2), 4 and 7 days later, respectively, compared with the control in both mango cultivars (Figs. 7 and 8). These result support the reports that 1-MCP application delayed fruit softening in banana (Saeed and Abu-Goukh, 2013), apricot, peach, guava and tomato (Blankenship and Dole, 2003; Abu-Goukh, 2013), mango, papaya and custard apple (Hofman *et al.*, 2001). Flesh firmness was delayed without negative impacts on the quantitative or qualitative aroma composition of the fruits.

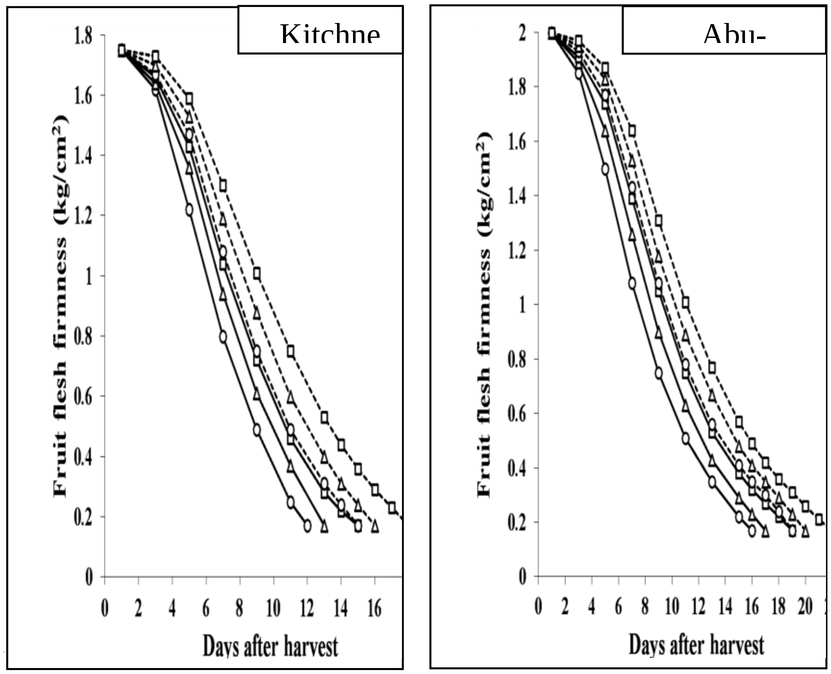

Fig. 4. Changes in fruit flesh firmness during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1 °C and 80% - 85% relative humidity.

1-methylcyclopropene with waxing was more effective in delaying flesh softening of mango fruits. The fruits treated with 250 and 500 ppb 1-MCP with waxing reached the final soft stage (0.14 kg/cm^2), 6 and 9 days later, respectively, than the control in both cultivars (Fig. 4). Wax treatment delayed fruit softening in mango (Mohamed and Abu-Goukh, 2003), guava (Mohamed-Nour and Abu-Goukh, 2013), orange (Martinez *et al.*, 1991) and grapefruit (Abu-Goukh and Elshiekh, 2008).

Effect on total soluble solids

During storage period, total soluble solids (TSS) progressively increased in both mango cultivars. The maximum TSS value reached by the untreated fruits was 19.9 % in 'Kitchner' after 11 days and 18.6 % in 'Abu- Samaka' after 13 days (Fig. 5). At that time TSS were only 18.6% and 16.6% in 'Kitchner' and 17.4% and 15.5% in 'Abu-Samaka' fruits treated with 250 and 500 ppb 1-MCP without waxing, respectively. 1-methylcyclopropene and waxing significantly delayed the accumulation of TSS during mango storage. The fruits treated with 1-MCP at 250 and 500 ppb without waxing had reached the maximum TSS of 19.9% in 'Kitchner' and 18.6% in 'Abu-Samaka' 4 and 7 days later, respectively, compared with the untreated fruits in both cultivars (Fig. 5). 1-methylcyclopropene delayed fruit ripening and all attributes related to it and hence it delayed accumulation of TSS during fruit ripening.

Waxing in conjunction with 1-MCP added to the delay in accumulation of TSS during storage of mango fruits. The maximum TSS was reached in fruits treated with 250 and 500 ppb 1-MCP with waxing, 6 and 9 days later, respectively, compared with the control in the two cultivars (Fig. 5). 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 and storage of guava (Mohamed-Nour and Abu-Goukh, 2013), orange (Martinez *et al.*, 1991) and grapefruit (Abu-Goukh and Elshiekh, 2008).

Effect on titratable acidity

Titratable acidity steadily decreased in all fruits regardless of the treatment. It was higher during storage in 'Abu-Samaka' than in 'Kitchner' mango fruits. Titratable acidity in the untreated fruits had decreased from 2.5 % and 3.4% in 'Kitchner' and 'Abu-Samaka' to 0.2% in the two cultivars after 12 and 14 days, respectively (Fig. 6). Fruits treated with 1-MCP at 250 and 500 ppb without waxing reached the minimum titratable acidity, 4 and 7 days later, respectively, compared with the control. Titratable acidity was higher in 1-MCP-treated plum fruits stored at 0 ˚C or 20 ˚C for 10 days and subsequently transferred to 20 ˚C (Manganaris *et al.*, 2007).

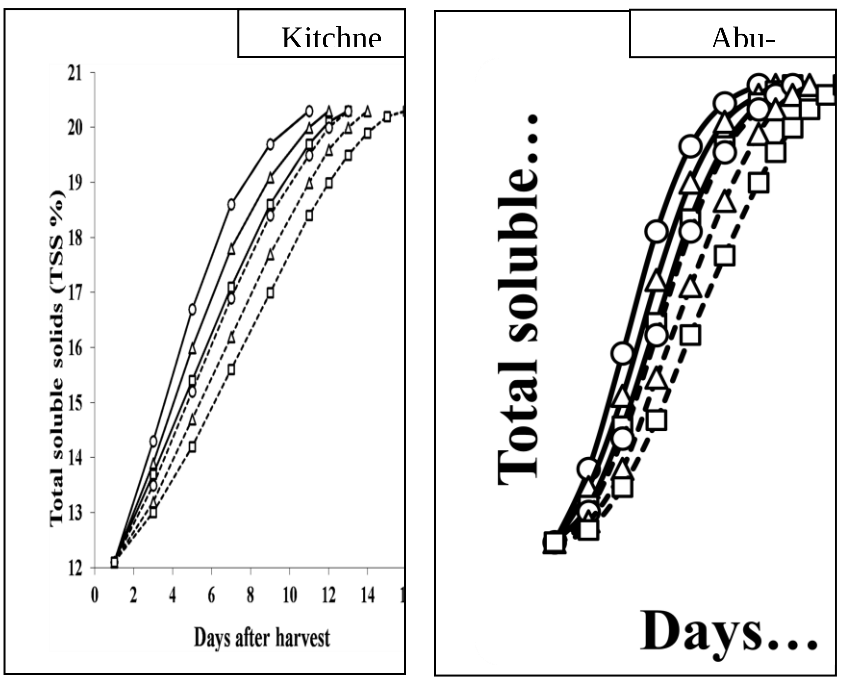

Fig. 5. Changes in total soluble solids (TSS) during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1˚C and 80% - 85% relative humidity.

1-methylcyclopropene with waxing was more effective in delaying the decrease in titratable acidity than 1-MCP alone. The fruits treated with 250 and 500 ppb 1-MCP with waxing reached the minimum value of titratable acidity, 6 and 9 days later, respectively, compared with the untreated fruits (Fig. 6). Abu-Goukh and Elshiekh (2008) reported that waxing delayed the drop in titratable acidity during storage of grapefruits. 1-methylcyclopropene and waxing delayed fruit ripening and consequently delayed the decrease in titratable acidity during ripening and storage of mango fruits.

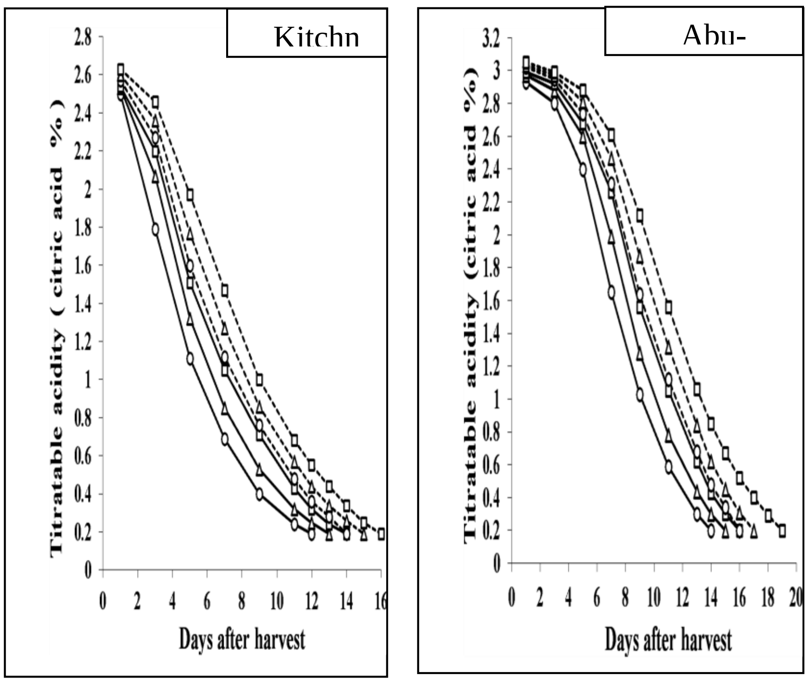

Fig. 6. Changes in titratable acidity during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1°C and 80% - 85% relative humidity.

Effect on ascorbic acid content

Ascorbic acid content progressively decreased during storage of the two mango cultivars (Fig. 7). It decreased in the untreated fruits from 41 to 15 mg/100 g fresh weight in 12 and 14 days in 'Kitchner' and 'Abu-Samaka' cultivars, respectively. This is in agreement with previous reports in mango (Abu-Goukh and Abu-Sarra, 1993), orange, pineapple (Adisa, 1986), and guava (Bashir and Abu-Goukh, 2003). Ascorbic acid (AA) was significantly higher in fruits treated with 1-MCP and wax. At the time the untreated fruits reached the minimum value of 15 mg/100 g, AA was on average 12.7% and 26.7% higher in fruits treated with 1-MCP at 250 and 500 ppb without waxing, and 22.7% and 32.7% higher in fruits treated with 250 and 500 ppb 1-MCP with waxing, respectively, compared with the control (Fig. 7). This is in agreement with reports that 1-MCP decreased or delayed loss of ascorbic acid in pineapple (Buda and Joyce, 2003). Ascorbic acid content was significantly higher in waxed fruits than the control (Mohamed and Abu-Goukh, 2003). Conditions favorable 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. 2), and consequently reduced ascorbic acid losses in the waxed fruits.

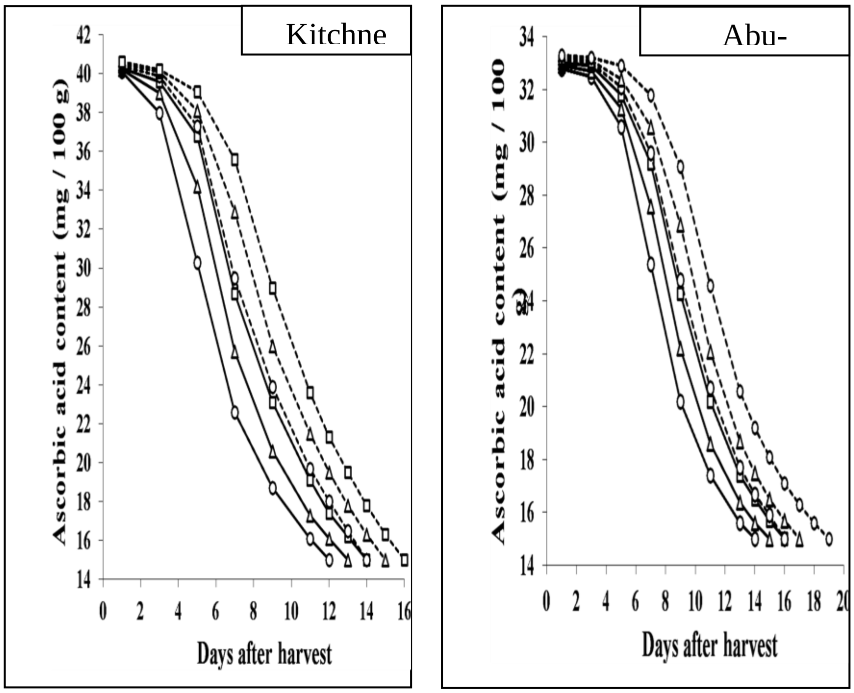

Fig. 7. Changes in ascorbic acid content during storage of 'Kitchner' and 'Abu-Samaka' mango fruits treated with 250 ppb (□) or 500 ppb 1-MCP (□) without waxing (——), or with waxing (------), compared with control fruits (□) at 18 □ 1°C and 80% - 85% relative humidity.

Effect on general quality

At the end of the storage period the fruits were evaluated for general quality. Table 1 shows percentages of 'Kitchner' and 'Abu-Samaka' mango fruits in each quality grade. The fruits treated with 250 and 500 ppb 1-MCP without waxing resulted, on average of the two cultivars, in 39.6 % and 53.5 % of fruits in ‘very good’ quality grade and 20.3 % and 22.2 % of fruits in ‘good’ quality grade, respectively. While the control fruits resulted, on average, in only 22.3% in ‘very good’ grade and 13.6 % in ‘good’ grade. On the other hand, the ‘unmarketable’ fruits were only 11.5 % and 5.6 % in fruits treated with 250 and 500 ppb without waxing, respectively, compared with 25.3 % in the control fruits. Similarly, the fruits in the ‘poor’ grade were, on average, of 12.3 % and 7.6 % in fruits treated with 250 and 500 ppb 1-MCP without waxing, respectively, compared to 21.3% in the untreated fruits (Table 1). 1-methylcyclopropene with waxing was more effective in reducing losses and maintaining quality than 1-MCP treatment alone. The fruits treated with 1-MCP at 250 and 500 ppb with waxing resulted, on an average, in 43.1 % and 55.1 % of fruits in ‘very good’ grade and 21.3 % and 24.1 % in ‘good’ quality grade, respectively, compared to 22.3 % in ‘very good’ grade and 13.6 % in ‘good’ grade in the control fruits. The 'unmarketable' fruits were only 11.5 % and 4.5 % and the 'poor' quality fruits were 10.7 % and 6.5 % in the fruits treated with 250 and 500 ppb 1-MCP with waxing, respectively, compared to 25.3 % in the 'unmarketable' and 21.3 % in the 'poor' grade in the untreated fruits. 1-methylcyclopropene and waxing resulted in delayed respiration rate (Fig. 1), reduced water loss (Fig. 2), delayed peel color development (Fig. 3), decreased fruit softening (Fig. 4), retained ascorbic acid content (Fig. 7) and delayed fruit ripening and senescence. All these were reflected in better appearance and quality of the treated fruits, compared with the control.

Table 1. Effect of 1-methylcyclopropene (1-MCP) andwaxing on mango fruit quality.

Cultivar	Treatment	Quality grades (%)				
		Very good	Good	Fair	Poor	Unmarketable
Kitchner	Control	17.0	14.9	15.9	21.3	30.9
	250 ppb	38.4	22.1	16.3	10.4	12.8
	250 ppb + Wax	41.3	23.8	16.2	8.7	10.0
	500 ppb	48.1	24.7	12.3	7.5	7.4
	500 ppb + Wax	48.8	25.0	11.9	7.2	7.1
Abu-Samaka	Control	27.6	12.4	19.2	21.2	19.6
	250 ppb	40.8	18.4	16.3	14.3	10.2
	250 ppb + Wax	44.8	18.9	14.5	12.7	9.1
	500 ppb	58.8	19.7	9.8	7.8	3.9
	500 ppb + Wax	61.4	23.1	7.8	5.8	1.9

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تأثير الميثايل سايكلوبروبين (1-MCP) والتشميع على جودة وطول العمر التسويقي لثمار المانجو

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الخلاصة

قُوم تأثير معاملة الثمار بالميثايل سايكلوبروبين (1-MCP) والتشميع على جودة وطول العمر التسويقي لثمار المانجو "كتشنر" و"أبوسمكة". عوملت الثمار بالميثايل سايكلوبروبين (SmartFresh, 0.14%) لمدة 24 ساعة على درجة حرارة 1 ± 18 °م فى حاويات بلاستيكية سعة 20 لتراً، وفقاً لتوصيات الشركة المصنعة. تم الحصول على التركيزات المطلوبة من الميثايل سايكلوبروبين (1-MCP) عن طريق إضافة25 ملى ليتر من الماء المقطر الدافئ في درجة حرارة 50 °م إلى الكميات المناسبة من مسحوق MCP، حسبت وفقاً لحجم المساحة الحرة، في دوارق سعة 100 ملى ليتر. بعد الذوبان الكامل لمسحوق الميثايل سايكلوبروبين (1-MCP) وضعت الدوارق مع الثمار داخل الحاويات البلاستيكية وتم فتحها ثم أغلقت الحاويات على الفور لتجنب فقدان الغاز. كما وضعت الثمار غير المعاملة في حاويات مماثلة، ولكن بدون إضافة الميثايل سايكلوبروبين . (1-MCP) بعد 24 ساعة فتحت الحاويات وأخذت الثمار منها. إستخدم شمع من نوعية الشموع المجازة للمواد الغذائية فى طبقة رقيقة مسحت على أسطح الثمار، وفى حالة إستخدام المعاملتين معاً تمت المعاملة بالميثايل سايكلوبروبين (1-MCP) أولاً ثم تلاها التشميع. كانت المعاملات (1) ثمار غير معاملة (شاهد) و (2) ثمار معاملة ب 250 جزء في البليون (1-MCP) و (3) ثمار معاملة ب 500 جزء في البليون (1-MCP) و (4) ثمار معاملة ب 250 جزء في البليون (1-MCP) مع التشميع و (5) ثمار معاملة ب 500 جزء في البليون (1-MCP) مع التشميع. من ثم تمت تعبئة الثمار في صناديق كرتون بأبعاد 15 × 33 × 43 سم وإستخدم التصميم كامل العشوائية بأربعة مكررات لإجراء التجربة، وحفظت الثمار على درجة حرارة 18 ± 1 °م ورطوبة نسبية 80 % - 85 %. أدت معاملة ثمار المانجو بمادة الميثايل سايكلوبروبين (1-MCP) بتركيز 250 و500 جزء في البليون إلى تأخير معنوى فى نضج الثمارفى صنفى ثمار المانجو. أدت المعاملة بمادة الميثايل سايكلوبروبين (1-MCP) مع التشميع إلى تأخير أكثر فى النضج وفى المحافظة جودة الثمار. إنعكس تأثير المعاملة فى تأخير وصول الثمار إلى ذروة التنفس وتلون القشرة وتراكم المواد الصلبة الذائبة فيها وليونة الثمار والتغيرات في الحموضة وفقدان الوزن والحفاظ على محتوى حمض الأسكوربيك والمحافظة على جودة الثمار. أدت المعاملة بالميثايل سايكلوبروبين (1-MCP) بتركيز 250 و500 جزء فى البليون بدون تشميع إلى تأخير نضج الثمار لفترة 4 و 7 أيام، كما أدت المعاملة بالميثايل سايكلوبروبين بتركيز 250 و500 جزء في البليون مع التشميع إلى تأخير النضج لفترة 6 و 9 أيام، على التوالي، مقارنة مع الثمار غير المعاملة. نتج عن المعاملة ب 250 و500 جزء في البليون من الميثايل سايكلوبروبين (1-MCP) مع التشميع أن 43.1 % و55.1 % من الثمار كانت في درجة الجودة "جيد جداً" و 21.3 ٪ و 24.1 % من الثمار في درجة "جيد"، على التوالى، مقارنة ب 22.3 % من الثمار في درجة "جيد جداً" و 13.6 % في درجة "جيد" فى الثمار غير المعاملة. من ناحية أخرى، فإن 11.5 % و 4.5 % فقط من الثمار كانت في درجة "غير القابلة للتسويق" و 10.7 % و6.5 % من ثمار "رديئة" في الجودة من الثمار المعاملة بالميثايل سايكلوبروبين بتركيز 250 و500 جزء في البليون مع التشميع، على التوالي، مقارنة ب 25.3 % من الثمار "غير القابلة للتسويق" و21.3 % من الثمار "الرديئة" في الثمارغير المعاملة.