EFFECT OF PLANT GROWTH REGULATORS ON POSTHARVEST QUALITY OF BANANA (*Musa* sp. AAA BERANGAN)

Wan Zaliha Wan Sembok, Yusnita Hamzah and Nor Atiqah Loqman
School of Food Science and Technology, Universiti Malaysia Terengganu,
21030 Kuala Terengganu, Terengganu,
MALAYSIA
Tel: +609-6684981; Fax: +609-6684949; Email: wzaliha@umt.edu.my

ABSTRACT

Banana is a climacteric fruit that has high rate of deterioration which contributes to high postharvest losses. These losses might be due to improper postharvest handling and storage and occurs at any point in banana supply chain. These serious postharvest losses could be reduced by adopting one of the feasible postharvest management practices which include applying plant growth regulators (PGRs) such as gibberellins (GA_3) and auxin (IAA). The treatments were 150 mg L^{-1} GA_3, 5.71 x 10^{-7} mg L^{-1} IAA, the combination of IAA and GA_3 (2.85 x 10^{-7} mg L^{-1} and 75 mg L^{-1} respectively) with three replications. The parameter assessments were internal ethylene production, percentage weight loss, fruit firmness, total soluble solids (TSS) and starch pattern index (SPI). The GA_3-treated-fruit resulted in delayed production of ethylene (day 7) whereas control fruit and combination of IAA and GA_3-treated-fruit showed the earliest production of ethylene which was on day 2. The earliest occurrence of climacteric peak was closely related to the rapid ripening process bringing about speedy changes in colour, texture, aroma, chemical composition and respiration rate of Berangan banana. In addition, GA_3-treated-fruit experienced SPI score 3 for the whole experimental period which was reflected by the delay in peel colour changes, fruit firmness while maintaining other quality attributes. As a conclusion, GA_3 was able to delay the climacteric peak of Berangan banana and also retard the peel color changes, fruit softening and extend its shelf life up to 16 days.

Keywords: plant growth regulators, hormone, postharvest life, ethylene, banana

INTRODUCTION

Banana (*Musa* sp. AAA) is one of the most important fruits grown and consumed world-wide. India ranks first in banana production, contributing approximately 24 million tones (mt), followed by China (10 mt), Phillipines (9 mt) and Ecuador (7 mt) (FAOSTAT 2012). In Malaysia, the production and planted areas of commercial varieties of bananas has an increasing trend from 2008 to 2013, indicating that demand has been greater than supply over time. The banana production and planted area both increased 0.5% from the year 2012 to 2013 (AgroFood statistic 2013). Bananas are one of the major food crop of the world that are consumed as an energy yielding food and as a dessert (Dadzie and Orchard 1997). On the other hand, banana is the cheapest source of carbohydrate, a good source of vitamin A, B and C and also minerals such as potassium (Samson 1980). Banana has been reported to contain various compounds that can prevent the risks of cancer and asthma, lower blood pressure, improve heart health and promote regularity (Koeppel 2008). This is possibly the reason why most people consume banana as their nutritional food source. However, bananas have a short storage life as it is classified under climacteric fruit. Being a climacteric fruit, it is exposed to deterioration due to the higher respiration rate and ethylene production. The rate of deterioration of harvested commodities is generally proportional to the respiration rate (Irtwange 2006).

Since banana is a climacteric fruit, it exhibits a respiratory peak during ripening, after being harvested at 20˚C. Within a couple of days, respiration rate of about 20 mg CO_2 $kg^{-1}h^{-1}$ in the hard green banana fruit may rise to about five times at the climacteric peak and then fall as the ripening advances and there is also a considerable water loss through transpiration after the initiation of ripening (Salunkhe and Kadam 1995). Exposure of climacteric fruits to ethylene advanced the onset of an irreversible rise in respiration rate and rapid ripening (Hailu et al. 2013). Ethylene appears to be intimately involved in the initiation of ripening in banana, as in other climacteric fruits (Seymour 1993). One of the effective

approaches to overcome the above problem is through applying different types of plant regulators such as auxin (IAA), gibberellin (GA_3) and its combination without giving unfavorable effects to the quality of banana.

Many researches have been done in delaying ripening and increasing quality of various climacteric fruits by using GA_3 with promising outcomes. Omero et al. (2000) claimed that peach treated with GA_3 maintained a higher firmness during storage at 2°C and the respiration rate and ethylene emission was also reduced significantly. Meanwhile, Dostal and Leopold (1967) reported that the ripening of GA_3-treated tomato can be delayed as it retards ethylene action. Banana fingers dipped in GA_3 at concentrations from 10^{-5} to 10^{-2} M resulted in delayed ripening and maintained the quality of the fruit and thus increased shelf life (Vendrell 1970). Other than that, Murthy and Rao (1982) found that GA_3 treatment on 'Alphonso' mango inhibited the ripening significantly during storage at 28°C. Recently, Zomo et al. (2014) and Patil et al. (2014) reported that GA_3 enhanced the shelf life and quality of banana and mango cv. Kesar, respectively. Therefore, GA_3 seems play an important role in delaying ripening, prolonging shelf life and maintaining postharvest quality of various fruit crops. However, many researches are focusing more on GA_3, not IAA. Therefore, this study aimed to evaluate the effects of auxin, gibberellin and its combination in delaying the ripening process and maintaining the postharvest performance of Berangan banana as well as prolonging its shelf life.

MATERIALS AND METHODS

Plant materials and experimental location

The experiment was carried out at the Postharvest Technology Laboratory, School of Food Science and Technology. Berangan bananas at maturity stage 1 were purchased from Exotic Star Kajang, Selangor. The uniform fruits in weight and size were sorted to remove defects and decay. The fruits were then immediately transferred to the Postharvest Technology Laboratory for further processing.

Experimental design and application of plant growth regulators

Sixty Berangan banana hands were used in the experiment, each containing six fingers per hand. The hand then washed with 100 mg/L of sodium hypochlorite. After that, the hands were air dried at room temperature (22 ± 2°C) before being treated with GA_3, IAA and its combination. Meanwhile, 48 polyvinylchloride (PVC) air tight containers, 20 cm × 29 cm × 19 cm were sanitized with 70% of alcohol to avoid fungus infection on fruit. All the bananas were exposed to calcium carbide, CaC_2 (4g per kg fruit), to promote ripening for 12 hours. After that, each hand of banana was placed in a sealed PVC container. Each container was added with silica gel to absorb water. Then, the PVC container which contained banana hands were stored at ambient temperature (22 ± 2℃) for 16 days. The experiment was laid out according to the Completely Randomised Design (CRD) with four treatments control (without PGR), IAA (5.70×10^{-7} mg L^{-1}), GA_3 (150 mg L^{-1}) and combination of IAA and GA_3 (2.85×10^{-7} mg L^{-1} and 75 mg L^{-1}) with three replications. The concentrations of IAA and GA_3 were based on previous study conducted by Vendrell (1970).

Parameters measurement

The postharvest parameters assessed were ethylene concentration, peel color, fruit firmness, total soluble solids concentration (TSS), starch pattern index (SPI) and weight loss. All postharvest parameters were recorded at four days intervals (0, 4, 8, 12 and 16 days) except for ethylene concentration which was measured on daily basis.

Internal ethylene concentration

Gas chromatography (GC) (Thermo Scientific, Runcom. Cheshire, UK) was used to determine the concentration of ethylene in each fruit sample. The method for ethylene determination was performed according to Wan Zaliha (2009). The GC was fitted with 30 cm long stainless steel Supleco column

and a flame ionisation detector (FID). Nitrogen gas was used as the carrier gas. The temperatures of the injector, column and detector were 100℃, 100℃ and 250℃ respectively. Ethylene concentration in the gas sample was determined by comparing its retention with authentic ethylene standard (99.9% purity, MCX Company). Ethylene was estimated using the software program and was calculated from the integrated areas of the sample and the corresponding standard (Wan Zaliha 2009). Two mililitres of ethylene gas was taken from the sealed containers with a lock-luer syringe and injected into GC. The ethylene concentration was expressed in μg mL^{-1}.

Starch pattern index

Banana was cut into 2 to 3 cm thick and the peel was separated from the pulp. One side of the cut surface of the pulp was immersed in iodine solution for a few minutes. The starch present in the pulp would react with iodine causing a dark blue color change. Assessment of starch pattern of each banana was observed by comparing the stain cut surface with the Starch Pattern Chart (Kader 2002). The starch patterns indicated the relative amounts of starch and sugars.

Fruit firmness, total soluble solid (TSS), and fruit colour

Fruit firmness was measured using TA.XT plus Texture Analyzer, a stable micro system with flat steel plate mounted on the machine. The texture analyser was calibrated together with Probe P/2N Stainless steel. Five milimetres of penetration were achieved at 1.00 mms-1 pre test speed, 0.50 mms-1 test speed and 5.00 mms-1 post test speed in (Wan Zaliha et al. 2014). The firmness of banana was measured at three different sites which were top, middle and bottom parts. The firmness values were expressed in Newton (N). TSS was recorded following the method of Dadzie and Orchard (1997). A 30g of pulp tissue was blended in 90 mL of distilled water for 2 minutes and filtered using muslin cloth. A single drop of the filtrate was placed on the prism of a hand-held refractometer. It was observed under the light source and the reading was measured in percentage (%). Then, the prism between samples was rinsed with distilled water and dried with a soft, lint-free tissue. The recorded value was multiplied by three since the initial pulp sample was diluted three times with distilled water. The peel color data were measured using Chroma Meter (Model CR400, Konica Minolta Inc. Japan) at three different sides of peel skin. The colour data were expressed in L*, a* and b* values (McGuire 1992).

Percentage weight loss

The weight of banana was taken on day 0, 4, 8, 12, and 16 using weighing balance. The weight loss was recorded in gram (g) and further calculated as formula below.

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

Statistical analysis

The experimental data collected were subjected to an analysis of variance (ANOVA) using GLM (General Linear Models) procedures and further separated by LSD for least significance at $P \leq 0.05$ (SAS Institute Inc., 1999).

RESULTS AND DISCUSSION

Plant growth substances such as IAA, Kinetin and GA_3 have been found to regulate and/or retard ageing, ripening and delay abscission. However, the outcomes were sporadic. Thus, this present study focused more on the role of GA_3, IAA and its combination in reducing ethylene and maintaining the quality of Berangan banana. The production of ethylene in various climacteric fruits is closely related to ripening process. The earlier the occurrence of climacteric peak the more rapid the ripening process. As shown in Figure 1, the GA_3-treated-fruit resulted in delaying the production of ethylene (day 7)

whereas control, IAA alone and combination of IAA and GA_3-treated-fruit showed the earlier production of ethylene on day 2, 3 and 4 respectively. In some climacteric fruits, GA_3 has been shown to delay the onset of climacteric peak as reported by Osman and Abu-Goukh (2016) and Siddiqui et al. (2013). The possible reason for GA_3-treated-fruits to be delayed in climacteric peak of ethylene production and at the same time caused an increase in its production, might be associated to its mode of action. However the exact mechanism on how GA_3 can reduce ethylene production warrants further investigation. Meanwhile, IAA-treated-fruits exhibited a climacteric peak at 0.007 µg mL^{-1} (day 3) which might be attributed to the fruit entering the next stage of fruit growth, senescence or may be due to the increase in 1-amino-cyclopropane-1-carboxylic acid synthase (ACS) and/or 1-amino-cyclopropane-1-carboxylic acid oxidase (ACO) enzyme activities. Hoffman and Yang (1980) claimed that low level of ACC in climacteric fruit is a limiting factor that regulates ethylene production. ACC starts to accumulate due to increased activity of ACS which is responsible in the conversion of ACC to ethylene. According to Alexander and Grierson (2002), during climacteric fruit ripening, the burst of autocatalytic ethylene co-ordinates and accelerates the ripening process. Although ethylene cannot induce immature tomato fruit to ripen rapidly, exposure will hasten its onset by shortening the 'green life', as in banana. They also claimed that the exact mechanisms of ethylene signal transduction are not yet fully understood.

As the ripening proceeds, the most striking post harvest chemical changes in banana are the hydrolysis of starch and the accumulation of sugar (Dadzie and Orchard 1997) which are responsible for the sweetening of the fruit. The starch test indicates that the green bananas have an ethylene production rate in the lower half and that the yellow bananas have an ethylene production near the maximum (Kader 1999). Thompson (1996) reported that the softening of banana fruit during ripening was associated with the conversion of starch to sugar, breakdown of pectin substances and the movement of water from the rind of the banana to pulp during ripening. In the present study, the conversion of starch was pronounced in control fruit followed by IAA-treated-fruits, combination of IAA and GA_3-treated-fruits and lastly GA_3-treated-fruits (Fig. 2). The application of PGRs might result in delaying the conversion process. GA_3 can impair the onset of starch degradation and affect some degradative enzymes (Rosetto et al. 2003). GA_3-treated-fruits started to show the changes in SPI on day 16 (score 3) while control, IAA and combination of IAA and GA_3 showed the earliest conversion of starch into sugar, SPI score 4 (Table 1).

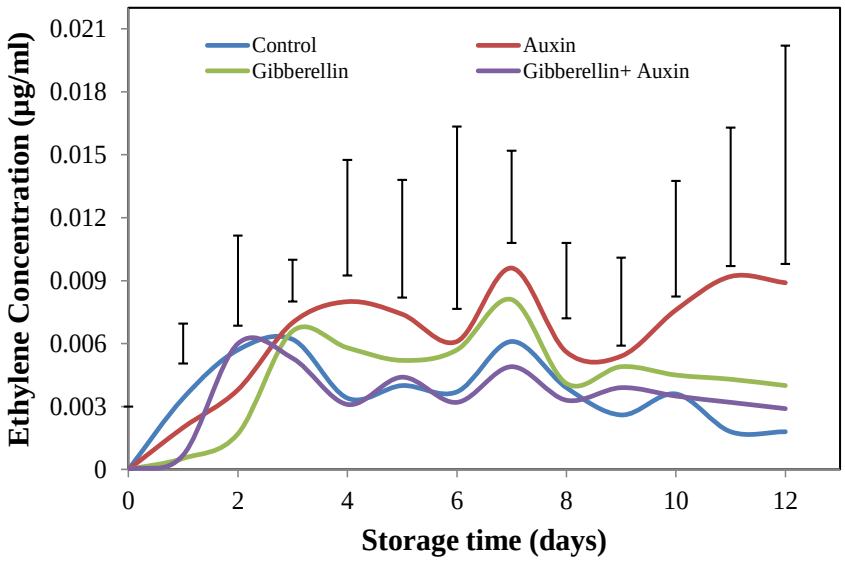
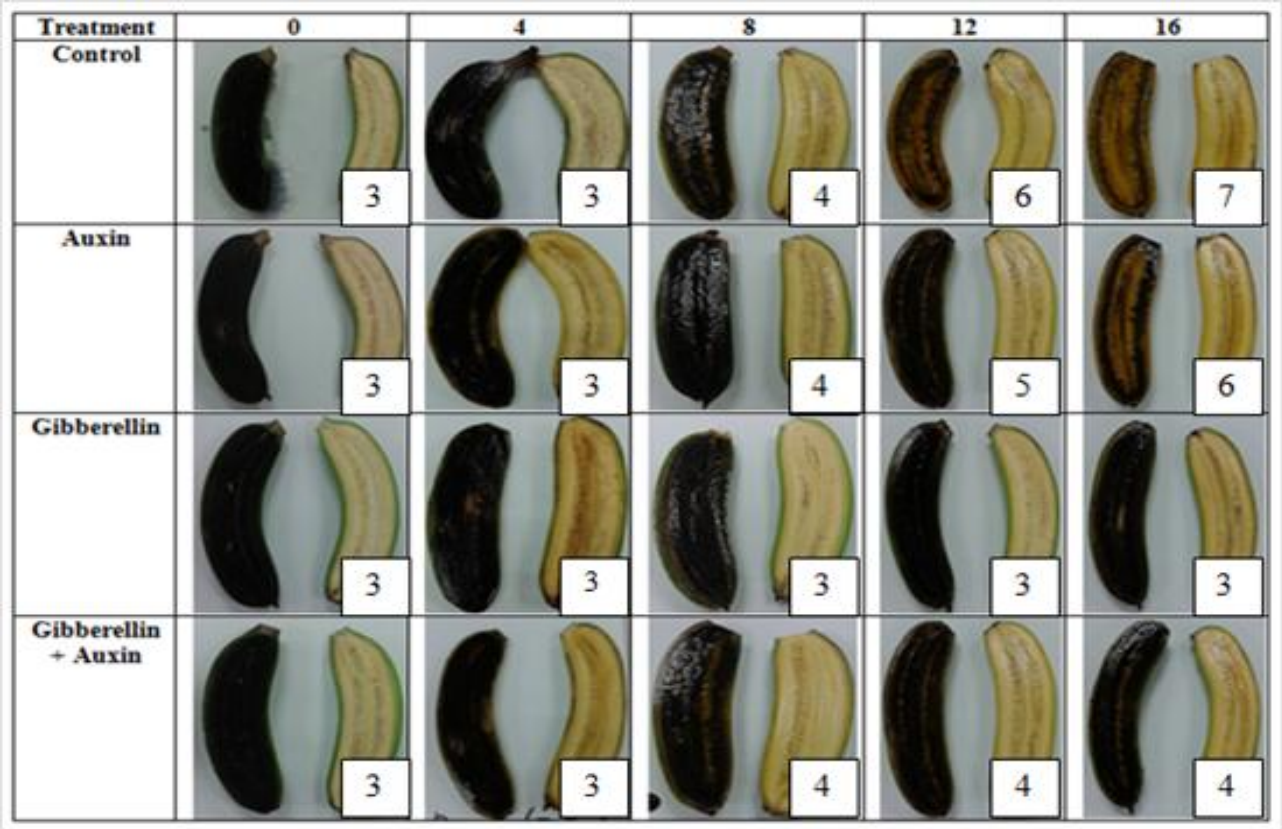


Figure 1. Effect of plant growth regulators on ethylene production of Berangan Banana. Vertical bars represent LSD ($P \leq 0.05$).

Table 1. Effect of plant growth regulators on the starch pattern index of Berangan Banana. Number in the small box denotes to SPI score.



Similarly, a delay in soluble solid accumulation in bananas following GA_3 infiltration was observed by Ahmed and Tingwa (1995). In general, control fruits had a faster increment of TSS content whereas fruits treated with GA_3 were the lowest (Pinto et al. 2004). They reported that increment in TSS content during ripening of fruits and decrease after attaining peak levels following natural fruit ripening and senescence processes are typical of postharvest change in climacteric fruits. This result is in agreement with the report of Dharmasenal and Kumari (2005) on the increase in TSS content of different banana varieties from 0 to 17 °Brix over a storage period of 16 days. In the present study, the slight increase of TSS at the climacteric peak of ripening might be ascribed to differences in the type of cultivars studied (Dadzie and Orchard 1997) and effects of the treatments applied (Fig. 2).

The most evident effect of GA_3 on fruit ripening is retaining of the green color of the banana peel because of a delay in chlorophyll degradation which was reported by Ahmed and Tingwa (1995). Meanwhile, in the present study, the peel color of Berangan banana changed from light green to yellow on day 4 except for GA_3 and the combination of IAA and GA_3-treated-fruits (data not shown). This might be ascribed to the degradation of chlorophyll that gradually unmasked carotenoid pigments lying underneath in the unripe fruit (Yang et al. 2009). Furthermore, Duguma et al. (2014) claimed that banana fruits treated with GA_3 delay the change of green skin color due to the retarding effect of the hormone on the synthesis of ethylene and, hence, reduced the respiration rate of the fruits in concentration dependent manner. Retardation in skin color development in Berangan banana could possibly be associated with the activities of ACS and ACO enzymes that are closely related to the production of ethylene (Wan Zaliha et al. 2014). Other reasons behind this may be attributed to the uneven ripening of Cavendish banana due to the variation in fruit maturity which was claimed by Harris et al. (2000).

In the present study, the percentage of weight loss of Berangan banana increased continuously throughout the experimental period which might be due to respiration of food reserve (Fig. 3). As fruit ripen, starch starts to convert into sugar and is used as energy since high energy is required to run the

chemical reactions in plant. As claimed by Dharmasenal and Kumari (2005), the excess energy produced from the respiration process is released from the tissue by the vaporization of water, which will subsequently be transpired from the fruit, 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). In the present study, even though PGR treatments had similar percentage weight loss as control fruit, GA_3-treated-fruit had a tendency to show the lower percentage weight loss. In general, all treatments had a lower percentage weight loss ranged between 0 % and 1.16 % which is acceptable for commercial saleable weight. As reported by Kader (1999), the critical commercial weight loss was between 5 to10%.

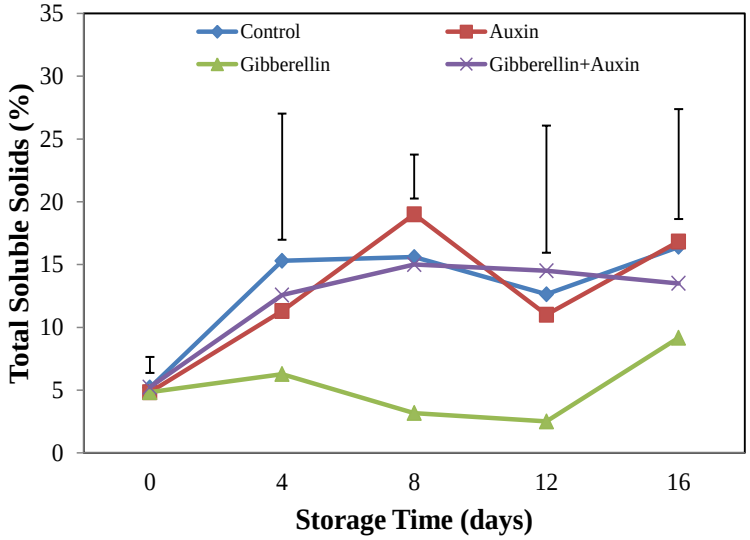


Figure 2. Effects of different plant growth regulators on total soluble soilds of Berangan banana. Vertical bars represent LSD at ($P \leq 0.05$).

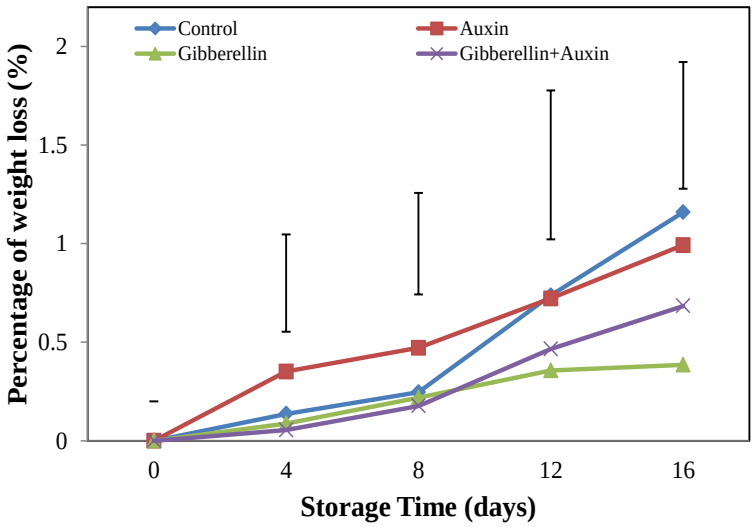


Figure 3. Effects of different plant growth regulators on percentage weight loss of Berangan banana. Vertical bars represent LSD at ($P \leq 0.05$).

The lower percentage weight loss of GA_3-treated-fruits might be associated with the softening and reduction of respiration substrate. The latter has been discussed above. The earlier, physical changes during ripening are closely related to a change in cell wall component and starch degradation (Seymour 1993). The firmness of Berangan banana tends to be low for control, IAA and combination of IAA- and GA_3-treated-fruits. GA_3 treated fruit showed higher firmness throughout the 16 days. Firmness of Berangan banana decreased steadily during the eight days of storage (Fig. 4). It was expected that during those periods all starch would be completely converted to sugar. According to Chin (2000), in guava fruit, increased pectin solubility and firmness loss during an extended ripening period as accompanied by increased pectin level, perhaps suggesting that pectin is being continuously synthesised throughout development of the fruit. While Ali et al. (2004) claimed that the rapidly softening banana as unique; though pectin solubility increased substantially, however, no discernible pectin depolymerisation was observed during ripening.

The maximum shelf life was exhibited by GA_3-treated-fruit (16 days) followed by combination of IAA and GA_3-treated-fruit and IAA-treated-fruit. All treated fruits tend to extend seven days longer then the normal shelf life (10 days). GA_3-treated-fruits were found to be better in term of qualities and extended shelf life. Fruit treated with GA_3 had dramatically delayed the fruits peel color changes, weight loss, ethylene, CO_2 production, total sugar content and extended the shelf life of banana as reported by Duguma et al. (2014).

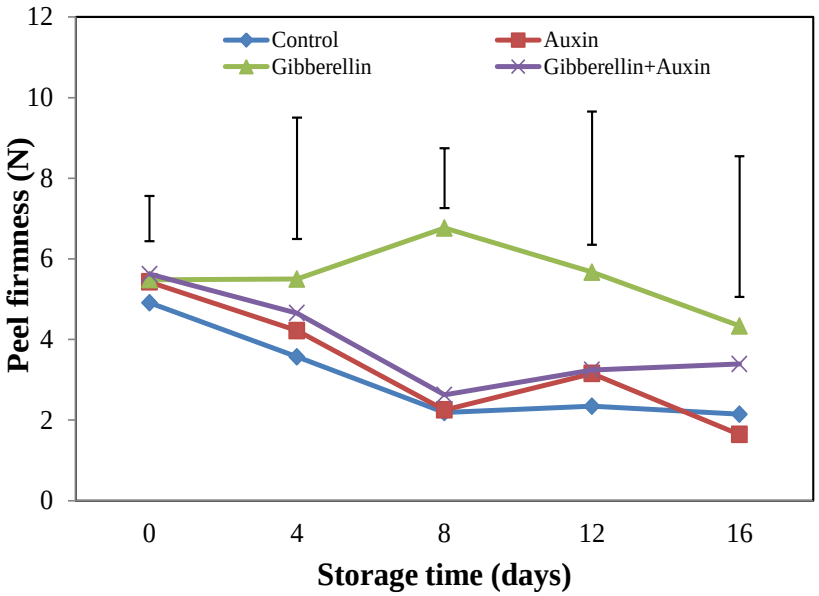


Figure 4. Effects of different plant growth regulators on firmness of Berangan banana. Vertical bars represent LSD at ($P \leq 0.05$).

CONCLUSION

Application of GA_3 (150 mg L^{-1}) was able to delay the climacteric peak of Berangan banana and also retard the peel color changes, fruit softening and extend its shelf life up to 16 days. Further studies should be conducted to determine the role of indigenous concentration of GA_3 in banana fruit during maturation and ripening as it may also give significant effect to the quality.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the School of Food Science and Technology, Universiti Malaysia Terengganu, Terengganu, Malaysia for financial support

REFERENCES

AgroFood Statistic, 2013. Strategic Planning and International Division, Ministry of Agriculture and Agro-Based Industry, Malaysia ISSN 2232-0407.

Ahmed OK and Tingwa PO, 1995. Effect of gibberellic acid on several parameters of ripening banana fruits (*Musa sp*. Cv. Dwarf Cavendish). *J Agri Sci* **3**(1), 47-49.

Alexander L and Grierson D, 2002. Ethylene biosynthesis and action in tomato: a model for climacteric fruit ripening. *J. Expt Bot*, **53**(377), 2039-2055.

Ali ZM, Chin LH and Lazan H, 2004. A comparative study on all degrading enzymes, pectin modifications and softening during ripening of selected tropical fruits. *Plant Sci* **167**, 317-327.

Babbitt JK, Powers MJ and Patterson ME, 1973. Effect of growth regulators on cellulase, polygalacturonase, respiration, color and texture of ripening tomatoes. *J Am Soc Hortic Sci* **98**,77-81.

Chin LH, 2000. Softening enzymes and cell wall modifications during ripening of carambola and other selected tropical fruits, Ph.D. Thesis, Universiti Kebangsaan Malaysia, Bangi, Malaysia.

Dadzie BK and Orchard JE, 1997. Routin postharvest screening of banana/plantain hybrids criteria and methods. International Network for banana and plantain (Inibap), Technical Guidelines. Pp 75-76.

Dharmasenal DA and Kumari AH, 2005. Suitability of charcoal-cement passive evaporative cooler for banana ripening. *J Agri Sci* **1**(1), 19-30.

Duguma T, Egigu MC and Muthuswamy M, 2014. The effect of gibberellic acid on quality and shelf life of banana (*Musa* spp.) Department of Biology, Haramaya University, Ethiopia.

FAOSTAT, 2012. Fishery and agriculture statistics. Food and Agricultural Organization of the United Nation. Rome, Italy.

Hailu M, Workneh TS and Belew D, 2013. Review on postharvest technology of banana fruit. *Afr J Biotechnol* **12**(7), 635-647.

Harris DR, Seberry JA, Wills RBH and Spohr LJ, 2000. Effect of fruit maturity on efficiency of 1-methylcyclopropane to delay the ripening of banana. *Postharvest Biol Technol* **20**(3), 303-308.

Hoffman NE and Yang SF, 1980. Changes of 1-aminocyclopropane-1-carboxylic acid content in ripening fruits in relation to their ethylene production rates. *J Am Soc Hortic Sci***105** (4), 492-495.

Irtwange SV, 2006. Application of modified atmosphere packaging and related technology in postharvest handling of fresh fruits and vegetables. *IJAE* **4**(8), 1-13.

Kader AA, 1999. Fruit maturity, ripening and quality relationships. *Acta Hort* **485**, 203-208.

Kader AA, 2002. Banana: Recommendations for Maintaining Postharvest Quality. Accessed January 18, 2015

Koeppel D, 2008. Banana: The fate of fruit that changed the world. Penguin Group Publishers. p 209.

McGuire RG. 1992. Reporting of objective colour measurements. *Hortic Sci* **27**, 1254-1255.

Osman HE and Abu-Goukh AA, 2008. Effect of polyethylene film lining and gibberellic acid on quality and shelf-life of banana fruits. *Univ Khartoum J Agric Sci* **16**(2), 242-261.

Pinto AC, Alues RE and Pereira EC, 2004. Efficiency of different heat treatment procedures in controlling disease of mango fruits. *Acta Hort* **645**, 551-553.

Rosetto MRM, Purgatto E, Nascimento JRO, Lajolo FM and Cordenunsi BR, 2003. Effects of gibberellic acid on sucrose accumulation and sucrose biosynthesizing enzymes activity during banana ripening. *Plant Growth Regul* **41**, 207-214.

Salunkhe DK and Kadam SS, 1995. Banana. Hand Book of Fruit Science and Technology. Marcel Dekker, Inc. New York. Pp 67-90

Samson JA, 1980. Tropical fruits. Longman group limited, London. p 121.

SAS Institute Inc, 1999. SAS Procedure Guide, Version 9.1. Cary, NC.

Seymour GB, 1993. Banana. Biochemistry of Fruit Ripening. Chapman and Hall, London.

Siriboon N and Banlusilp P, 2004. A study on the ripening process of 'Namwa' Banana. Faculty of Biotechnology, Assumption University Bangkok, Thailand.

Thompson AK, 1996. Postharvest treatments in postharvest technology of fruit and vegetables, ed. By Thompson AK. Blackwell Publishing. Oxford. Pp 95-124.

Siddiqui MW, Dutta P, Dhua RS and Dey A, 2013. Changes in Biochemical Composition of Mango in Response to Pre-Harvest Gibberellic Acid Spray. *Agric Consp Sci* **78** (4), 331-335.

Vendrell M, 1971. Acceleration and delay of ripening in banana fruit tissue by gibberellic acid. *Aust. J Biol Sci* **23**, 553-559.

Wan Zaliha WS, Siti Hajar A, Yusnita H and Zuraida AR, 2014. Effect of different ethylene removals on Berangan Banana (*Musa* sp. AAA Berangan). *Trans Mal Soc Plant Physiol* **22**, 69-73.

Wan Zaliha WS, 2009. Regulation of fruit color development, quality and storage life of 'Cripps Pink' apples with deficit irrigation and plant bioregulators. PhD Thesis. Pp: 1-246.

Yang XT, Zhang ZQ, Joyce D, Huang XM, Xu LY and Pang XQ, 2009. Characterization of chlorophyll degradation in banana and plaintain during ripening at high temperature. *Food Chem* **114**, 383-390.