



# THE EFFECTS OF GIBBERELIC ACID ON QUALITY AND SHELF LIFE OF BANANA (*MUSA SPP.*)

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## ABSTRACT

Banana (*Musa spp.*) is one of the most important fruit crops of the tropical and subtropical areas over the world. Worldwide, post-harvest losses in fruits and vegetables range from 25 to 40% and this high loss is due to lack of packaging, storage facilities and poor means of transportation. So, this experiment aimed at evaluating the efficiency of postharvest treatments to improve the storage of banana fruits by using gibberellic acid (GA3). Mature green banana fruits were treated by immersion in 100, 200 and 300ppm of GA3 for 15 minutes. The control fruits were immersed in distilled water the same way. Then, all fruits were stored in the lab at about 13±2°C temperature for 35 days and evaluated for different quality parameters over six periods (0, 7, 14, 21, 28 and 35 days). All fruits treated with GA3 delayed in ripening in concentration dependent manner when compared to control fruits. The ripening of fruits treated with 300ppm GA3 delayed more than other treatments. The treatment with higher concentration of gibberellic acid delayed peel color changes, weight loss, ethylene, CO<sub>2</sub> production and total sugar content as compared with control groups. In the meanwhile, the pulp to peel ration and total soluble solids were increased with increasing the concentration of gibberellic acid treatments. This indicate that gibberellic acid prevent the fruit ripening. Therefore, postharvest application of gibberellic acid was an efficient method to delay banana fruit ripening. As gibberellic acid concentration increased, ripening was further delayed.

**Key Words:** Postharvest loss, Gibberellic acid 3, Ripening, *Musa spp.*

## INTRODUCTION

Banana is cultivated in more than 120 countries over about 10 million hectares. It ranks first in global fruit production with just over 106 million tons being produced annually worldwide. Currently, banana is most exported fruit and ranks second after citrus fruits in terms of value over the world. Total world exports of banana in 2006 accounted for 16.8 million tons (FAOSTAT, 2006). In Ethiopia, banana is one of the widely produced and used tropical fruits. From introduced and locally collected varieties, Dwarf Cavendish, Giant Cavendish, Poyo and Ducasse hybrid were recommended for production in Ethiopia (Seifu, 1999). The area under cultivation and the total annual production of banana in the year 2000 were 15,000 ha and 100,000 tones, respectively. This grew to 39,428 ha and 260,000 tones, respectively in 2008. Most of the banana produced in Ethiopia are consumed locally with only a few exported to Djibouti, Saudi Arabia and Somalia (FAO, 2010).

Banana is a fragile, perishable fruit and cannot be preserved for longer time after harvesting (Taiwo and Adeyemi, 2009). It is highly desirable to delay or postpone the ripening and senescence until they are to be consumed (Ramana *et al.*, 1989). Therefore, the current study is aimed at extending the shelf life and keeping quality of banana fruits by using different concentrations of gibberellic acid 3 (100, 200 and 300ppm).

## MATERIALS AND METHODS

Banana fruits of Giant Cavendish cultivar were obtained from Melkassa Research center, Ethiopia. From the collected banana fruits, approximately equal sized fruits with no bruises or damage were selected for treatments with different concentrations of gibberellic acid GA3 (100, 200 and 300ppm) separately. The experimental design was a complete randomized design with three replications. For each GA3 treatments, 10 banana fruits

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were randomly assigned to prepared concentrations and immersed into their respective concentrations for 15 minutes. After 15 minutes of immersion, fruits were made to dry in air for 30 minutes. The control group was only washed with distilled water and air dried in the same way and then all fruits packed into labeled carton box, and stored for 35 days at temperature of  $13 \pm 2^\circ \text{C}$  in the lab. Thereafter, fruit quality assessments with respect to the following parameters were carried out 6 times in 7 day's interval.

### FRUIT COLOR DETERMINATION

Fruit peel color analysis was assessed visually by matching the peel color with standardized color charts that describe the seven ripening stages, and color score were assigned accordingly; 1 = full green, 2 = green with yellow tip, 3 = greener than yellow, 4 = more yellow than green, 5 = yellow with green tip, 6 = fully yellow, 7 = yellow with black spots. The banana was considered unripe at stages 1-4, and ripe at stages 5-7 (Li et al., 1997).

### Determination of Pulp to Peel Ratio and Physiological weight loss

The ratios of pulp to peel of each finger was calculated and mean value were recorded (Dadzie and Orchard, 1997). The physiological weight loss was determined by using method indicated by Teferra et al. (2007)

### Ethylene and $\text{CO}_2$ Determination

Ethylene production was measured as described by Jiang et al. (2004). Banana fruit was placed in a sealed 1.5 L jar at  $20^\circ\text{C}$  and incubated for 1hr to accumulate ethylene. 10ml of gas was then taken from the headspace of the jar using a gastight syringe, and injected into a gas chromatograph (Type CG, 9002 German) equipped with a flame ionization detector to determine the identity of ethylene and quantify it. For  $\text{CO}_2$  analysis, 1mL of gas was taken from the headspace of the jar using a gastight syringe and was injected into a gas chromatograph equipped with a flame ionization detector to determine its identity and quantity. Known concentrations of ethylene and  $\text{CO}_2$  standards both in synthetic air were used to generate calibration curves so as to estimate their concentrations.

### Measurement of Vitamin C (Ascorbic acid) Content and Titratable Acidity (TA)

Ascorbic Acid (AA) content of banana was determined by the 2, 6-dichlorophenolindophenol method (AOAC, 2000). Measurement of titratable acidity was calculated as percentage of malic acid since it is the dominant acid in banana (Dadzie and Orchard, 1997).

### Measurement of Total Soluble Solid and Total sugar content

Total soluble solids (TSS) were determined following the procedures described by Wasker et al. (1999). Total sugars were estimated by using the techniques of Seyoun (2002).

### Statistical Analysis

Data obtained were subjected to analysis of variance and mean comparison using the SAS computer software version 9.1. Pearson's correlation test was used to determine the correlation between each parameter. The p-value less than 0.05 were considered statistically as significant.

## RESULTS AND DISCUSSION

### Peel Color Change

The peel color showed the significant difference between treatments on each sampling day ( $P < 0.001$ ) (Fig.1). The fastest color change was observed in control (untreated fruits) where fruits reached fully yellow color (stage 7) on the 14<sup>th</sup> day. On the same day, fruits treated with gibberellic acid 3 (GA3), were at advanced peel color development. Fruits treated with 300 and 200ppm GA3 were at stage 2 (highly delayed in color change) and fruits treated with 100ppm were at stage 4. On day 21<sup>st</sup> all fruits treated under control group was fully ripe and showed yellow color with increasing brown spot after which all fruits in this group were discarded. On the same day fruits treated with 300, 200 and 100ppm were at stage 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup>, respectively. In the same way, on 35<sup>th</sup> day of storage fruits treated with 100ppm GA3 were at stage 7 (yellow color with increasing brown color) while fruits treated with 300 and 200ppm were at stage 6 (fully yellow).

The observed delay in color change of banana fruits treated with GA3 as compared to banana fruits in control group could be due to the retarding effect of this hormone on the synthesis of ethylene and, hence, reduced the respiration rate of the fruits in concentration dependent manner. The peel color development from green to yellow in this study is in agreement with the work of (Dharmasena and Kumari, 2005; Salvador et al., 2006). The results are also in agreement with previous reports that GA3 retarded color development in banana (Ahmed and Tingwa., 1995).

### Pulp to Peel Ratio

Effect of GA<sub>3</sub> acid on pulp to peel ratio of banana fruit have been investigated during ripening and showed significant difference ( $P \leq 0.001$ ) except on 0<sup>th</sup> day during storage period. Starting from day 7<sup>th</sup> all treatments

showed significant differences throughout storage period (Fig.2).

On day 7<sup>th</sup> storage period, the observed pulp to peel ratio for control fruit was 2.15 while that of fruits treated with GA3 was below 1.84. In the same way on day 14<sup>th</sup>, the observed pulp to peel ratio for fruits treated with GA3 was below 2 while that of control fruit was 2.66. On 21<sup>st</sup> day, the pulp to peel ratio of banana fruit treated under control group was 3.14 (which was over ripe and after which all of fruits were discarded) while that of fruits treated with 100, 200 and 300ppm GA3 were 2.45, 2.32 and 2.23, respectively. On 35<sup>th</sup> day the pulp to peel ratios of fruits treated with 100 and 200ppm GA3 were 2.76 and 2.68, respectively while the minimum ratio (2.62) was observed for fruits treated with 300ppm GA3.

There was an increase in the pulp to peel ratio of banana fruit during the storage period for all fruits, but banana fruits treated with GA3 showed slight increase in pulp to peel ratios. Pulp to peel ratio suggested a delay in ripening of banana fruit in the presence of GA3. The increase in pulp to peel ratio is due to the displacement of water from the peel towards the fruit pulp during the ripening process, resulted from the osmotic pressure gradient from the higher sugar concentration of the pulp relative to the peel. The averages obtained in the experiment were between 1.43 and 2.82, similar to the numbers reported by Cerqueira *et al.* (2000).

### Physiological Weight Loss (%)

Variation was observed in the percent weight loss of banana fruits treated with different concentrations of GA3 except on 0<sup>th</sup> day. The differences were significant ( $P \leq 0.001$ ) among all treatments during the storage period of 35<sup>th</sup> days (Fig.3).

The highest percentage of weight loss was recorded for control fruits on each sampling day up to 21<sup>st</sup> days. On day 21<sup>st</sup>, the percentage of weight loss for control fruit was 19.86% after which all fruits in this group were discarded. But, banana fruits treated with GA3 showed reduced weight loss significantly compared to control. There were also significant differences between all treatments on day 28<sup>th</sup>. The maximum %weight loss was recorded for fruits treated with 100 and 200ppm (12.89 and 12.17%), respectively while the minimum was recorded for 300ppm (11.68%). There were also significant differences ( $P \leq 0.001$ ) for each treatment on 35<sup>th</sup> day of storage. The minimum %weight loss were observed in fruits treated with 300ppm GA3 (15.15) which shows delay in ripening and maximum percent weight loss were recorded for fruits treated with 100ppm GA3 (16.99%) while values recorded for fruits treated with 200ppm GA3 was (16.63%).

The result is in line with the work of Dharmasena and Kumari, (2005) that Excess energy produced from the

respiration process in the form of heat is released from the fruit by evaporation of water causing a weight loss. Similarly, increase in the membrane permeability following the respiratory climacteric could result in loss of moisture through the peel (Siriboon and Banlusilp, 2004).

### Ethylene production

The effects of the different concentrations of GA3 showed significant difference ( $P \leq 0.001$ ) on Ethylene production throughout the storage period. Banana fruits treated with GA3 showed minimum ethylene production while control group showed maximum production of ethylene. On the first day of storage, fruits treated under control group produced maximum amount of ethylene (11.70 $\mu$ l/kg/hr) while those treated with 300, 200 and 100ppm GA3 produced lower amount (9.42, 9.54 and 9.86 $\mu$ l/kg/hr) respectively. On 7<sup>th</sup> day of storage, ethylene production increased in all treatments but highly increased in control groups (18.55 $\mu$ l/kg/hr) while slight increase in GA3 treated fruits (all are below 11 $\mu$ l/kg/hr). The ethylene production increased in all treatments and rose to 62.12 $\mu$ l/kg/hr in control group on 28<sup>th</sup> day and declined to 49.20 $\mu$ l/kg/hr on 35<sup>th</sup> day fruit treated with GA3 (Fig.4)

The result was in line with the work of Seymour *et al.* (1993) who reported that unripe bananas show a constant low level of ethylene production. At the onset or ripening, ethylene production rose up, which was followed by a high rate of respiration. The pre-climacteric stage started from the first day to the 21<sup>st</sup> day, while the climacteric rose on the 21<sup>st</sup> day to the 28<sup>th</sup> day, and reached a climacteric peak on the 28<sup>th</sup> day, then, entered its senescence on the 35<sup>th</sup> day and onwards.

### Effect on Respiration Rate (CO<sub>2</sub> production)

The effects of the different concentrations of GA3 showed significant difference ( $P \leq 0.001$ ) on CO<sub>2</sub> production during storage period (Fig. 5). Control fruits produced highest amount of CO<sub>2</sub> during storage period while banana fruits treated with GA3 showed lower amount of CO<sub>2</sub> production in concentration dependent manner. On the first day of storage control fruits produced 27.4ml/kg/hr while those treated with 300 and 200ppm GA3 produced 24.6 and 24.8ml/kg/hr, respectively. On the 7<sup>th</sup> day of storage carbon dioxide production increased in all treatments, but highly increased in untreated fruits (49.8ml/kg/hr) while slight increase in GA3 treated fruits. Fruits treated with 300, 200 and 100ppm GA3 produced 36, 37 and 38.5ml/kg/h, respectively. The production of CO<sub>2</sub> increased in all treatments and rose to 116.0ml/kg/hr in control group on 28<sup>th</sup> day and declined to 79.7ml/kg/hr on 35<sup>th</sup> day while GA3 treated fruits still showed gradual increase in CO<sub>2</sub> production and each treatment produced less than 80 ml/kg/hr.

Generally, in control fruits the rate of respiration was found to increase with ripening exhibiting a peak on day 28<sup>th</sup> (climacteric peak). GA3 treatment resulted in a lower rate of respiration as well as a delay in appearance of climacteric peak in a concentration dependent manner, as compared to control. There was a gradual increase in respiration rate of GA3 treated fruits up to 35<sup>th</sup> day of storage period, suggesting a delay in ripening. As observed from the current study 300ppm GA3 is the concentrations of choice in delaying banana fruit ripening by inhibiting CO<sub>2</sub> production (respiration rate). This agrees with previous reports that GA3 delays the onset of the climacteric peak in banana fruits (Ahmed and Tingwa 1995).

### Ascorbic Acid

A significant ( $P \leq 0.001$ ) difference was observed in the ascorbic acid (AA) content of banana fruits receiving different postharvest treatments except on 0<sup>th</sup> day (Fig.6). Control fruits showed a rapid decrease in AA content than fruits treated with GA3. On 21<sup>st</sup> day of storage the AA content of banana fruit placed in control group decreased from 34.81 to 15.18 mg/100gfw while fruits treated with 300 and 200ppm GA3 reduced to 26.51 and 25.14mg/100gfw, respectively. In similar way, on 35<sup>th</sup> day of storage period the AA content of banana fruits treated with 100, 200 and 300ppm were reduced to 14.30, 15.81 and 16.53mg/100gfw, respectively.

There was a progressive decrease in ascorbic acid content up to the end of shelf life. The decrease in ascorbic acid on prolonged storage might be mainly due to rapid conversion of L-ascorbic acid into dehydro ascorbic acid in the presence of enzyme ascorbinase. The difference in the AA levels among fruits in the different treatments could be due to the effects of respective treatments on ripening as described for other parameters in the earlier sections. These results show that concentration of 300ppm GA3 is the most effective in delaying ripening of banana fruits. The result of the current study is in agreement with the report of Wenkam (1990) and Lee and Kader (2000) who indicated a decline in AA content of banana fruits during ripening. It is also in line with the work of Ghanta (1994) who reported that ascorbic acid content declined from 33.30mg/100gfw to 10.64 mg/100gfw during ripening.

### Titrateable Acidity (%)

Treatment of different concentrations of GA3 showed significant difference ( $P \leq 0.001$ ) on TA (titrateable acidity) content of banana fruits throughout the storage period except on day 0<sup>th</sup> (Fig.7). On 7<sup>th</sup> day of storage period, control fruits reached its peak (0.66%) and thereafter started to decline and reached 0.36% on 21<sup>st</sup> day of storage period after which all fruits in this group were discarded. The TA content of fruits treated with

300, 200 and 100ppm GA3 reached their peaks (0.58, 0.62 and 0.59% respectively) on 21<sup>st</sup> day of storage period and thereafter started to decline up to the end of storage period (35<sup>th</sup> day). This result is in agreement with observations by Siriboon and Banlusilp (2004) who reported that TA increased to its peak, which coincided with the accumulation of ethylene and ripening, then started to decline afterwards. Hernandez *et al.* (2006) also reported the amount of TA at; unripe, half ripe and ripe maturity stages were 0.30, 0.57 and 0.45 g /100gfw, respectively. This range is similar to the present observation, but with a slight difference, which could be due to cultivar difference.

### Total Soluble Solids

Postharvest treatments with different concentrations of GA3 are significantly ( $P \leq 0.001$ ) affected the TSS (total soluble solids) content of banana fruits (Fig.8). Control fruits showed a faster increment in their TSS content, increasing from 2.29 °Brix on day 0<sup>th</sup> to 22.90 °Brix on day 14<sup>th</sup> and declined to 16.82 °Brix on day 21<sup>st</sup>, after which all fruits in this group were discarded. On the other hand, fruits treated with GA3 were the slowest to reach their TSS peak. Banana fruits treated with 100 and 200ppm GA3 reached their peak (22.85 and 22.34°Brix, respectively) on day 28<sup>th</sup> while fruits treated with 300ppmGA3 were still increasing in its TSS and reached its peak (22.00°Brix) on day 35.

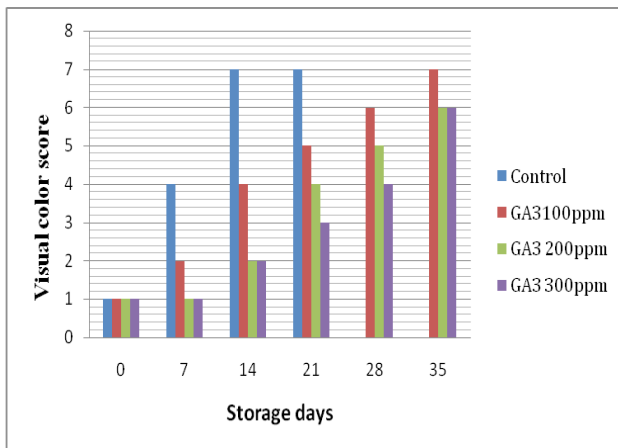
The observed increment in TSS content during ripening of fruits and decrease after attaining peak levels followed natural fruit ripening and senescence processes that have also been exhibited in related traits including color change and fruit marketability which are typical of postharvest change in climacteric fruit (Pinto *et al.*, 2004). This result is in agreement with the report of Dharmasena and Kumari (2005) that showed increase in TSS contents of different banana varieties from 0 to 17<sup>th</sup> °Brix over a storage period of 16 days. The slightly more amount of TSS at the peak of ripening in the present study could be due to differences in the type of cultivars studied (Dadzie and Orchard, 1997) and effects of the treatments applied.

### Total Sugar Contents

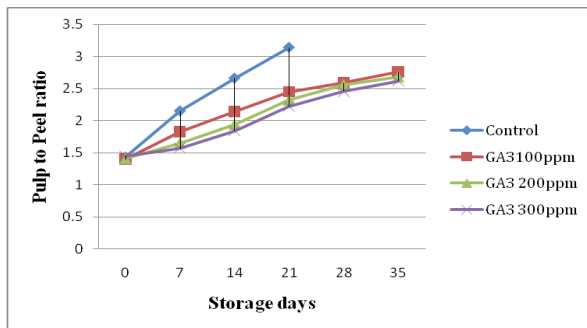
Postharvest treatments with different concentrations of GA3 were significantly ( $P \leq 0.001$ ) affected the total sugar content of banana fruits (Fig.9). Banana fruits treated with different concentrations of GA3 showed slight increase in total sugar contents during storage period and decreased after reaching their peaks in concentration dependent manner while untreated fruits showed rapid increase to their peak and decrease thereafter. On day 0<sup>th</sup> the total sugar content of control fruit was 0.84 g /100gfw and reached its peak 20.98g /100gfw on

14<sup>th</sup> day of storage period and thereafter started to decline. On 21<sup>st</sup> day of storage period total sugar content of all fruits treated under control group were reduced to 16.89g /100gfw after which all fruits in this group were discarded. But, total sugar content of banana fruits treated with GA3 were still increasing and reached their peak on 28<sup>th</sup> day and started to decline on 35<sup>th</sup> day of storage period except fruits treated with 300ppm GA3, which was still increasing up to 35<sup>th</sup> day of storage period.

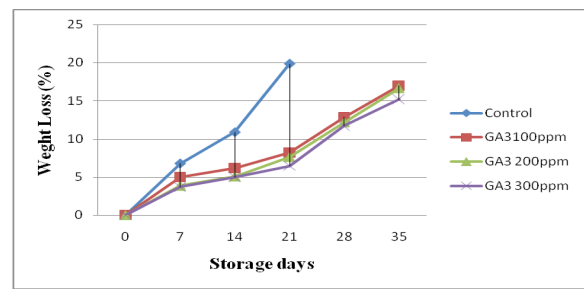
In the current study, the sugar content of the fruits during the storage period ranged from 0.85g/ 100gfw to 21.45 g /100gfw which are in agreement with that reported by Robinson (1996). The author reported that the fruits declined from starch content of about 20.0 to 23.0 g /100gfw at harvest to 1.0 to 2.0 g/ 100gfw in ripe fruits, while the amount of sugar increased in about the same proportion. Rapid increment in the total and reducing sugar as well as a rapid decrease in sugar contents of control fruit could be due to faster ripening process which converts starch in to sugar, while the slower rate in the rest of the treatments could be due to the effects of the treatments in delaying the ripening process (Golding et al., 2005).



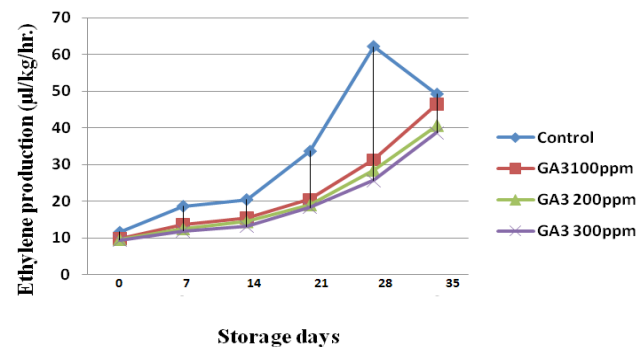
**Figure 1:** The effects of the different concentrations of GA3 and storage day on banana peel color of undergoing post-harvest treatments and stored for 35 days, according to the visual color scale.



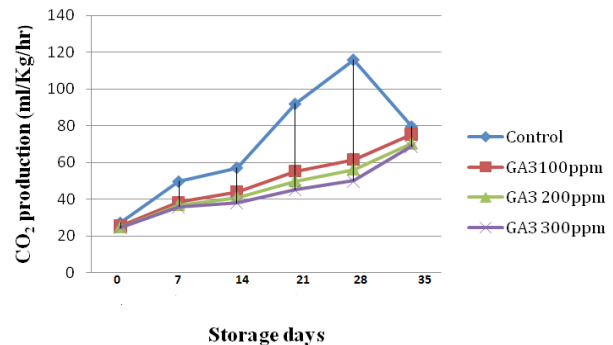
**Figure 2:** The effects of the different concentrations of GA3 and storage day on pulp to peel ratio of banana fruits undergoing post-harvest treatments and stored for 35 days.



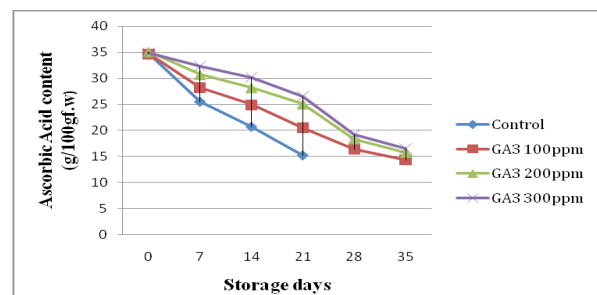
**Figure 3:** The effects of the different concentrations of GA3 and storage day on physiological weight loss (%) of banana fruits undergoing post-harvest treatments and stored for 35 days.



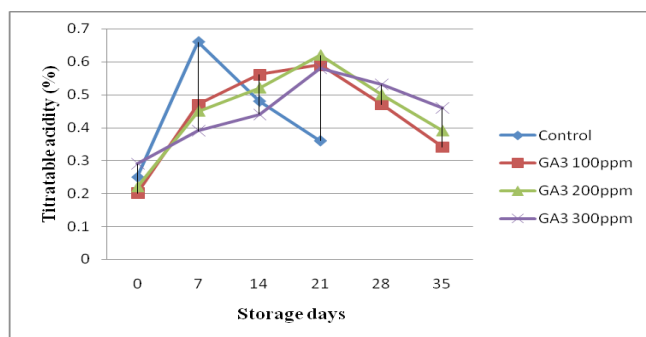
**Figure 4:** The effects of the different concentrations of GA3 and storage day on ethylene production (µl/kg/hr) of banana fruits undergoing post-harvest treatments and stored for 35 days.



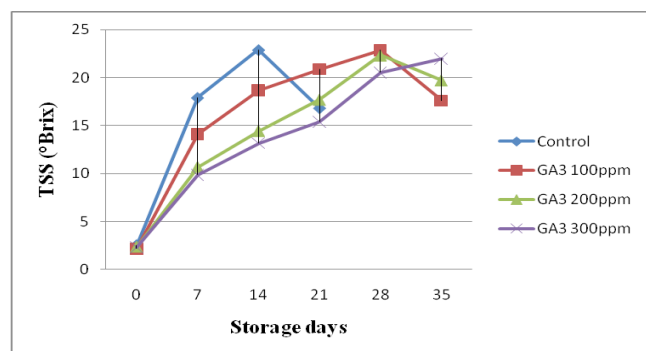
**Figure 5:** The effects of the different concentrations of GA3 and storage day on Carbon dioxide production (ml/kg/hr) of banana fruits undergoing post-harvest treatments and stored for 35 days.



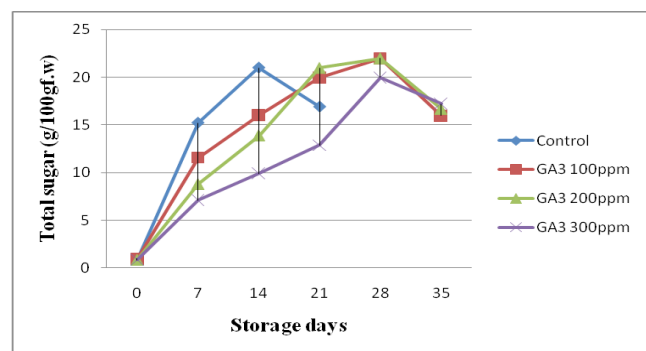
**Figure 6:** The effects of the different concentrations of GA3 and storage day on Ascorbic Acid (mg/100gfw) of banana fruits undergoing post-harvest treatments and stored for 35 days.



**Figure 7:** The effects of the different concentrations of GA3 and storage day on Titrateable acidity (% malic acid) of banana fruits undergoing post-harvest treatments and stored for 35 days.



**Figure 8:** The effects of the different concentrations of GA3 and storage day on Total Soluble solid (expressed in °Brix) of banana fruits undergoing postharvest treatments and stored for 35 days.



**Figure 9:** The effects of the different concentrations of GA3 and storage day on Total sugar content (g/100gf.w) of banana fruits undergoing post-harvest treatments and stored for 35 days.

## CONCLUSIONS

Postharvest application of gibberellic acid was an efficient method of delaying banana fruit ripening. Fruit treated with gibberellic acid had dramatically delayed the fruits peel color changes, weight loss, ethylene,  $\text{CO}_2$  production and total sugar content. As gibberellic acid content increased, ripening was further delayed as compared with control groups. Thus, with the concentrations

tested, gibberellic acid allows growers to schedule banana fruit ripening.

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