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Physiological Studies on the Marketability of Williams Banana Fruits

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ABSTRACT

The effect of postharvest treatments with hot water (HW), gibberellic acid (GA_3), salicylic acid (SA) and potassium permanganate ($KMnO_4$) on enhancing or delaying the ripening quality aspect of mature Williams banana fruits were investigated. Untreated and treated fruit had a normal ripening process and similar good freshness at the ripening time (45 days at ambient temperature). This clearly that the used these materials were relatively in delaying ripening and as, can be arrange the appearance of banana fruits in the market with good quality. Such, color development, peeling condition, loss of firmness, increase of pulp/peel ratio, soluble solids content, titratable acidity, pH, total sugar and total starch were used as a good criterion of assessment the banana fruit ripening.

Key words: Williams banana, hot water (HW), gibberellic acid (GA_3), salicylic acid (SA), potassium permanganate ($KMnO_4$), marketability

INTRODUCTION

Bananas (*Musa* spp.) are planted in all moisture tropical area and represent the fourth largest food crop of the world after rice, wheat and maize (Arias *et al*., 2003). Bananas also today represent the second largest produced fruit after citrus contributing about 16% of the world's total fruit production with an annual production of 129,906,098 metric tons (FAO, 2010).

In Egypt, the total cultivated area of banana reached more than 55000 feddan produced more than 1.100.000 tons (FAO, 2010). Williams (*Musa cavendishii* L.) is one of the most important cultivars newly grown under the local condition, especially at the desert under drip irrigation system. Bananas are a usual climacteric fruits wherever previously ripening have been starting by ethylene, they revealed a short life because of rapid declining of peel color and pulp firmness (Seymour, 1993).

Bananas are harvested when reach to full maturity for local market and immature for export. Sometimes, markets do not absorb all the bananas full for harvest. Due to the short life of bananas which reduces their survival in the market a long time for this, prolonging the life of banana to the largest possible period is considered beneficial to the dealer, whether for export or domestic consumption.

Hot water (HW) has been often evaluated as a means for quarantine for banana and extends commercial life of the fruit (Lopez-Cabrera and Marrero-Dominguez, 1998). Also, Lurie (1998) recommended that the decline in fruit hardness affected by hot water treatment was reason for the inhibition of pectin cell wall hydrolysis, reduced level of cell wall degrading enzyme activity or the inhibition of ethylene production due to a reduction in the activity of ethylene-forming enzyme.

Respiration rate as well as chlorophyll degradation were reduced by dipping Kluai Khai banana fruit in hot water at 50°C for 10 min. Also, peel color change was retarded and fruit firmness was maintained, however catalase and peroxidase activities were higher compared to the other treatments (Varit and Songsin, 2011).

The main use, of gibberellins (GA_3) is as a growth regulator to retard ripening, senescence of fruits and extending shelf-life, however GA_3 delays climacteric peak of respiration peel color development of Dwarf Cavendish banana, total soluble solids accumulation, fruit softening and reduced weight loss during storage (Osman and Abu-Goukh, 2008). The immersion of banana fruits with GA_3 after harvest at rates of 50 to 250 mg L^{-1} for 5 to 30 min resulted in prolonged green and yellow fruit life as a consequence of delayed maturation (Patil and Hulamani, 1998). Friedman (1996) mentioned that GA_3 treatments were effective in reducing the susceptibility of the fruits to be mechanically damaged and delaying senescence of the fruits, prolong storage life and inhibited ethylene production. Also, GA_3 delays chlorophyll degradation and fruit softening (Khader, 1992).

Salicylic acid (SA), a ubiquitous plant phenolic, has been reported to regulate a number of processes in plants. It was shown to interfere with the biosynthesis and/or action of ethylene, abscisic acid and cytokinins in plants. SA treatment has been found to delay the ripening of banana fruits (Srivastava and Dwivedi, 2000). Acetyl salicylic acid (a derivative of SA) application increased the endogenous SA levels, inhibited ethylene production and maintained firmness of kiwi fruit during cold storage (Zhang *et al*., 2003).

Potassium permanganate ($KMnO_4$) is a stable purple solid that is a strong oxidizing agent and readily oxidizes ethylene (Wills and Warton, 2004). Treatment of $KMnO_4$ as an ethylene absorbent, delayed fruit ripening proved most effective in reducing rot and maintained the physical appearance and quality of fruit in fresh conditions (Bairwa *et al*., 2002). Postharvest application with $KMnO_4$ had delaying of ripening with good quality of mature Maghrabi banana fruits (Abd El-Naby, 2010).

The purpose of this study was to investigate the response of Williams banana fruits to control ripening with some safe treatments to maintain ideal eating quality and regulate their marketing life.

MATERIALS AND METHODS

Mature green bunches of Williams banana were used in the present study during two successive seasons of 2011 and 2012. Bunches were taken from a private orchard at El-Behira governorate, Williams banana plants were in a good physical condition, uniformity and adequate irrigation, fertilizers and other cultural practices recommended for banana plantations in sand soil. Mature banana fruits for both first and second seasons were harvested in first half of January at commercial maturity, i.e., (three quarter full, 120 days after shooting and bunch weighted 23-27 kg with light green color (Stover and Simmonds, 1987). Bunches were immediately transported to the laboratory of postharvest at Hort. Res. Inst. Mansoura, Egypt. Bunches were left at ambient condition for two days as a sweating period, then bunches were de-handed and individual bananas were washed with tap water and air dried. Physical and chemical properties of fruits were measured.

Banana handed were received one of the following treatments as follows:

- Control (Dipping fruits in tap water for 10 min)
- Dipping fruits in hot water at 45°C for 10 min

- Dipping fruits in gibberellic acid at 50 ppm for 10 min
- Dipping fruits in salicylic acid at 50 ppm for 10 min
- Small packet potassium permanganate, each content 20 g

*$KMnO_4$ encased in small polyethylene bags perforated only on one side of banana box to avoid staining the fruits.

For shelf life study, hands of each treatment were placed within polyethylene bag (thickness 0.04 mm) in 9 carton box each box containing 3 hands. The total numbers of boxes were 45 for all treatments. After the treatments, carton boxes were held at room temperature on 20°C±2 and 65-70% relative humidity until the natural ripening (when the fingers reached color between 5-7 degree). Banana fruits in three boxes (3 replicates) for each treatment were taken 15 days intervals to determine the following properties:

Weight loss (%): Was calculated according to the following equation:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Weight at sampling date}}{\text{Initial weight}} \times 100$$

Angulation: Was determined by measuring the equatorial diameter of two different sides and calculated by dividing the difference between the average of total lowest reading and average of total highest reading by the average of total highest reading and multiplying by 100 (Abou-Aziz *et al*., 1993).

Fruit firmness (Ib inch^{-2}): Was measured using PHSH-PULL Dynanomteter Modle DT (01) having plunger of 8 mm diameter probe.

Peel color: Was determined according to the standard color index of the united fruit Co. (7 grades from full green to complete yellow).

Peeling condition: Was scored as follows, (1): Unpeeling, (2): Hard peeling, (3): Peeling and (4): Easy peeling.

Pulp/peel ratio: Pulp and peel are separated, weighed individually and expressed as pulp to peel ratio (i.e., pulp weight divided by the peel weight).

Soluble solids content SSC%: Was determined refractmetrically according to AOAC (2005).

Total acidity (%): Was determined in by titrating by against 0.1 N sodium hydroxide using phenolphthalein as indicator. Results were expressed as percentage of Malic acid in flesh pulp weight according to AOAC (2005).

SSC/acid ratio (%): Was calculated by dividing the value of SSC over the value of titratable acidity of each sample.

Pulp pH: Was measured in the pulp juice with a digital bench top pH meter. pH values give a measure of the alkalinity of a product.

Total sugar: The extract was prepared by taking 0.5 g of fresh pulp and extracting the same with 80% ethanol by centrifuging three times. The supernatant was collected and measured quantity of distilled water was added to it and heated until all ethanol got evaporated. Then volume of sample was made up to 150 mL by adding distilled water. The total sugar was estimated using anthrone's reagent (Ranganna, 1979). The 1 mL of alcoholic extract was taken in a test tube and chilled. After a while 4 mL of anthrone's reagent was carefully run down the walls of the test tube. The test tubes were thereafter immersed in ice water. The tubes were brought to ambient temperatureand boiled in water bath for 10 min. After proper cooling, the absorbance was measured at 625 nm. Total sugars were calculated as gm of glucose 100 g^{-1} weight.

Starch: The banana and solvent mixer was blended and then stirred slowly for 2 h. The suspension was centrifuged at 3500 rpm for 15 min. The supernatant was discarded and the sediment was resuspended in two volumes of distilled water and centrifuged, this step was repeated to wash the sediment. The starch suspension was then neutralized to pH 7 and the sediment starch was dried in an air oven at 50°C (Eggleston *et al*., 1992).

Pulp moisture (%): Was determined by during a pre weighted amount of material in a vacuum oven at 70°C, until it reached a constant weight.

Statistical analysis: Data of both seasons of the study were designed (Completely Randomize Designed) by using analysis of variance (ANOVA), with two factors; time and temperature. Differences among treatment means were statistically analyzed by using the least significant differences test (LSD) at p = 0.05%, means separation using the CoStat program.

RESULTS AND DISCUSION

Weight loss percentage: Data presented in Table 1 show clearly that during the two seasons of study, the loss weight gradually increased as the shelf life period prolonged. The data also indicated that all materials treatments significantly reduced the weight loss% than the control after 45 days of shelf life during the two seasons of this study. Since the weight loss%in banana fruits untreated were 2.96 and 4.23% after 45 days held under room temperature in two seasons respectively. While fruits treated with GA_3 had the lowest loss percentage in fruit weight (2.16 and 2.90%) in the two seasons. Although the weight loss% values ranged (2.33-3.23%), (2.40-3.53%) and (2.56-3.80%) for banana fruits treated with HW, SA and $KMnO_4$ after 45 days at shelf life in two seasons, respectively.

With regard to the effect of GA_3, Valero *et al*. (1998) found that gibberellin application is followed by an increase in polyamine levels and in the activities of their biosynthetic enzymes and exogenous polyamines delayed senescence and prolonged fruit storage, physiological processes that are usually accompanied by decreases in plant polyamines. Also, Osman and Abu-Goukh (2008) reported that GA_3 treatment resulted in more reduction of weight loss of banana fruits during shelf life. Recently, salicylic acid has also been shown to inhibit ACC oxidase activity. Ethylene synthesis is normally limited by the supply of the immediate precursor amino cyclopropane-1-carboxylic acid (ACC) (Fan *et al*., 1996). Thus, the effect of salicylic acid in delaying the ripening of banana fruits may be of due to inhibition of ethylene biosynthesis and action.

Table 1: Effect of post-harvest treatments on weight loss%, angulation% and firmness (Ib inch^{-2}) of Williams banana fruits during ripening at room temperature at 2011and 2012 seasons

	Loss weight (%)				Angulation (%)				Firmness (Ib inch^{-2})			
	Storage period in days											
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control	0.00	0.80	1.00	2.96	14.66	13.46	7.73	5.96	11.16	10.90	9.60	5.16
Hot water at 45°C	0.00	0.46	0.90	2.33	14.66	14.06	8.80	7.23	11.16	10.86	10.23	7.20
GA_3 at 50 ppm	0.00	0.36	0.80	2.16	14.66	14.30	9.33	7.30	11.16	11.10	10.56	7.10
Salicylic acid at 50 ppm	0.00	0.53	1.16	2.40	14.66	13.93	8.96	7.30	11.16	10.93	10.40	7.03
$KMnO_4$ at 20 g	0.00	0.70	1.03	2.56	14.66	13.66	8.16	6.73	11.16	10.80	9.93	6.13
Mean	0.00	0.57	0.98	2.48	14.66	13.88	8.60	6.90	11.16	10.92	10.14	6.52
L.S.D. at 5%												
Treatment	0.098				0.156				0.123			
Time	0.085				0.580				0.353			
Treatment (time)	0.190				0.313				0.246			
Season 2012												
Control	0.00	0.39	1.90	4.23	13.96	12.03	6.90	5.16	10.76	10.23	8.40	4.20
Hot water at 45°C	0.00	0.60	1.53	3.23	13.96	13.13	8.13	6.56	10.76	10.63	9.70	6.20
GA_3 at 50 ppm	0.00	0.46	1.26	2.90	13.96	13.20	8.46	6.66	10.76	10.63	6.96	6.40
Salicylic acid at 50 ppm	0.00	0.76	1.73	3.53	13.96	12.76	8.23	6.50	10.76	10.76	9.73	6.33
$KMnO_4$ at 20 g	0.00	0.86	1.93	3.80	13.96	12.33	7.40	5.93	10.76	10.56	8.66	5.10
Mean	0.00	0.72	1.67	3.54	13.96	12.69	7.82	6.16	10.76	10.56	8.68	5.64
L.S.D. at 5%												
Treatment	0.108				0.262				0.997			
Time	0.090				0.204				0.907			
Treatment (time)	0.203				0.456				2.028			

Moreover, Abd-El-Wahab (2007) reported that hot water dips reduced the percentage of decay, weight loss and phenols of apricot and peach fruits.

In addition, $KMnO_4$ decreases respiration and delays ripening by maintaining ethylene at a low level for a long period (Illeperuma and Jayasuriya, 2002).

Finger angulation percent: From Table 1 the data show clearly angulation percent for Williams banana fruits, gradually decreased with the advanced in shelf life at room temperature during the two season of study. At the end of shelf life period (45 days) angulation, ranged between (7.23-6.56%), (7.30-6.66%), (7.30-6.50%) and (6.73-5.93%) for banana fingers treated with HW, GA_3, SA and $KMnO_4$in both seasons respectively, while angulation% for control banana finger ranged between (5.96-5.16%) in two seasons. That means that treatment of $KMnO_4$ and control gave the best results in this respect in both seasons of study.

Abou-Aziz *et al.* (1993) reported that the angulations percent is one of the principal parameters for using to determine banana fruit maturation. Tourky *et al.* (2006) reported that angulations percent for Williams and Grand Nain banana fruits, gradually decreased with the advance in shelf life at room temperature.

Fruit firmness (Ib inch^{-2}): It is clear from Table 1 that the average fruit firmness had a gradual and continual decrease with the progress of storage period at 20°C±2 and 65-70% R.H. (room

Table 2: Effect of post-harvest treatments on peel color, peeling condition and pulp/peel ratio of Williams banana fruits through ripening at room temperature during 2011 and 2012 seasons

	Peel color				Peeling condition				Pulp/peel ratio			
	Storage period in days											
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control	2.00	2.66	3.66	6.00	1.00	1.66	3.00	4.00	1.50	1.33	1.66	2.10
Hot water at 45°C	2.00	2.00	2.66	4.66	1.00	1.00	2.00	2.66	1.50	1.53	1.53	1.76
GA_3 at 50 ppm	2.00	2.00	2.33	4.33	1.00	1.00	2.00	2.66	1.50	1.36	1.36	1.96
Salicylic acid at 50 ppm	2.00	2.00	2.33	4.66	1.00	1.33	2.33	3.00	1.50	1.43	1.43	2.13
$KMnO_4$ at 20 g	2.00	2.33	3.33	5.33	1.00	1.66	3.00	4.00	1.50	1.43	1.43	2.03
Mean	2.00	2.20	2.86	5.00	1.00	1.33	2.46	3.26	1.50	1.42	1.48	2.00
L.S.D. at 5%												
Treatment	0.374				0.315				0.126			
Time	0.194				0.222				0.124			
Treatment (time)	0.735				0.497				0.277			
Season 2012												
Control	2.00	3.00	4.00	6.66	1.00	1.66	3.00	4.00	1.33	1.36	1.53	1.90
Hot water at 45°C	2.00	2.00	2.33	4.00	1.00	1.00	2.00	2.66	1.33	1.46	1.60	1.80
GA_3 at 50 ppm	2.00	2.00	2.66	4.33	1.00	1.00	2.33	3.00	1.33	1.33	1.50	1.80
Salicylic acid at 50 ppm	2.00	2.33	2.66	5.00	1.00	1.00	2.66	3.33	1.33	1.40	1.66	2.03
$KMnO_4$ at 20 g	2.00	2.66	4.00	6.33	1.00	1.33	2.66	3.66	1.33	1.50	1.60	2.00
Mean	2.00	2.40	3.13	5.26	1.00	1.20	2.53	3.33	1.33	1.41	1.58	1.90
L.S.D. at 5%												
Treatment	0.243				0.321				0.060			
Time	0.347				0.242				0.097			
Treatment (time)	0.776				0.541				0.217			

temperature) in the two season of investigation. Results also, revealed that all materials treatments used significantly increased the values of fruit firmness than the control at the first and second seasons. Banana fruits treated with HW, GA_3 and SA recorded the highest values of fruit firmness (7.20-6.20 Ib inch^{-2}), (7.10-6.40 Ib inch^{-2}) and (7.03-6.33 Ib inch^{-2}) after 45 days at ambient condition in the two seasons respectively. On the contrary, untreated banana fruits gave the lowest value of fruit firmness (5.16-4.20 Ib inch^{-2}) at the end of the shelf life period in two seasons, respectively.

These results are in agreement with Martinez-Romero *et al.* (2000) studied the effect of GA_3 at 100 mg L^{-1} on Baby Gold peach then stored at 2°C for 14 days and found that GA_3 maintained higher fruit firmness during storage, the respiration rate and ethylene emission were reduced compared with control.

Furthermore, Abd El-Naby (2010) reported that postharvest treatments with hot water for Maghrabi banana treatment had the higher firmness at ripening compared to those treated with hot water. Also, treated banana fruits with hot water (50°C for 10 min) were most effective in delaying firmness loss or softening.

Lurie (1998) suggested that the reduction in fruit softening caused by hot water treatment was caused by the inhibition of pectin cell wall hydrolysis, indicative of a reduced level of cell wall degrading enzyme activity of the inhibition of ethylene production due to a reduction in the activity of ethylene-forming enzyme. On the other hand, Srivastava and Dwivedi (2000) observed that SA treatment inhibited the process of banana fruit softening during ripening.

Generally, pulp firmness of most bananas do not change significantly during the early stage of maturation, but as growth progresses changes in pulp firmness may occur. It is therefore important to ascertain pulp firmness during fruit maturation. Also, the crisp, hard and green fruit turns into a yellow fruit with tender and soft internal pulp at the optimal ripening stage and becomes mushy as it advances towards senescence. The loss of firmness during ripening leads to lower quality and higher incidence of mechanical damage during handling and transportation (Dadzie and Orchard, 1997).

Loss of firmness or softening during ripening has been associated with two or three processes. The first is the breakdown of starch to form sugar. The second is the breakdown of the cell walls or reduction in the middle lamella cohesion due to solubilisation of pectic substances (Smith *et al*., 1989).

Peel color: The disappearance or loss of peel green color and the corresponding increase in yellowing of the peel during ripening are the obvious manifestations in banana. So, the peel of banana that represents about 40% of the total weight of fresh banana (Tchobanoglous *et al*., 1993).

Peel color score progressively during storage Williams banana fruits at room temperature Table 2. The untreated fruits reached the full yellow stage (color score 6.0-6.66) after 45 days while, fruits treated by HW, GA_3, SA and $KMnO_4$ reduced score (4.0 to 6.33) at the end of shelf life period in two seasons respectively. That means that treatments with HW, GA_3, SA and $KMnO_4$ resulted delay in peel color development. These results are in agreement with previous reports that GA_3 retarded color development in banana (Ahmed and Tingwa, 1995) also, Osman and Abu-Goukh (2008) reported that GA_3 and ethylene have opposite effects on fruit ripening and senescent, seeing that GA_3 treatment delayed fruit maturation and retarding ripening process through its effect on retarding the content of chlorophyll degradation in the peel.

During ripening of banana, the flesh color changes from the typical "opaque white" of a product with a high starch content to a "very soft yellow" as the yellowing of the skin intensifies. Also, in fresh banana, the color changes of peel during storage as a result of ripening have been observed as a loss of greenness and increase in reddish and yellowness tones (Salvador *et al*., 2007). The loss of green color is due to degradation of the chlorophyll structure. External changes in peel color during ripening often reflect changes in pulp color (Wainwright and Hughes, 1990).

Regarding the effect of hot water, Varit and Songsin (2011) showed that treated banana fruit by hot water (45°C for 15 min or 50°C for 10 min) retarded peel color. In this respect, SA treatments have been found to delay the ripening of banana fruits (Srivastava and Dwivedi, 2000).

Bairwa *et al*. (2002) and Abd El-Naby (2010) reported that $KMnO_4$ application as an ethylene absorbent, delayed ripening, proved most effective in reducing rot and maintained the physical appearance and quality of fruit in fresh condition.

Consumers prefer yellow peel banana (score index 6), therefore, application of $KMnO_4$ as ethylene absorber through clay powder as carrier is useful to prolong storage of banana var. Raja Bulu (Santosa *et al*., 2010).

Peeling condition: Peeling condition is used as a good criterion for evaluation the ripening. Increase in weight loss is usually followed by lack of peel appearance; therefore, control moisture during storage is important. The results in Table 2 showed that all postharvest treatments (HW, GA_3, SA and $KMnO_4$) gave least values of peeling condition at the end of shelf life period (45 days), since HW, GA_3 and SA had values (2.66), (2.66-3.0) and (3.0-3.33) in the two season respectively.

While, $KMnO_4$ treatment and control gave the highest values of peeling condition (4.0-3.66) and (4.0) this hold true in the two seasons.

Banana peel represents about 40% of total weight of the fresh fruit (Anhwange *et al.*, 2009). Recent studies demonstrated that banana peel generally include higher phenolic compounds than that of banana pulps (Sulaiman *et al.*, 2011).

Abd El-Naby (2010) found that the used hot water and $KMnO_4$ were relatively more effective in delaying ripening of Maghrabi banana fruits, also delay in ripening of banana fruits is reported by SA (Srivastava and Dwivedi, 2000).

In addition, GA_3 can be applied post-harvest to control fruit ripening and maintain quality through packaging, long-distance shipping and shelf-life (Osman and Abu-Goukh, 2008).

Pulp/peel ratio: According to Table 2 it is clear that pulp/peel ratio showed a significant progressive and almost uniform trend of increase as shelf life for all treatments during two seasons. At the end of shelf life period (45 days), pulp/peel ratio reach to a maximum values. The ratio were (2.10-1.90), (2.13-2.03) and (2.03-2.00) for control, SA and $KMnO_4$ treatment, at the end of shelf life respectively. While banana fruits treated with HW and GA_3 gave ratio between (1.76-1.80) and (1.96-1.80), respectively.

Pulp to peel ratio is a good and consistent index of ripening of banana. Changes in pulp to peel ratios during ripening of banana indicate differential changes in moisture content of the peel and pulp. The increase in pulp to peel ratio during ripening is related to sugar concentration in the two tissues. During ripening, there is a rapid increase in the sugar concentration in the pulp compared to the peel thus contributing to a differential change in osmotic pressure. The peel looses water both by transpiration to the atmosphere and also to the pulp by osmosis, thereby contributing to an increase in the fresh weight of the pulp as the fruit ripens (Stover and Simmonds, 1987). This results in an increase in the pulp to peel ratio during ripening. Abd El-Naby (2010) showed that the pulp/peel ratio was increased of banana fruits by postharvest $KMnO_4$, while hot water treated fruit gave the lowest ratio at fruit ripening. On the other hand, Srivastava and Dwivedi (2000) found that SA treatment decreased the pulp/peel ratio during ripening of banana fruits.

Soulble solids content (SSC): The results in Table 3 show that soluble solids content of Williams banana fruits increased gradually and significantly with increasing shelf life period, reached the maximum values at the end of shelf life periods at the two seasons. Fruits of control and $KMnO_4$ treatments recorded the highest SSC% (14.60-15.40%) and (14.13-15.03%), while treatments of HW, GA_3 and SA gave the least value (12.90-13.36%), (13.16-13.80%) and (13.66-13.46%) compared with other treatments. This is in line with Ahmed and Tingwa (1995) reported that GA_3 decreased sugar accumulation, TSS and sugar/ratio in banana.

Abd El-Naby (2010) indicated that postharvest treatments with HW and KMnO4 to Maghrabi banana fruits gave highest values of TSS in the first season compared to the other treatments.

Fruits including banana, contain many compounds which are soluble in water (sugars, acids, vitamin C, amino acids and some pectin). These soluble compounds form the soluble solids content of the fruit. In most ripe fruits including banana, sugar forms the main component of soluble solids, total soluble solids (TSS) are an important postharvest quality attribute in the screening. Since the amount of TSS or sugar in fruits usually increases as they mature and ripen, the soluble solids content of the fruit can be a useful index of maturity or stage of ripeness (Dadzie and Orchard, 1997).

Table 3: Effect of post-harvest treatments on SSC (%), acidity (%) and SSC/acid ratio of Williams banana fruits through ripening at room temperature during 2011 and 2012 seasons

	SSC (%)				Acidity (%)				SSC/acid ratio			
	Storage period in days											
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control	0.93	4.93	7.76	14.60	0.321	0.458	0.563	0.741	2.86	10.73	13.73	19.70
Hot water at 45°C	0.93	3.96	6.30	12.90	0.321	0.393	0.432	0.540	2.86	10.06	14.50	23.80
GA_3 at 50 ppm	0.93	4.06	6.76	13.16	0.321	0.404	0.476	0.528	2.86	10.03	14.20	24.90
Salicylic acid at 50 ppm	0.93	3.23	6.50	13.66	0.321	0.420	0.516	0.617	2.86	7.63	12.56	22.13
$KMnO_4$ at 20 g	0.93	5.06	6.90	14.13	0.321	0.421	0.524	0.696	2.86	12.00	13.13	20.23
Mean	0.93	4.25	6.84	13.69	0.321	0.419	0.502	0.624	2.86	10.09	13.62	22.15
L.S.D. at 5%												
Treatment	0.184				0.011				0.557			
Time	0.146				0.011				0.475			
Treatment (time)	0.328				0.026				1.062			
Season 2012												
Control	0.96	4.93	6.93	15.40	0.312	0.440	0.620	0.732	3.03	11.20	11.16	20.96
Hot water at 45°C	0.96	4.56	6.23	13.36	0.312	0.386	0.478	0.567	3.03	11.80	13.00	23.50
GA_3 at 50 ppm	0.96	4.26	6.66	13.80	0.312	0.391	0.474	0.558	3.03	10.86	13.50	24.63
Salicylic acid at 50 ppm	0.96	4.10	6.20	13.46	0.312	0.405	0.520	0.621	3.03	10.10	11.90	21.63
$KMnO_4$ at 20 g	0.96	5.20	7.10	15.03	0.312	0.408	0.517	0.690	3.03	12.70	13.66	21.70
Mean	0.96	4.61	6.62	14.21	0.312	0.406	0.522	0.633	3.03	11.33	12.64	22.48
L.S.D. at 5%												
Treatment	0.137				0.016				0.713			
Time	0.162				0.010				0.360			
Treatment (time)	0.363				0.023				0.805			

Total acidity: The data in Table 3 noticed that during shelf life periods, increase of total acidity content throughout shelf life period and reached their maximum values at the end of shelf life periods (45 days). Fruit acidity for all materials treatments were lowest values (0.528-0.696%), while fruit acidity of control were about (0.741-0.732) in both seasons respectively at the end of shelf life periods.

Commonly, the content of total acidity in fruit juice were slowly decline as a storage period advanced from harvest till 30 day at cold storage or during marketing at room temperature, which may be attributed to the use of acids as substrate for respiration (Echeverria and Valich, 1989).

Abd El-Naby (2010) found that postharvest $KMnO_4$ treatment for Maghrabi banana fruits gave low values of total acidity at fruit ripening. Al-Qurashi and Awad (2012) show that, acidity concentration was not affected by either SA treatment or storage temperature but, fluctuated during storage with a significant decrease after 40 days of storage and during storage, acidity concentration was much lower than the initial value of harvest.

SSC/acid ratio: It is clear from Table 3 that SSC/Acid ratio% of Williams banana fruits increased gradually and significantly with increasing shelf life period reached the maximum values at the end of shelf life periods at the two seasons. Fruit SSC/Acid ratio% for all materials treatments were highest values (20.23-24.90%), while fruit SSC/Acid ratio% of control were about (19.70-20.96%) in both seasons respectively at the end of shelf life periods.

Table 4: Effect of post-harvest treatments on pH, total sugar and total starch of Williams banana fruits through ripening at room temperature during 2011and 2012 seasons

	pH (%)				Total sugar (%)				Total starch (%)			
	Storage period in days											
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control	5.10	4.90	4.80	4.80	0.78	3.80	7.40	14.06	24.13	20.50	10.23	4.40
Hot water at 45°C	5.10	4.60	4.63	4.40	0.78	3.23	6.10	12.30	24.13	21.33	15.40	8.10
GA_3 at 50 ppm	5.10	4.63	4.60	4.56	0.78	3.40	6.20	12.90	24.13	21.30	15.16	7.96
Salicylic acid at 50 ppm	5.10	4.86	4.70	4.70	0.78	3.16	6.30	13.96	24.13	21.16	14.86	8.36
$KMnO_4$ at 20 g	5.10	4.80	4.70	4.53	0.78	3.76	6.40	13.66	24.13	21.23	10.56	6.96
Mean	5.10	4.76	4.68	4.60	0.78	3.47	6.48	13.38	24.13	21.10	13.24	7.16
L.S.D. at 5%												
Treatment	0.107				0.195				0.087			
Time	0.089				0.149				0.103			
Treatment (time)	0.200				0.333				0.230			
Season 2012												
Control	5.00	4.93	4.90	4.80	0.87	4.10	7.46	15.06	24.86	20.93	10.93	4.76
Hot water at 45°C	5.00	4.50	4.40	4.36	0.87	3.90	6.40	13.23	24.86	21.23	16.26	8.80
GA_3 at 50 ppm	5.00	4.53	4.53	4.46	0.87	4.03	6.50	13.06	24.86	21.03	16.30	8.13
Salicylic acid at 50 ppm	5.00	4.86	4.80	4.60	0.87	3.46	6.03	12.76	24.86	21.33	15.80	8.16
$KMnO_4$ at 20 g	5.00	4.70	4.66	4.60	0.87	4.13	7.10	13.63	24.86	20.80	11.10	7.73
Mean	5.00	4.70	4.66	4.56	0.87	3.92	6.70	13.55	24.86	21.06	14.08	7.52
L.S.D. at 5%												
Treatment	0.119				0.132				0.078			
Time	0.117				0.179				0.087			
Treatment (time)	0.262				0.400				0.196			

During ripening of banana the total soluble solids content increases. However, sugar forms the main component of soluble solids, since the amount of sugar in fruits usually increases as the fruit matures and ripens (Dadzie and Orchard, 1997). Usually organic acids decline during ripening as they are respired or converted to sugar (Wills *et al*., 1989). Organic acids are important in giving a desired sugar-to-acid balance which results in pleasing fruit taste during ripening. Acidity shows large increases during ripening progresses therefore, total titratable acidity could be used as an index of ripening (Dadzie and Orchard, 1997).

Pulp pH: The pH of banana pulp decreased with the increase in shelf life periods. This is may be to as ripening advances, acidity increases which resulted in decrease of pH. From Table 4 it is clear that the initial values of pH for all treatments ranged from 5.10 to 5.0 which decreased from 4.36 to 4.80 after 45 days of shelf life. Fruit pH of all materials treatments gave decrease of pH at the end of shelf life period while, pH of control banana fruits gained the highest values (4.80%) in the end of shelf life. Yet, all materials application gave the lowest values of fruit pH indicating delayed of fruit ripening.

Pulp pH and total titratable acidity are important post-harvest quality attributes in the assessment of fruit ripening quality. In most bananas, there is a rapid decline in pulp pH in response to increasing ripeness. However the magnitude of decline is cultivar dependent. Generally,

when fruits are harvested at matured green stage, the pulp pH is high but as ripening progresses pH drops. Thus, the pulp pH could be used as an index of ripening (Dadzie and Orchard, 1997).

Total sugar (%): According to Table 4, it could observed that the total sugars of Williams banana fruits showed a gradual and highly significantly increase from the beginning of shelf life and it had high sugars values, at the end of shelf life period at both seasons. The data also disclose that, all treatments decreased values of total sugars than the untreated fruits during the two seasons under the study.

Srivastava and Dwivedi (2000) reported that SA treatment resulted in decreased levels of reducing sugar content in banana fruits while an opposite effect on non reducing sugar content, on the other hand SA delays banana fruit ripening. Also, this is in line with earlier reports that GA_3 decreased sugar accumulation, TSS and sugar /ratio in banana fruit Ahmed and Tingwa (1995). GA_3 slows ripening and senescence of bananas fruits by delaying chlorophyll degradation and reducing sugar accumulation (Osman and Abu-Goukh, 2008).

Total starch (%): Table 4 clearly indicated that the amount of starch content in Williams banana fruits decreased significantly as the advance in shelf life period at two season of study. The rate of decreased continued as the shelf life period advanced, reaching to their minimum values at the end of the shelf life period (45 days). The general trend of starch content ended to decrease sharply through 30 and 45 days of shelf life for all treatments at two seasons. Since, starch hydrolyzed enzymatically during ripening process progress. At the beginning of the shelf life of banana fruits, the total starch content ranged between (24.13-24.86%) in banana pulp fruits.

While, at the completion of the shelf life starch was ranged between (4.40-8.80%). Moreover, all materials treatments gave significant decrease of starch content at the end of shelf life period compared with control fruits.

Muthoo and Chetan (1997) who disclosed that the highest GA_3 concentration on Flordasun peach fruits caused a significant increase in SSC compared with control, it may be due to the starch hydrolysis as result of synthesis of alpha-amylase.

The most striking post-harvest chemical change which occurs during the post-harvest ripening of banana is the hydrolysis of starch and the accumulation of sugar which are responsible for the sweetening of the fruit (Dadzie and Orchard, 1997).

Peel moisture (%): Peel and pulp moisture are important post-harvest parameters in the evaluation of the ripening quality of banana. During ripening, the moisture content of the peel decreases whereas that of the pulp increases, this is because the peel looses water both to the atmosphere and to the pulp (Dadzie and Orchard, 1997).

Data from Table 5 show that peel moisture% decreased with increase in storage life for untreated or treated fruits at the two seasons of investigation. Postharvest materials had lowest values of peel moisture% compared to control throughout the storage period at the two seasons. Since, banana fruit treated with HW, GA_3, SA and $KMnO_4$ recorded the lowest peel moisture content values (90.40-89.80%), (90.13-89.66%), (89.63-88.43%) and (89.73-88.50%), respectively at the end of storage period during the two seasons of study. Data also recorded that the peel moisture content of banana fruits seemed to have an opposite trend of pulp moisture content during the storage period (45 days). Similar results were obtained by Tourky *et al.* (2006) who reported that peel moisture content of banana fruits decreased gradually during storage period.

Table 5: Effect of post-harvest treatments on peel and pulp moisture% of Williams banana fruits through ripening at room temperature during 2011 and 2012 seasons

	Peel moisture (%)				Pulp moisture (%)			
	Storage period in days							
Treatments	0	15	30	45	0	15	30	45
Season 2011								
Control	98.53	97.26	93.53	89.20	61.06	63.33	68.80	71.86
Hot water at 45°C	98.53	98.30	95.20	90.40	61.06	61.76	67.13	70.76
GA_3 at 50 ppm	98.53	98.06	94.50	90.13	61.06	62.03	67.10	70.90
Salicylic acid at 50 ppm	98.53	97.43	94.40	89.63	61.06	62.76	67.40	71.76
$KMnO_4$ at 20 g	98.53	92.06	93.93	89.73	61.06	62.50	67.16	71.46
Mean	98.53	96.62	94.31	89.82	61.06	62.48	67.52	71.35
L.S.D. at 5%								
Treatment	1.152				0.180			
Time	0.856				0.280			
Treatment (time)	1.914				0.628			
Season 2012								
Control	97.90	96.93	92.76	88.13	59.13	61.80	66.80	70.80
Hot water at 45°C	97.90	97.70	94.16	89.80	59.13	59.76	65.20	69.06
GA_3 at 50 ppm	97.90	97.43	93.86	89.66	59.13	59.80	65.53	69.40
Salicylic acid at 50 ppm	97.90	97.20	93.50	88.43	59.13	61.00	66.20	69.20
$KMnO_4$ at 20 g	97.90	96.93	93.10	88.50	59.13	61.06	66.10	69.76
Mean	97.90	97.24	93.48	88.90	59.13	60.68	65.96	69.46
L.S.D. at 5%								
Treatment	0.323				0.209			
Time	0.223				0.143			
Treatment (time)	0.499				0.319			

Pulp moisture (%): According to Table 5, it is clear that the pulp moisture% of treated or untreated banana fruits showed significant increase as ripening process progress, reaching their maximum moisture content after 45 days at storage at room ambient during the two successive season of investigation. Banana fruit treated with HW, GA_3, SA and $KMnO_4$ recorded the lowest pulp moisture content values (70.76-69.06%), (70.90-69.40%), (71.76-69.20%) and (71.46-69.76%) respectively at the end of storage period during the two seasons of study. While, untreated banana fruits gave highest pulp moisture values (71.86-70.80%) at the end of storage.

These results are confirmed with those reported by Stover and Simmonds (1987) and Tourky *et al.* (2006) who reported that pulp moisture content increased gradually during storage periods. Generally, the water content of peel and/or the ripening environment may also play a role in peel de-greening during fruit ripening. It has been shown that there is an increase in weight ratio between pulp and peel during ripening.

The increase in pulp moisture content during ripening is due to carbohydrate breakdown and osmotic transfer from the peel to pulp (John and Marchal, 1995). This is through to be the result of the migration of water from the skin (peel) to pulp for the increasing content of sugar in the latter and development of skin color and easily peeling condition. Our data suggested a delay in ripening process of banana fruits treated with HW, GA_3, SA or $KMnO_4$ pre storage at room ambient. Of the entire factor which affects the quality of banana, moisture contents probably the most important, since moisture of banana fruit increased with the increase in storage duration in all varieties. This may be due to movement of water from peel to pulp (Sarode and Tayade, 2009).

CONCLUSION

From the above mentioned results it can be arrange the appearance of banana fruits in the market by using these materials which cause different ripening rate of banana fruits with gain acceptance by the user. This demonstrate that the used materials were relatively more effective in delaying ripening, since these materials play an integrated role in many of the biochemical changes occur during ripening such as, moisture, starch, sugar, color and texture.

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