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Research article

# Effect of different levels of gibberellic acid and kinetin on quality and self-life of banana (*Musa spp*.) fruits

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ABSTRACT

Artificial fruit ripening agents have become increasingly popular in recent years. During the off-seasons, various ripening agents are used for the ripening of banana fruits. The effects of various ripening agents of banana fruits (variety: Malbhog) were studied. Seven treatments consisting of distilled water, Gibberellic acid (GA3) @ 100 ppm, GA3 @ 200 ppm, GA3 @ 300 ppm, kinetin @ 3 ppm, kinetin @ 5 ppm, and kinetin @ 7 ppm were laid out in a Completely Randomized Design with three replications. The maximum loss in weight (9.195%), Total Soluble Solids (20.33B), the highest color score (6), pH (4.767), Total Soluble Solids/Titratable Acidity TA (34.23), and Pulp peel ratio (2.84) were observed in banana sprayed with distilled water whereas the minimum value for TSS (12.67B), pulp peel ratio (1.813), peel color rating (2.67), TSS/TA (15.32) were observed in GA3 @ 300 ppm treated fruits. The maximum (32.67 days) and the minimum (18.33 days) shelf-life was observed in GA3 @ 300 ppm and distilled water respectively. This research will help in the regulation of ripening as per the needs of consumers and the distance of the market. In horticulture, it will help to extend storage life and reduce quality and economic loss.

## 1. Introduction

Banana (*Musa spp*., family Musaceae) is a monocot, monocarpic, and perennial plant grown in tropical and subtropical parts of the world (Shrestha, 2016). It occupied an area of 17,839 hectares with a total productive area of 15,223 hectares and the production of 247,622 Mt (metric tons) and productivity 16 Mt $ha^{-1}$ in Nepal, while in Chitwan the net area, productive area, production and productivity of bananas were 1,665 ha, 1,218 ha, 21,680 Mt and 18 Mt $ha^{-1}$ respectively (MOAD, 2017). The presence of oligosaccharides: fructo-oligosaccharide and polyphenols, catechin, epicatechin, epigallocatechin, and gallic acid in bananas have been found useful in the prevention of colon cancer, diabetes, muscular contraction, blood pressure regulation, and the treatment of intestinal disorders (Bantayehu, 2017). Jhapali Malbhog is a commercially grown local cultivar in Jhapa, Morang, Sunsari, Chitwan, and Nawalparasi which is superior in quality, storability, and taste and has got higher demand (Basnyat et al., 1996). Changes in carbohydrate content, increase in sugar content, changes in color, texture, aroma volatiles, flavor compounds, phenolic compounds, and organic acids are all signs of fruit ripening (Maduwanthi and Marapana, 2019). The banana is a climacteric fruit that undergoes rapid ripening by an autocatalytic climacteric burst of the gaseous hormone ethylene. Rapid textural change is followed by excessive tissue softening and subsequent spoilage of bananas during the late-ripening phase, resulting in a heavy crop loss each year, with post-harvest losses ranging from 25 to 50%. To delay ripening and softening, use certain growth regulators like gibberellic acid and kinetin and other chemical compounds like potassium permanganate and 1-Methylcyclopropene (1-MCP) which act against exogenous or endogenous ethylene (Sahithya et al., 2017).

Application of plant growth regulators results in better output as it amends various physiological disorders to improve the quality and yield of fruit. The use of different plant growth regulators like Gibberellic Acid (GA3) and BA were seen as highly significant in respect of prolonging the shelf life of bananas (Sultana et al., 2012). Vargas and Lopez (2011) reported the delaying of ripening in Cavendish banana by 3–4 days is achieved through the application of $GA_3$ at concentrations ranging from 50-250 mg/L Osman and Abu-Goukh (2008) reported that Gibberellic acid treatment (100 ppm) by dipping the fruit whole showed the highest shelf life than by dipping tip only and control where an association of whole fruit dipping with sealed film liners showed superior results.

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Mayak and Halevy (1974) observed the effect of kinetin on cut flower roses was senescence, less reduction in dry weight, and better water balance. The effect of 5 different concentrations of $GA_3$ (250 ppm, 350 ppm, 500 ppm, 750 ppm) on the shelf life of banana was studied by the University of Jaffna and it has been reported that the 500 ppm and 750 ppm concentration of $GA_3$ extends the shelf life more and less weight loss as compared to other treatments. Similarly, TSS was highest in control than $GA_3$ treated bananas (Archana and Sivachandiran, 2015).

Generally, the rate of deterioration of harvested commodities is proportional to the rate of respiration (Irtwange, 2006). Bananas are harvested when they are mature green and then allowed to ripen in market areas. Because the banana is a climacteric fruit, it has a respiratory peak during ripening, which occurs after harvest at 20 °C. Within a few days, the hard green banana fruit's respiration rate of about 20 mg $CO_2$ $kg^{-1}$ $h^{-1}$ may rise to about five times at the climacteric peak and then fall as ripening progresses, and there is also a significant water loss through transpiration after the onset of ripening (Salunkhe and Kadam, 1995). Ethylene production rates increase with harvest maturity, physical injuries, disease incidence, temperature increases up to 30 °C, and water stress. Thus, fruits that must be transported over long distances should be treated with chemicals that inhibit ethylene synthesis in fruits. With these view points, the present experiment was undertaken to determine the appropriate concentration of $GA_3$ and kinetin for prolonging the shelf life of bananas and their effects on quality attributes.

## 2. Materials and methods

### 2.1. Site selection for research materials

The banana bunches were brought from Amritnagar which is 22 km South of Narayangadh, Chitwan for the post-harvest treatment of bananas. Geographically, Amritnagar is situated in the Terai belt at 27° 60′ N latitude and 84° 31′ E longitude, at an elevation of 185 m above sea level.

### 2.2. Selection of the cultivar

The cultivar selected for the research was Malbhog which is one of the most popular and commonly cultivated varieties in that locality. Malbhog is one of the Cavendish types of bananas, phenologically resembling Harichhal, and popularly grown in Nawalparasi, Chitwan, Jhapa, Morang, and Sunsari Districts.

### 2.3. Location and time of the experiment

The post-harvest analysis was carried out at the Horticulture Laboratory of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal (Figure 1). It is located in the Terai belt at 27° 40′ N Latitude and 84° 19′ E Longitude, at an elevation of 228 mean average sea level. This

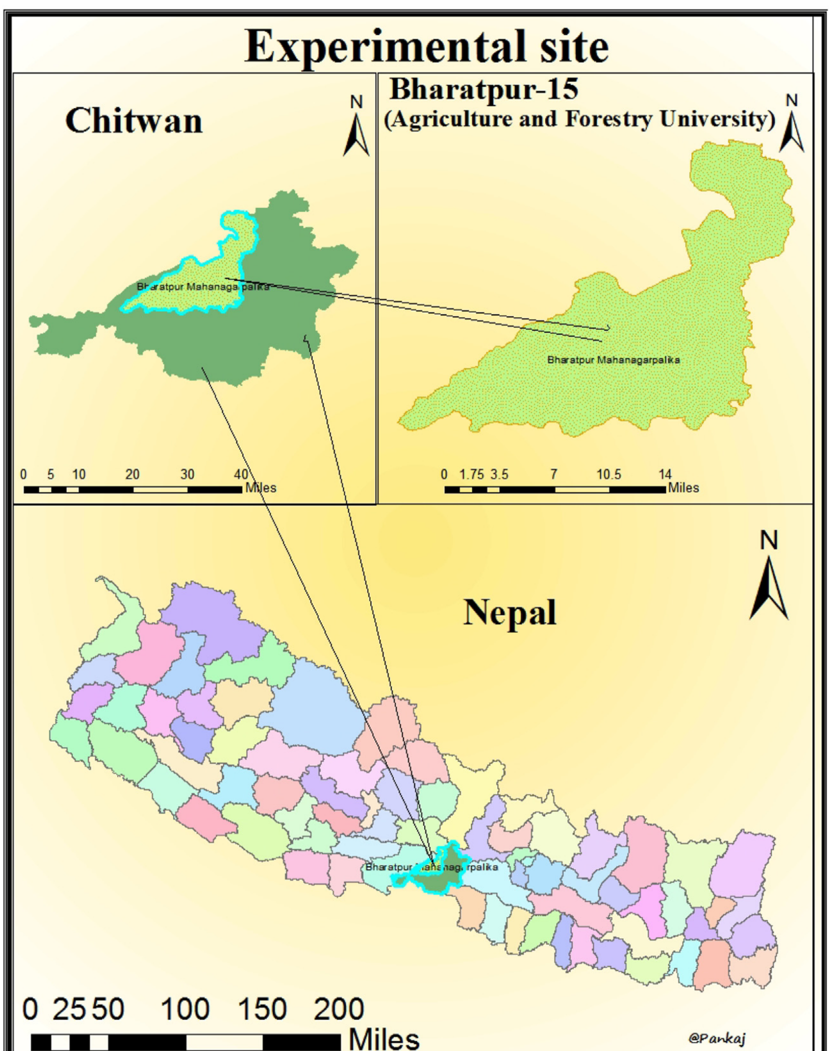


Figure 1. Map of Nepal indicating the study area.

location has a humid subtropical climate, with hot summers and cold winters, and a total annual rainfall of 1582.6 mm. July to September is the monsoon season. This experiment was conducted from 14th March to 16th April 2019.

### 2.4. Harvesting of bananas and selection of fruits

Uniform bunches of bananas were selected and harvested with a sharp knife. Then the bunches were brought to Rampur, Chitwan. The individual fingers were separated from the hand and washed with water. Then the individual fingers were dried in the shade overnight. The hand at the uppermost portion and lowermost portion of each bunch were discarded as they represent the extreme range of maturities and size in a bunch. The uniform fingers free from wounds, cracks, insect damage and blemishes were selected.

### 2.5. Design of experiment

In this study, there were 7 treatments; T1 = Control, Spraying with distilled water, T2 = Spraying with GA3 @ 100 ppm, T3 = Spraying with GA3 @ 200 ppm, T4 = Spraying with GA3 @ 300 ppm, T5 = Spraying with Kinetin @ 3 ppm, T6 = Spraying with Kinetin @ 5 ppm, T7 = Spraying with Kinetin @ 7 ppm. These seven treatments were laid out in Completely Randomized Design (CRD) with three replications. Twelve fingers were selected for each treatment. Thus, there were 84 bananas (=12 banana x 7 treatments) for single replication.

Twelve fingers were divided into two parts. Five non-destructive samples were numbered individually by stickers for observations like physiological loss in weight, spoilage loss, storage life, and peel color. Seven other fingers were selected as destructive samples for observations like TSS, TA, pulp-peel ratio at every 3 days interval.

### 2.6. Establishment of experiments

The sample for each treatment was separated and then each sample was sprayed with a different treatment. Then the sample was air-dried for 10 minutes by keeping in air perforated plastic trays. Then each treatment was covered with transparent plastic by making some perforations for 48 hours for proper dissemination and to prevent volatile loss preventing infection. After 48 hrs, the plastics were removed and observations were made.

### 2.7. GA3 and kinetin solution

The stock solution of 1000 ppm of GA3 (C9H22O6) was prepared by dissolving 1 g GA3 in 900 mL of distilled water having the minimum assay of more than 90% of Central Drug House (P.) Ltd. Bombay. A working solution of 100, 200 and 300 ppm of GA3 was prepared by diluting 100, 200 and 300 mL of GA3 stock solution with 900, 800 and 700 mL of distilled water separately and respectively. Similarly, a stock solution of 1000 ppm of kinetin (6- furfuryl aminopurine, C10H9N50) was prepared by dissolving 1 g in 995 mL distilled water having the minimum assay 99.5% of central Drug House (P.) Ltd. Bombay. The working solution of 3, 5 and 7 ppm of kinetin was prepared by diluting 3mL, 5 mL and 7 mL in 997, 995 and 993 mL of distilled water separately and respectively. 12 fingers of each treatment are sprayed separately with a given concentration of solution as described above in the listing of the treatment.

### 2.8. Parameters to be taken for observation

#### 2.8.1. Physiological loss in weight (PLW%)

A digital-sensitive balance was used to determine fruit weight. The weight loss was calculated according to the formula adopted by Tourky et al. (2014) (Eq. 1):

$$W_1 = \frac{W_0 - W_t}{W_0} \times 100\% \tag{1}$$

Where $W_1$ is the percentage weight loss, $W_0$ is the initial weight of fruits and $W_t$ is the weight of the fruits at the designated time.

#### 2.8.2. Change in peel color

Five fingers were kept for a peel color rating. Peel color rating was done in all treatments at the initiation of treatment until ripening at every two days interval. To categorize the color in the different indexes, peel color rating chart was used as described by (Acedo and Bautista, 1991) which is as follows:

1 = Green, 2 = pale green, 3 = Greenish yellow, 4 = Yellow green, 5 = Yellow with green tip 6 = Full yellow, 7 = Yellow, lightly flecked with brown, 8 = Yellow with increasing brown areas.

#### 2.8.3. Pulp to peel ratio

During the collection of data at every 2 days interval, Pulp and peel were separated with the help of a sharp knife and weighed individually with the electronic digital balance at the time of TSS and TA determination and expressed as peel pulp ratio. Pulp to peel ration was calculated by a formula adopted by Tourky et al. (2014) (Eq. 2);

$$\text{Pulp to peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}} \tag{2}$$

#### 2.8.4. Sensory evaluation or organoleptic test

The organoleptic tas te in bananas at the CI-6 (full yellow) stage was carried out by groups of five people for flavor, astringency, sweetness, and overall acceptability. Rating and Scoring were done by using a five-point rating scale technique (Miah, 1993). Banana of different treatments and replications were divided into 5 people and their experience or evaluations of sensory quality attributes were recorded.

Scale assigned to different parameters is given in Table 1.

#### 2.8.5. Shelf life

The shelf life of the fruits was measured in days from the initiation of the experiment up to 50% rotting.

#### 2.8.6. Total soluble solid ($^0$ Brix)

Total soluble solids (Brix) were determined with the help of a hand-held refractometer (Model: ERMA, Japan). One good fruit was randomly taken from each replication of all the treatments. After measuring the weight of these sampled fruits, the peel was removed; the flesh was ground and sieved as well as squeezed in a muslin cloth and juice was obtained. Two drops of homogenized juice were put on the prism of the refractometer and the reading was taken. Before recording the observation, calibration was done. These readings were averaged as per treatment and replications.

#### 2.8.7. Titratable acidity (TA)

TA of the banana pulp was measured by using the following formula adopted by Islam et al. (2013) (Eq. 3);

$$\text{Titratable acidity } (\%) = \frac{\text{T x N x V1 x E}}{\text{V2 x W x 1000}} \text{ x } 100 \tag{3}$$

**Table 1.** Scale assigned to different organoleptic parameters.

| Scale | Sweetness | Astringency | Flavour | Overall acceptability |
|---|---|---|---|---|
| 1 | Excellent | Excellent | Very astringent | Excellent |
| 0.8 | Good | Good | Astringent | Good |
| 0.6 | Fair | Fair | Medium | Fair |
| 0.4 | Poor | Poor | Less | Poorly acceptable |
| 0.2 | Very poor | Very poor | No astringent | Unacceptable |

where T is the titre, N is the normality of NaOH, V1 is the volume made up, E is the equivalent weight of acid, V2 is the volume of extract, and W is the weight of the sample.

#### 2.8.8. TSS/TA ratio: this ratio was calculated as below (Eq. 4)

$$\frac{TSS}{TA} = \frac{\text{Total Soluble Solids}}{\text{Titratable Acidity}} \tag{4}$$

#### 2.8.9. pH of the pulp

The juice extracted by homogenizing the pulp in a juice blender was previously squeezed and sieved in a muslin cloth and collected in a beaker. The PH meter was first calibrated using buffer solution and then the sensor electrode was dipped in the mixture contained in the beaker. Then the digital PH meter showed data which was then recorded.

### 2.9. Statistical analysis

The information gathered was compiled and entered into MS-Excel 2010. The analysis of variance for all parameters was performed following the procedures outlined in GenStat 15$^{th}$ edition. Duncan's Multiple Range Test (DMRT) for mean separations was performed at a 5% level of significance (Gomez and Gomez, 1984). MS-Excel 2010 software was used to create graphs and tables.

## 3. Results and discussion

The results were assessed and discussed with supporting evidence from previous works.

### 3.1. Physiological weight loss in percentage (PLW%)

Physiological weight loss in bananas due to the effect of different concentrations of GA3 and Kinetin is presented in Table 2. The result showed a significant variation on the 3$^{rd}$ and 15$^{th}$ days of treatment whether non-significant results were recorded on other days. The results showed that as the shelf life prolonged, physiological weight loss gradually increased where the maximum loss was recorded in control and the minimum in bananas treated with 200 ppm gibberellic acid. The result was in harmony with Shrestha (2010) where the minimum total weight loss was achieved in 200 ppm GA3 treated fruits followed by kinetin 10 ppm treated. Similar to this result, Tourky et al. (2014) also recorded the lowest PLW% loss (2.16% and 2.9%) in GA3 treated banana fruits in two seasons. Archana and Sivachandiran (2015) was also in accordance with present results where a higher concentration of GA3 results in lower PLW % and vice-versa. Tapas (2016) observed that Gibberellic acid dipping at 150 ppm resulted in the lowest PLW during storage compared to the other treatments.

This could be due to the effect of GA3 in retaining more water against the force of transpiration, as well as a lower rate of respiration and transpiration, as supported by the findings of Sahithya et al. (2015), where kinetin also showed a beneficial effect in decreasing weight loss. Kinetin 20 ppm on the other hand showed the lowest PLW% in kinnow mandarin which might be due to its effect in reducing senescence, the rate of respiration and ripening of fruits (Kaur et al., 2014). Sahithya et al. (2015) also found the minimum weight loss in GA3 150 ppm treated banana fruits and Kinetin also showed a positive response to decreasing weight loss as compared to control. GA3 also causes an increase in polyamine levels as well as the activity of their biosynthetic enzymes, as well as delayed senescence, physiological process, and weight loss (Valero et al., 1998).

### 3.2. Pulp peel ratio

Table 3 shows the pulp-to-peel ratio of postharvest treated fruits as well as their mean values. The result showed a continuous increase in pulp peel ratio during the storage period which is quick in control as compared to other treatments. At 15$^{th}$ DAS the maximum pulp-peel ratio was recorded at control (2.84) and the lowest at 300 ppm GA3 treated fruits (1.813). This might be due to the climacteric peak in control at 15 DAS resulting in an increment of soluble sugars in the pulp that ultimately leads to osmotic transfer from peel to the pulp. This result is in accordance with Tourky et al. (2014) where 2.1–1.9, and 1.96–1.8 values were obtained for GA3 treated and untreated banana fruits respectively at the end of shelf life. During the ripening process increment in the levels of hydrophilic soluble solids in the pulp created osmotic gradient which leads to flowing of water from peel to pulp which increases the weight of pulp and evaporation and transpiration loss from the peel again decrease the weight of peel (Marriot, 1980; Sultana et al., 2012). A similar result was obtained by Tapas (2016) where the maximum pulp peel ratio was obtained in control and the lowest in GA3 (150 ppm) treated fruits on the 9$^{th}$ day of treatment. An increment in pulp peel ratio during ripening was also observed by Sultana et al. (2012) where the pulp peel ratio was recorded with the value of 3.42, 3.16 and 2.9 in control, kinetin @ 15 ppm and GA3 @ 150 ppm respectively.

**Table 2.** Physiological Weight Loss in Percentage (PLW%) of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatments | Physiological loss in weight (%) | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 1.979 a | 2.777 | 5.339 | 7.463 | 9.195 a |
| GA3 @100 ppm | 1.299 b | 2.102 | 5.092 | 4.943 | 6.694 b |
| GA3 @200 ppm | 1.144 b | 2.121 | 4.698 | 6.947 | 4.396 c |
| GA3 @300 ppm | 1.125 b | 1.138 | 5.463 | 3.526 | 5.321 bc |
| Kinetin @3 ppm | 1.451 b | 2.153 | 4.312 | 6.265 | 6.269 bc |
| Kinetin @5 ppm | 1.324 b | 2.066 | 7.282 | 6.391 | 6.922 b |
| Kinetin @7 ppm | 1.149 b | 2.207 | 4.886 | 5.839 | 7.334 ab |
| Grand mean | 1.353 | 2.08 | 5.30 | 5.91 | 6.59 |
| SEM | 0.216 | 0.442 | 1.322 | 1.29 | 0.895 |
| F test | * | NS | NS | NS | ** |
| LSD (0.05) | 0.4643 | - | - | - | 1.919 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. NS = Not significant, *Significant at 0.05 level of significance, ** Significant at 0.01 level of significance. SEM = Standard error of mean, LSD = Least significant difference.

**Table 3.** Pulp peel ratio of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatments | Pulp peel ratio | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 1.63 | 2.023 | 2.217 a | 2.487 a | 2.84 a |
| GA3 @100 ppm | 1.523 | 1.75 | 1.71 b | 1.88 bc | 2.427 b |
| GA3 @200 ppm | 1.433 | 1.78 | 1.67 b | 1.72 bc | 2.173 bc |
| GA3 @300 ppm | 1.323 | 1.687 | 1.69 b | 1.593 c | 1.813 c |
| Kinetin @3 ppm | 1.523 | 1.69 | 1.82 ab | 2.003 b | 2.233 b |
| Kinetin @5 ppm | 1.383 | 1.74 | 1.837 ab | 1.977 bc | 2.2 bc |
| Kinetin @7 ppm | 1.493 | 1.57 | 1.747 ab | 1.873 bc | 2.127 bc |
| Grand mean | 1.473 | 1.749 | 1.813 | 1.933 | 2.259 |
| SEM | 0.1673 | 0.213 | 0.2072 | 0.1674 | 0.173 |
| F test | NS | NS | * | ** | ** |
| LSD (0.05) | - | - | 0.4444 | 0.3589 | 0.3715 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. NS = Not significant, *Significant at 0.05 level of significance, ** Significant at 0.01 level of significance. SEM = Standard error of mean, LSD = Least significant difference.

### 3.3. Peel color rating

The effect of different concentrations of Gibberellic acid and Kinetin in the peel color rating of bananas is given in Table 4. The result showed that there was no any significant variation in initial 3rd and 6th days of treatment whereas significant result was obtained at 9th, 12th and 15th days of treatment. Peel color score progressively during the storage period of banana. The experiment showed a delay in color development with GA3 and kinetin treatment as compared to control. The minimum color score was observed with GA3 @300 ppm treated banana. This result is in accordance with the result of Shrestha (2010), Tourky et al. (2014) and Archana and Shivachandiran (2015). Similar result was observed by Tapas (2016) where peel color become marketable only after 15 days in 150 ppm GA3 treated which might be due to control in ethylene level and respiratory activity. Cytokinins inhibit the degradation of chlorophyll and a similar effect can be seen from Gibberellins (Shrestha, 2010). The effects of GA3 and ethylene on fruit ripening, and senescence are opposed, with GA3 delaying fruit maturation, ripening, and chlorophyll degradation (Osman and Abu-Goukh, 2008). This was also in harmony with Huang et al. (2014).

### 3.4. Total Soluble Solids

The recorded data related to the TSS content of the banana is presented in Table 5. The experiment derived the lowest TSS (14) in bananas treated with GA3 @300 ppm and the highest (20.33) in control. The result showed a gradual increment in TSS during the storage period whereas the rate showed slightly slower in GA3 and kinetin-treated fruits. The result was following Tourky et al. (2014) and Archana and Shivachandiran (2015). Tapas (2016) also observed a similar result where GA3 @150 ppm showed the minimum TSS and control record the maximum at 9th DAS. Further, he concluded that the increment in TSS during ripening was because of the breakdown of starch and polysaccharides into sugar which is also conformity with Pendharkar et al. (2011) and Kulkarni et al. (2011) in banana fruits. The lower TSS in Gibberellic acid-treated fruits might be due to a reduced rate of respiration and delayed ripening. A similar result was obtained by Sembok et al. (2016) and Zomo et al. (2014) where TSS in control showed the highest value at the initial condition as compared to other PGR and decreases after the climacteric peak. This result is in harmony with Bains et al. (2017) where the increment in GA3 concentration decreases the TSS value which is also lower as compared to untreated fruits. The minimum TSS in GA3-treated fruits might be due to the reduced rate of starch hydrolysis and delayed ripening (Rossetto et al., 2003). This experiment showed lower TSS in Kinetin-treated fruits than untreated fruits which are non-contradictory with the result obtained by Kaur et al. (2014) in Mandarin. The result obtained by Shrestha (2010) with 10 and 15 ppm kinetin at the fully ripe stage is in harmony with the above finding. Sahithya et al., (2017) are also in accordance with the above findings.

**Table 5.** Total Soluble Solids of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatment | Total soluble solids (Brix) | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 9.667 a | 12.333 a | 15 a | 18.33 a | 20.33 a |
| GA3 @100 ppm | 9 ab | 10.333 b | 12.67 b | 15.33 ab | 16.67 b |
| GA3 @200 ppm | 7.333 c | 8.333 c | 10 c | 11.67 cd | 14 cd |
| GA3 @300 ppm | 7.667 bc | 8 c | 8.67 c | 11 d | 12.67 d |
| Kinetin @3 ppm | 9 ab | 10 b | 13 b | 14.67 bc | 16 bc |
| Kinetin @5 ppm | 8.333 abc | 10 b | 12.67 b | 15 b | 15.67 bc |
| Kinetin @7 ppm | 7.667 bc | 8.667 c | 10.33 c | 14.33 bc | 15.67 bc |
| Grand mean | 8.38 | 9.67 | 11.76 | 14.33 | 15.86 |
| SEM | 0.67 | 0.563 | 0.836 | 1.44 | 1.008 |
| F test | * | *** | *** | ** | *** |
| LSD (0.05) | 1.4360 | 1.208 | 1.792 | 3.081 | 2.162 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. *Significant at 0.05 level of significance, **Significant at 0.01 level of significance, ***Significant at 0.001 level of significance. SEM = Standard error of mean, LSD = Least significant difference.

### 3.5. Titratable acidity (TA)

The effect of different concentrations of PGR on TA of banana during the storage period and their mean values expressed in percentage are displayed in Table 6. The experiment showed an increment in TA during the ripening process at the initial condition and a slight decrease after the climacteric peak. The highest TA was recorded at 300 ppm GA3 treated fruits and the lowest TA in control. The findings of Shrestha (2010) was following with these findings where GA3 @100 ppm showed the highest

**Table 4.** Peel color rating of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatment | Peel color rating | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 1.667 | 2 | 3 a | 5 a | 6 a |
| GA3 @100 ppm | 1 | 1.333 | 2.333 ab | 3.333 b | 4.333 b |
| GA3 @200 ppm | 1 | 1 | 1.667 bc | 2 b | 3 d |
| GA3 @300 ppm | 1 | 1 | 1.333 c | 2 b | 2.667 d |
| Kinetin @3 ppm | 1.333 | 1.333 | 2.333 ab | 2.667 b | 3.333 cd |
| Kinetin @5 ppm | 1.333 | 1.667 | 2 bc | 2.667 b | 3.333 cd |
| Kinetin @7 ppm | 1 | 1.333 | 2 bc | 2.667 b | 4 bc |
| Grand mean | 1.190 | 1.381 | 2.095 | 2.90 | 3.810 |
| SEM | 0.309 | 0.3563 | 0.3563 | 0.642 | 0.3563 |
| F test | NS | NS | ** | ** | *** |
| LSD (0.05) | - | - | 0.7643 | 1.378 | 0.7643 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. NS = Not significant, ***Significant at 0.001 level of significance, **Significant at 0.01 level of significance. SEM = Standard error of mean, LSD = Least significant difference.

**Table 6.** Titratable Acidity of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatment | Titratable Acidity (%) | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 0.509 | 0.5667 b | 0.6183 | 0.6377 | 0.5967 c |
| GA3 @100 ppm | 0.5467 | 0.577 b | 0.6543 | 0.7567 | 0.76 ab |
| GA3 @200 ppm | 0.5867 | 0.67 a | 0.7377 | 0.8467 | 0.8267 a |
| GA3 @300 ppm | 0.6 | 0.6567 a | 0.76 | 0.83 | 0.8367 a |
| Kinetin @3 ppm | 0.5393 | 0.5777 b | 0.66 | 0.8 | 0.7433 ab |
| Kinetin @5 ppm | 0.5257 | 0.5957 ab | 0.6767 | 0.74 | 0.72 abc |
| Kinetin @7 ppm | 0.542 | 0.62 ab | 0.69 | 0.7177 | 0.6867 bc |
| Grand mean | 0.5499 | 0.6091 | 0.685 | 0.761 | 0.739 |
| SEM | 0.0365 | 0.0324 | 0.047 | 0.071 | 0.056 |
| F test | NS | * | NS | NS | * |
| LSD (0.05) | - | 0.06960 | - | - | 0.1211 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. NS = Not significant, *Significant at 0.05 level of significance, SEM = Standard error of mean, LSD = Least significant difference.

value of TA. On the other hand, the finding of Tourky et al. (2014) is discordant with this finding. The result is in harmony with Sahithya et al. (2017) where both GA3 and kinetin recorded a higher value of TA than control. An increment in TA during the initial condition might be due to the excessive biosynthesis of oxalic acid and the predominance of malic acid with the advancement of ripening. Zomo et al. (2014) observed a decrease in TA during the ripening process but recorded the highest TA in GA3 treated fruits as compared to control which is also following Bains et al. (2017).

### 3.6. *Juice pH*

The pH of the juice of bananas as influenced by different post-harvest treatments is presented in Table 7. The present experiment showed a decrease in PH during the storage period. This finding is in harmony with Tourky et al. (2014) where a decrease in PH during the advancement of ripening might be due to an increase in acidity. The maximum PH was recorded at the control and the minimum PH was recorded at 200 ppm GA3 treated fruits which might be due to more acidity in Gibberellic acid-treated fruits as compared with control. This result is in harmony with Bains et al. (2017) and Zomo et al. (2014) where the minimum PH was recorded in GA3 treated fruits but non-contradictory with the pattern it follows during the storage period where the PH keeps increasing during the storage period. Generally, the banana pulp has higher PH during harvesting at the matured green stage and as the ripening accelerates PH starts declining which are the most important maturity indices of banana (Dadzie and Orchard, 1997).

### 3.7. *TSS/TA ratio*

The influence of different post-harvest treatments on the TSS/TA ratio is presented in Table 8. The result showed significantly different results during observation. It is seen that this ratio increases continuously during the storage period. The highest ratio (34.23) was achieved in control and the minimum (15.32) was achieved in GA3 @300 ppm treated fruits which might be due to higher TSS and lower TA in control fruits and vice-versa. Tapas (2016) are in harmony with the above findings where the highest Brix-acid ratio (19.66, 39.37, and 39.26%) was observed in control and the minimum in GA3 treated fruits. Tourky et al. (2014) also reported the gradual increase in TSS/TA ratio during ripening but he observed the minimum ratio in control which is non-contradictory with our result. This finding was similar to the findings of Biniam Mesfin and Bower (2017) who recorded at two different temperatures, the maximum TSS/TA ratio was recorded in control and its lower value in GA3-treated papaya. Zomo et al. (2014) were in accordance with the above findings.

**Table 7.** PH of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatment | pH | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 5.167 a | 5 | 4.883 a | 4.8 a | 4.767 a |
| GA3 @100 ppm | 4.97 b | 4.863 | 4.77 b | 4.693 b | 4.623 bc |
| GA3 @200 ppm | 4.85 b | 4.767 | 4.667 c | 4.617 c | 4.55 c |
| GA3 @300 ppm | 5.017 ab | 4.9 | 4.783 b | 4.71 b | 4.617 bc |
| Kinetin @3 ppm | 4.967 b | 4.867 | 4.76 bc | 4.683 bc | 4.66 b |
| Kinetin @5 ppm | 4.967 b | 4.83 | 4.733 bc | 4.667 bc | 4.65 b |
| Kinetin @7 ppm | 5.017 ab | 4.867 | 4.76 bc | 4.65 bc | 4.633 b |
| Grand mean | 4.993 | 4.87 | 4.765 | 4.6886 | 4.6429 |
| SEM | 0.074 | 0.069 | 0.044 | 0.03152 | 0.03427 |
| F test | * | NS | * | ** | *** |
| LSD (0.05) | 0.1578 | - | 0.0939 | 0.06761 | 0.07351 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. NS = Not significant, *Significant at 0.05 level of significance, **Significant at 0.01 level of significance, ***Significant at 0.001 level of significance, SEM = Standard error of mean, LSD = Least significant difference.

**Table 8.** TSS/TA of banana under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Treatment | TSS/TA | | | | |
|---|---|---|---|---|---|
| | 3 DAS | 6 DAS | 9 DAS | 12 DAS | 15 DAS |
| Control | 18.99 a | 21.82 a | 24.27 a | 29.11 a | 34.23 a |
| GA3 @100 ppm | 16.56 ab | 18.09 b | 19.64 b | 20.52 b | 22.13 b |
| GA3 @200 ppm | 12.65 c | 12.43 c | 13.55 cd | 13.71 c | 16.96 c |
| GA3 @300 ppm | 12.83 c | 12.15 c | 11.49 d | 13.24 c | 15.32 c |
| Kinetin @3 ppm | 16.67 ab | 17.33 b | 19.68 b | 18.39 bc | 21.59 b |
| Kinetin @5 ppm | 15.8 b | 16.85 b | 18.75 b | 20.33 b | 21.84 b |
| Kinetin @7 ppm | 14.17 bc | 13.99 c | 14.97 c | 20.22 b | 22.98 b |
| Grand mean | 15.38 | 16.10 | 17.48 | 19.36 | 22.15 |
| SEM | 1.28 | 1.25 | 1.50 | 2.42 | 2.092 |
| F test | ** | *** | *** | *** | *** |
| LSD (0.05) | 2.742 | 2.675 | 3.210 | 5.199 | 4.486 |

Means in column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. **Significant at 0.01 level of significance, ***Significant at 0.001 level of significance. SEM = Standard error of mean, LSD = Least significant difference.

### 3.8. *Shelf life*

For researchers, it is the most important deal to prolong the shelf life of bananas where it showed significantly different results with different postharvest treatments from this experiment. The shelf life of bananas under different GA3 and kinetin application is given in Figure 2. Banana treated with Kinetin @7 ppm and GA3 @100 ppm showed statistically similar results with shelf life of 25 and 22.33 days respectively. The shortest shelf life of bananas (18.33 days) was observed with the untreated fruits. Shelf life was recorded the maximum i.e., 32.67 days with the application of GA3 @ 300 ppm and the minimum i.e., 18.33 days in untreated fruit whereas the different concentrations of kinetin also showed a positive response in prolonging the shelf life. This observation is also in accordance with the finding of Shrestha (2010) where he found the maximum shelf life of 44.33 days with GA3 @150 ppm followed by GA3 @ 200 ppm and the minimum in untreated fruits which might be

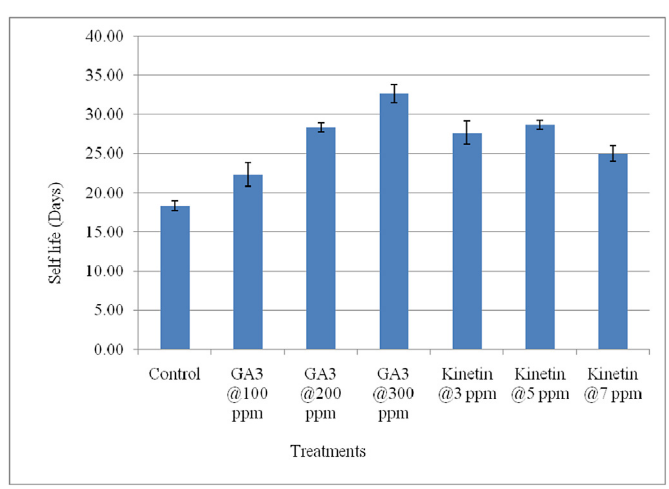


**Figure 2.** Bar graph illustrating the mean and standard deviation (error bars) of Shelf life of banana under different post harvest treatments during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

**Table 9.** Acceptability of banana for different organoleptic parameters under different concentration of GA3 and Kinetin during storage at ambient room temperature (28 ± 5 °C), Rampur, Chitwan, 2019

| Parameters | Rating | T1 | T2 | T3 | T4 | T5 | T6 | T7 |
|---|---|---|---|---|---|---|---|---|
| Flavor | Index value | 0.8a | 0.76ab | 0.68abc | 0.64bc | 0.72abc | 0.6c | 0.64bc |
| | Rank | I | II | IV | V | III | VI | V |
| Astringency | Index value | 0.32c | 0.48b | 0.64a | 0.6ab | 0.48b | 0.64a | 0.68a |
| | Rank | V | IV | II | III | IV | II | I |
| Sweetness | Index value | 0.92a | 0.68bd | 0.76bcd | 0.8b | 0.8bc | 0.64d | 0.68bcd |
| | Rank | I | IV | III | II | II | V | IV |
| Overall acceptability | Index value | 0.88a | 0.84ab | 0.72ab | 0.68b | 0.76ab | 0.68b | 0.72ab |
| | Rank | I | II | IV | V | III | V | IV |

Means within the same column followed by same letter do not differ significantly at 5 % level by DMRT.
*Note: T1, T2, T3, T4, T5, T6 and T7 represent different treatments.

due to the counteracting effect of ethylene by GA3 and cytokinin. The result is in accordance with Sembok et al. (2016), Sahithya et al. (2015), Tourky et al. (2014) and Archana and Sivachandiran (2015). Archana and Shivachandiran (2015) observed the four different concentrations of GA3 (250 ppm, 350 ppm, 500 ppm and 750 ppm) to obtain qualitative and quantitative data for analyzing the shelf life in Kathali banana where they observed more shelf life in 500 ppm and 750 ppm treated banana by 4 and 5 days. Bains et al. (2017) observed the effect of 50 ppm, 100ppm and 150 ppm in bananas where they found higher shelf life in 150 ppm treated experiment. Another similar experiment was done in Rampur with 100, 150 and 200 ppm GA3 concentration and 5, 10 15 ppm of kinetin concentration where higher shelf life was seen in 150 ppm GA3 concentration with higher retention of quality attributes in 200 ppm GA3. Similarly, 5 ppm of kinetin showed a higher shelf life than other kinetin concentrations (Shrestha, 2010). According to the findings of Sahithya et al. (2015) fruits treated with 150ppm GA3 retained excellent fruit quality and overall acceptance and fruits were able to keep for 24.33 days and extended the shelf life for 8 days over control.

Further Tapas (2016) observed the highest shelf-life of 20.23 days in 150 ppm GA3 treated fruits followed by GA3 @ 200 ppm (19.23 days) treated fruits and the lowest self-life in control with 9 days which might be due to the effect of Gibberellic acid in controlled ethylene production as well as enzymatic activity resulting into reduction in the ripening process. Kaur et al. (2014) also reported the positive response of kinetin in prolonging the shelf life of Kinnow Mandarin. For extended the shelf life of a banana, Nitric oxide alters endogenous ethylene levels at various levels by modifying many pathways with coordination of other signal molecules such as Gibberellic acid and Cytokinin, changing post climacteric biochemical changes which are linked to fruit quality (Manjunatha et al., 2012). Zomo et al. (2014) found that treatment GA3 causes a decrease in the tissue permeability and thereby reduced the rate of water loss leading to delayed fruit ripening.

### 3.9. *Organoleptic taste*

Acceptability of bananas for different organoleptic parameters under different concentrations of GA3 and Kinetin is given in Table 9. A group of five persons individually evaluated the sensory quality attributes of bananas of different postharvest treatments for flavor, Astringency, Sweetness and Overall acceptability at the CI-6 stage of ripening. A significant difference was observed in terms of all quality attributes of bananas. Untreated fruits showed higher sensory quality attributes by ranking 1$^{st}$ in terms of sweetness, flavor and overall acceptability. The 100 ppm Gibberellic acid and 3 ppm kinetin treated banana fruits also ranked second and third respectively in terms of Flavor and overall acceptability. In terms of Astringency kinetin @ 7ppm treated fruits ranked 1$^{st}$ followed by Kinetin @5 ppm and GA3 @200 ppm. In this experiment, control showed a higher sensory score with 1$^{st}$ ranking in sweetness, flavor and overall acceptability followed by 100 ppm GA3 treated fruits which might be due to a higher TSS/TA ratio in control fruits. Jain et al. (2014) are non-contradictory with the above findings where the application of plant growth regulator had significantly increased the ascorbic acid and sensory score of the Nagpur mandarin fruit over control. Archana and Sivachandiran (2015) revealed that the application of GA3 did not alter the quality characters of the banana fruits. Shrestha (2010) observed the higher sensory quality attributes in Kinetin @15 ppm treated fruit followed by GA3 @150 ppm treated fruit and then control.

## 4. Conclusion

The study indicates that GA3 and Kinetin caused significant effects on the Physico-chemical parameters and shelf life of bananas. GA3 @ 300 ppm treated fruits showed the lowest value for all the quality parameters and Kinetin @ 5 ppm showed superior results than other concentrations of kinetin. During the advancement of the storage period bananas continually lose water, TSS increase, TA increased till the ripening peak but the process was lesser in higher GA3 treated banana fruits. Shelf life can be regulated to 32.67 days with GA3 @ 300 ppm. Prolongation of storage life and marketing quality of banana fruits could be maintained better with the use of different concentrations of GA3 and Kinetin. Similarly, for the prolongation of shelf life, GA3 @ 300 ppm will be best in bananas. This finding will help the banana farmer, business in enhancing the storage life and minimizing quality and economic loss.

## Declarations

### *Author contribution statement*

Ritambar Ghimire; Pankaj Kumar Yadav; Shovit Khanal: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Arjun Kumar Shrestha; Ananta Raj Devkota: Performed the experiments; Wrote the paper.

Jiban Shrestha: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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### *Data availability statement*

Data will be made available on request.

### *Declaration of interests statement*

The authors declare no conflict of interest.

## Additional information

No additional information is available for this paper.

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