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### Non-destructive maturity index of “Amritsagor” banana using RGB and HSV values

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#### Abstract

Massive changes in physicochemical composition and color variation usually occur in fruits during maturation and ripening. This study is conducted to implement an image processing system and develop a maturity color chart of banana. Actually, natural ripening color is different than impose ripening. Maturity color chart will help the consumer when it will be in the packet of banana. The earliest physiological maturity (stage-1) was marked as the stage when the flesh color was olive green and the pulp turning yellow and the subsequent maturity stages determined whenever changes the color as stage-2 (green smoke), stage-3 (apple green), stage-4 (olive drab), stage-5 (yellow) and stage-6 (golden rod) color. For each of the maturity stages, physical (peel color, firmness, and weight loss) and biochemical (anthocyanin content, carotenoids content, titrable acidity, pH, total soluble solids, ascorbic acid, reducing sugar, non-reducing sugar, and total sugar) maturity indices were determined. We had classified the maturity stages of banana based on the RGB (Red, Green, and Blue) and HSV (Hue, Saturation and Value) values. Average, median, minimum and maximum values were used in this study. After completing the qualitative analysis of RGB and HSV values we found the correlation coefficient of RGB and HSV values. The red color (R) values of bananas would increase when stages increase and the hue (H) means the pure color of bananas decreases when stages increase. Therefore, we can say that maturity stages of bananas mainly depend on R and H values. In case of Amritsagor banana at stage-6 (golden rod) color, TSS (Total Soluble Solid) (2.1%), TA (Titrable Acidity) (0.96%), pH (5.2), sugar (1.25%), vitamin C (2.5 mg/100g), reducing sugar (1.04%), non-reducing sugar (0.2%), anthocyanin (0.55 mg/100g) carotenoids (0.38 mg/100g) and at stage-1 (olive green) color, pH (6.8), vitamin C (8.75 mg/100g) are significantly highest. The results show that as maturation progressed, firmness decreased gradually and flesh color turned olive green to golden rod with ripening. Total soluble solids increased while TA (Titrable acidity) gradually increased with maturity. The results revealed that, there is a significant relationship between nutritional value, firmness and fruit skin color. So, the fruit of stage-1 (olive green) is suitable for harvesting and stages-6 (golden rod) color is suitable for consumption. Actually this message for grower/ owner or who would like to harvest and consumer. Fruit is banana, to observe the change of color keep it at room temperature. Neither artificial nor chemical system used here. Each and every box will carry the real maturity color chart.

#### Introduction

Bananas are the fifth most important agriculture commodity in world trade after cereals, sugar, coffee and cocoa (Dadzie and Orchard 1997). The fruit is variable in size, color and firmness, but is usually elongated and curved, with soft flesh rich in starch covered with a rind which may be green, yellow, red, purple, or brown when ripe. Almost all modern edible parthenocarpic (seedless) bananas come from two wild species – *Musa acuminata* and *Musa balbisiana*. Amritsagor banana (*Musa paradisiaca*) usually harvested at the matured green stage and they remain firm and green without significant changes in peel color, texture or composition (Aguilera *et al.*, 2003). Maturity stage at harvest of fresh banana fruit is an important factor that affects the fruit quality during marketing.

Bananas are extremely healthy and delicious. It contains several essential nutrients, and has benefits for digestion, heart health and weight loss. Banana is one of the high calories, tropical fruits. Hundred grams of fruit carry ninety calories (Ortiz *et al.*, 1995). Besides, it contains good amount carbohydrates, proteins, phenols,  $\beta$ -carotene, minerals (Na, K, Ca, Mg, P, Fe, Zn, B, Cu, and Mn), and vitamin C (Sunil pareek, 2016).

The changes occurred during ripening are in physical, mechanical and chemical properties of banana fruits. Skin color changes from green to yellow, firmness is decreased, fruit gets softened and starch is converted into sugar. Commercial standard color charts are available for (*Musa sp* var ‘Robusta’) varieties of banana, in which 6 stages of peel color were reproduced and translated to a numerical scale where Stage-1= all

green, Stage-2 = green with trace of yellow, Stage-3 = more green than yellow, Stage-4 = more yellow than green, Stage-5 = yellow with trace of green, and Stage-6 = full yellow. According to color chart, in terms of peel color slight difference occurs among the advanced stages of maturity i.e. stage 5 and 6 as compared to initial stages. Knowing the physical and mechanical properties of banana fruit and changes in these parameters during different ripening stages is the most important attributes to design handling, sorting, peeling, processing and packaging system. The ability to identify maturity of fresh banana fruit will be a great support for farmers to optimize harvesting phase which helps to avoid harvesting either under-matured or over-matured banana (Surya and Kumar 2015). Some common physicochemical parameters used for this purpose are anthocyanine, firmness, acidity, total soluble solids and total sugar, reducing sugar and non-reducing sugar. Quantitative determination of chemical constituents is destructive and entails the use of chemicals and instruments which are relatively expensive. Since the ripening banana fruit changes color from green to yellow, orange or red, non-destructive methods based on photometry may be applied to quantitatively determine the degree of fruit ripeness. The surface color of a fruit is a major visual parameter that has been used traditionally to determine its ripeness. Maturity stages as well as degree of maturation of fresh bananas color may calculate using surface color of banana. The objectives of this study are:-

- i. to evaluate the physical quality in relation to external color;
- ii. to observe the chemical characteristics at different color stages of the Amritsagor banana fruits.

## Materials and Methods

### Sample collection

A total of 70 healthy bananas with uniform size shape and color were selected from tree of Amrita sagor banana plant belonging to the BADC (Bangladesh Agricultural Development Corporation) farm at Lakutia in Barisal. Fruits were carried out to the Postharvest laboratory, Department of Horticulture, Patuakhali Science and Technology University (PSTU). After harvesting, immediately we started our job. The bananas were harvested at stage-1 and then the changes in the bananas stages were observed and monitored carefully once a day. At each maturity stage of these bananas, the sample images were captured and determined physical and chemical characteristics.

**Determination of color:** At first a total of 70 green bananas images were acquired with a resolution of 13 mega pixels using camera of ASUS\_X008. To measure color of stages, 3 replications were used for each stage. Each replication containing 4 fruits total 12 fruits. Sixty fruits were used for Stage 2 – 6 (5x12= 60). For initial data and other uses 10 fruits were used. The images were captured between 9AM to 2PM whenever changed the color of fruits using natural light under ambient

temperature. A white background was used so that segmentation can be done easily. The color of bananas peels was determined using an Android Application Software namely “On Color Measure” (developed by potato tree Soft, Version 3.0) equipped with an aim pointer. A white background was used so that segmentation can be done easily. Images could be captured at 9 cm distances. It provides the easiest way to store the information of each color detection. Color measurements were done at each face of banana and a mean value was obtained. The bananas color determination were expressed in chromaticity values of Red (R\*), Green (G\*) and Blue (B\*). For measuring the color the camera was aimed at the target color point and clicked on crosshair pointer and moved it to any place on the screen. The dashboard displays the information of the color detected. Grab button was clicked to capture the screen image and saved all the detailed color information RGB, color names and screen images.

**Weight loss:** The weight loss was determined with an electronic balance (Model-668ALED, RFL). Seven bananas per treatment represented seven replications were marked for this purpose and the same banana was used until the end of the experimental period. The percentage of weight loss was calculated using the following formula:

$$\text{Weight Loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,  $W_1$  = Initial weight of the fruit;  $W_2$  = Weight of fruits at various storage periods.

**Determination of firmness (N):** Firmness of banana was measured using the digital fruit firmness testing machine (Model GY-802). The instrument was equipped with a 4 mm diameter cylindrical probe that was penetrated in the normal direction. The reading was taken for each fruit at collar, middle and end points according to Hassan (2006).

**Determination of titrable acidity (% Citric Acid):** The titrable acidity was estimated through the chemical analysis using banana pulp. The titrable acidity of banana was determined according to Ranganna (1979).

**Determination of total soluble solid (TSS) concentration:** The total solids concentration of banana pulp was determined using a refractometer (Model N-1, BOECO Germany). The remaining of the filtrated juice from TA determination was used to measure the soluble solid content (SSC) of the pulp. Before measurement, the refractometer was calibrated with distilled water to give a 0% reading. About 1-2 drops of the filtrate was placed on the prism glass of the refractometer to obtain the percentage of soluble solid content (SSC) reading. The readings were multiplied by the by dilution factor to obtain the original percentage of the pulp tissues. Since differences in sample temperature could affect the measurement of soluble solid content (SSC).

**Determination of pH:** The remaining of the filtrated juice from titrable acidity (TA) determination was used to measure the pH of the banana pulp. The pH was determined using a glass electrode pH meter (GPL 21, Crison, Barcelona, EEC). Before being used, the pH meter was calibrated with buffers at pH 4.0 followed by pH 7.0. After that, the glass electrode was placed into the filtrate to measure the pH and stabilized reading was recorded. For accuracy of the reading, the glass electrode was washed after each reading with distilled water and wiped to dry with soft tissue paper.

**Determination of the ascorbic acid (Vitamin C):** The ascorbic acid content was determined according to Ranganna (1979). The following equation was used for the estimation of ascorbic acid content-

$$\text{Ascorbic acid (mg } 100 \text{ g}^{-1}\text{)} = \frac{\text{Titre (ml)} \times \text{dye factor (0.125)} \times \text{volume made up (50ml)} \times 100}{\text{Aliquorused for estimation (5ml)} \times \text{sample weight (10g)}}$$

**Sugar Content:** The sugar content of the banana pulp was determined according to the method of Ranganna (1986).

**Reducing sugar content:** Percentage of the reducing sugar was calculated according to the following formula-

$$\text{Reducing sugar content (\%)} = \frac{F \times D \times 100}{T \times W \times 1000}$$

Where,

F= Fehling's factor

D=Dilution

T= Titre and

W= Weight or volume of the sample

- **Titration of the total invert sugar:** Fifty milliliters purified solution was taken in a 250 ml conical flask. Five grams of citric acid and 50 ml distilled water was added to it. The conical flask containing sugar solution was boiled for inversion of sucrose and finally cooled. Then the solution was transferred to a 250 ml volumetric flask and neutralized by 1N NaOH using the phenolphthalein indicator. The volume was made up to the mark with distilled water. Then the mixed Fehling's solution was titrated using similar procedure followed as in the case of invert sugar (reducing sugar) mentioned earlier. The percentage of the total invert sugar was calculated using the formula used in case of reducing sugar.
- **Non-reducing sugar:**  
The percentage of non-reducing sugar = Percentage of total sugar – Percentage of reducing sugar.
- **Estimation of total sugar:** The total sugar was calculated as follows:  
Percentage total sugar = Percentage of reducing sugar + Percentage of non-reducing sugar.

**Determination total anthocyanine:** Total anthocyanine content of banana peel and the carotenoid content of pulp were determined as per Sims and Gamon (2002). For anthocyanine and carotenoid measurement, 5 mg tissue

samples were properly homogenized with 10 ml in 80% cold acetone and centrifuged for 4 min at 800 rpm at 4°C. The clear supernatant diluted to a final volume of 5 ml with additional acetone and was used for the estimation of total anthocyanin content, carotenoid content and evaluated for antioxidant activity. The absorbance of the extract solutions was measured at 665 nm, 649 nm, 646 nm, 663 nm, 470 nm, 529 nm and 650 nm wavelengths with a double beam spectrophotometer (Dynamica HALO-DB-20S UV-VIS Double Beam Spectrophotometer). Content of anthocyanine content was calculated by using the following formula:

$$\text{Anthocyanine } (\mu\text{mol/ml}) = A_{529} - 0.288 A_{650}$$

$$\text{Anthocyanine}(\mu\text{mol/g} \times 207.247 = \mu\text{g/g}) = A_{529} - 0.288 A_{650}$$

Where Ax is the absorbance of the extract solution in a 1-cm path length cuvette at wavelength x.

**Image analysis:** The images of bananas were analyzed by an Android Application Software namely "On Color Measure" (developed by potatotree Soft, Version 3.0). We have implemented a rule of based method to classify bananas according to their maturity stages based on the RGB and HSV values. Average, median, min and max values are used in this study. After the qualitative analysis of RGB and HSV values we found the correlation coefficient of RGB and HSV values.

**Statistical analysis:** The recorded data on different parameters of the experiment were tabulated and analyzed with appropriate design of experiment (Gomez and Gomez, 1984) adopting a statistical programme MSTAT-C. All the treatment means were calculated and the analysis of variances (ANOVA) of different characters considered was done by the help of Duncan's Multiple Range Test (DMRT). The means were separated by Least Significant Difference (LSD) test at 1% and 5% levels of significance.

## Results and Discussion

The results of the analysis of variance in respect of all parameters studied in the present investigation have been presented and discussed below:

### Studies on the physical characteristics at different stages of the fruits

**Peel color:** Color change is the result of pigments, which were always present in the fruit, becoming visible when chlorophyll is degraded. However, additional pigments are also produced by the fruit as it ripens. In fruit, the cell walls are mainly composed of polysaccharides including pectin. During ripening, a lot of the pectin is converted from a water-insoluble form to a soluble one by certain degrading enzymes.

Change of peel color during ripening and senescence of fruits involves chlorophyll degradation or qualitative and quantitative alternation of the green pigment into other pigments. During color change the pulp becomes softer and sweeter as the ratio of the sugar to starch increased.

### Classification result using RGB and HSV values

We have implemented a rule based method to classify bananas according to their maturity stages based on the RGB and HSV values. Average, median, min and max values are used in this case. After the qualitative analysis of RGB and HSV values we found the correlation coefficient of RGB and HSV values. The value of the correlation coefficient for R values and the stage numbers is 0.408587 which means R has positive moderate linear correlation with the stage number.  $G = -0.22843$  that means G has negative weak linear correlation and  $B = -0.23761$  indicating that B has also negatively weak linear relationship. To improve the classification accuracy, the RGB values have been converted into HSV values as it resembles the color sensing properties of human vision. Here the value of the correlation coefficient for H values and the stage numbers is  $-0.88926$  which means H has negative strong linear relationship. On the other hand  $S = -0.284792$  which shows positive weak relationship and  $V = 0.070647$  indicating no linear relationship with the stage number. Therefore, we can say that maturity stages of bananas mainly depend on R and H values. Here red color values of bananas would increase when stages increase and hue means pure color of bananas decreases when stages increase.

This correlation is also similar to our manual observation as bananas become more yellowish with the advancement of the stages. The yellow color is a combination of green and red. Therefore, increase of red color values with the stage numbers is reasonable. Also, in the higher stages, especially in stage 6, the number of color pigments reduces and thus the hue values (pure color measures) decrease with the increase of stages. Hence, this strong negative correlation between the hue values and the stage numbers is also reasonable.

**Weight loss:** The changes in weight of banana are shown in Fig. 3.

Significant variation was observed in respect of total weight loss at different maturity stages of the fruits. The highest weight loss was 1.190% at the stage-6 and lowest weight loss was 1.120% at the stage-1 (Table 2). The weight loss of the fruits was occurred due to the loss of water from the fruits, microbial decay and storage environment like temperature and humidity and respiration. Decreases the weight of banana at high temperature during ripening and storage. The percent of the weight loss was increased continuously during ripening due to a high storage temperature. Since high energy is required to run the process, starch is converted to sugar and used as energy. 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.

### Firmness

Firmness is important criteria of fruits quality. The firmness of banana pulp from stage-1 to stage-6 is an obvious change during storage. During firmness change the pulp become softer and sweeter as the ratio of the sugar to starch increases. The change of the firmness of banana at different maturity stage is shown in (Fig. 4).

During matured stage i.e. when banana was green the firmness was high. Firmness decreases as ripening continued. The maximum firmness was 31.50 N at stage-1 and lowest value 10.02 N at stage 2 (Table 2). Significant difference was observed among stage-1 to stage- 6. Softening of fruits is related to a change in cell wall component and starch degradation (Seymour, 1993). The starch granules, packed in the tissue of banana flesh give rise to the toughness of the unripe fruit, and are hydrolyzed to sugar while an increase of the cell wall solubility allows water and nutrients to pass in and out of the cells. Fruit firmness decreased steadily during the six-day storage. It was expected that during those periods all starch would be completely converted to sugar.

### Bio-chemical characteristics at different stages of the fruits

**Titration acidity:** The titration acidity content of fruits varied significantly (Table 2) at different stages during storage. In banana flesh, the total amount of acid increases during ripening; the main acids being: malic, citric and oxalic acid. While the first two acids are responsible for tartness in the unripe banana, oxalic acid is contributed to astringent taste of the fruit (Seymour, 1993). As the fruit ripened, these acids were reduced and, the taste changed to a sweet taste, mainly from the hydrolyzed sugar from the starch degradation. The titration acidity is increased from 0.51 to a peak of 0.96 up to sixth day (Fig. 5 and Table 2).

**pH:** The pH of the fruit pulp at different stages of maturity varied significantly (Fig. 5) at different stages during storage. The pH of the fruit pulp at different stages under the study varied from 5.2-6.8 depending on varieties and maturity stages (Table 2). The pH of banana was gradually decreased from stage- 1 to stages- 6. The highest pH was recorded at the stage-1 (6.8), and the lowest pH (5) was recorded at stage-6. The reduction of pH may be due to continuous increases of acidity during ripening. Significant difference of pH was observed among stage- 1 to stage- 6. pH influences the catalytic activity of cell wall enzymes and can have a profound effect on anthocyanin stability and color expression. The reduction of pH may be due to continuous increases of acidity during ripening. The highest pH content in Amrapali is recorded (4.54) while Mallika contain (4.09) when ripening and the lowest pH content in Mallika is recorded (2.79) while Amrapali (3.96) in unripen condition. Statistically highly significant variation of pulp pH was observed at different stages due to conversion of pectin into sugars. (Asutosh *et al.*, 2016).

**Table 1. Pearson's correlation coefficient between the stage numbers and the color values**

Color	Stages
R	0.408587
G	-0.22843
B	-0.23761
H	-0.88926
S	0.284792
V	0.070647

**Table 2. Duncan's multiple range test (DMRT) value for weight loss, firmness, titrable acidity (TA), pH, total soluble solid (TSS) and vitamin C content at different maturity stages of Amrit sagor banana**

Stages	Weight Loss (%)	Firmness (N)	TA (%)	pH	TSS (%)	Vit C (mg/100 g)
Stage 1	1.120 <sup>f</sup>	31.50 <sup>a</sup>	0.510 <sup>f</sup>	6.80 <sup>a</sup>	0.01 <sup>f</sup>	8.75 <sup>a</sup>
Stage 2	1.130 <sup>e</sup>	28.45 <sup>b</sup>	0.570 <sup>e</sup>	5.97 <sup>b</sup>	0.6 <sup>e</sup>	7.50 <sup>b</sup>
Stage 3	1.140 <sup>d</sup>	24.58 <sup>c</sup>	0.640 <sup>d</sup>	5.86 <sup>c</sup>	0.87 <sup>d</sup>	6.25 <sup>c</sup>
Stage 4	1.160 <sup>c</sup>	20.30 <sup>d</sup>	0.762 <sup>c</sup>	5.72 <sup>d</sup>	1.5 <sup>c</sup>	5.72 <sup>d</sup>
Stage 5	1.170 <sup>b</sup>	15.05 <sup>e</sup>	0.830 <sup>b</sup>	5.62 <sup>e</sup>	1.8 <sup>b</sup>	3.75 <sup>e</sup>
Stage 6	1.190 <sup>a</sup>	10.02 <sup>f</sup>	0.960 <sup>a</sup>	5.20 <sup>f</sup>	2.1 <sup>a</sup>	2.50 <sup>f</sup>
LSD	0.1486	0.7676	0.046	0.093	0.105	0.066
CV (%)	0.29	2.39	0.72	1.07	6.08	0.83

Significant at 1% level of probability

### Total soluble solid (TSS)

The TSS content of fruits varied significantly at different stages during storage. The TSS content of fruit at different stages under the study was increased depending on maturity stages (Fig. 7).

The highest sugar content was recorded 2.1% at stage-6 and the lowest sugar content was recorded 0.01% at stage-1 (Table 2). In most ripen fruits including banana, incidence of post-harvest causes sugar formation as a result of starch hydrolysis. During the development of the flesh of a fruit, in many species, nutrients are deposited as starch, which during the ripening process is transformed into sugars. The progression of the ripening process leads to increasing sugar levels. In the flesh more movement of water and the degradation of starch to soluble sugar within the cell contributed to the increase of TSS. (Salvador *et al.*, 2007).

### Vitamin C

The ascorbic acid (vitamin C) content of fruits varied significantly at different stages during storage. The vitamin C content of fruit at different stages under the study varied from 2.5-8.75 mg/100g depending on the maturity stages (Fig. 8).

The highest vitamin C content was 8.75 mg/100g at stage-1 and the lowest vitamin C content was recorded 2.5 mg/100g at stage-6 (Table 2). The vitamin C content of banana fruit is higher when it is slightly immature, and declines as the fruit hits peak ripeness. The value of vitamin C content significantly varies from different stage of ripening. In some fruits, the amount of vitamin C varies between different varieties of the same species (Romero and Rodriguez, 2012).

### Reducing sugar

The reducing sugar content of fruit at different stages under the study varied significantly from 0.31-1.04% depending on maturity stages (Fig. 9). In case of Amritsagor banana, at stage-1, the lowest reducing sugar (0.31%) was recorded followed by stage- 2 (0.4%) and stage-3 (0.5%). Then the reducing sugar was increased up to fully ripen and the highest reducing sugar (1.04%) was recorded at stage-6 and not greatly significant (Table 3). The increase in reducing sugar may be attributed to enzymatic conversion of starch to reducing sugar (Islam, 1998). Bhadra and Sen (1999) mentioned that the total sugar and reducing sugar contents increased with in the progress of the storage period.

### Non-reducing sugar

The non-reducing sugar content of fruit at different stages under the study significantly varied from 0.08-0.2% depending on maturity stages of banana (Figure 10). At stage-1, the lowest non reducing sugar (0.08%) was recorded followed by stage- 2 (0.09%) and stage-3 (0.1%). Then the non-reducing sugar was increased up to stage-6 significantly. The highest non reducing sugar (0.2%) was recorded at stage-6. Rapidly increased non-reducing sugar was probably due to breakdown of starch into non-reducing sugar and then that non-reducing sugar was converted into reducing sugar resulting slowly increase in non-reducing sugar (Table 3). In mango, (Rangavalli *et al.*, 1993) found a gradual increase in the non-reducing sugar content during its storage. Uddin *et al.*, (2006) conducted an investigation on some biochemical characteristics of twenty two germplasm of mango. The non-reducing sugar content of the fruit pulp of mangoes varied from 2.34 to 5.95%. A gradual increase in non-reducing sugar was observed with the advancement of maturity due to various enzymatic activities.

**Table 3. Duncan's multiple range test (DMRT) value for reducing sugar, non-reducing sugar, total sugar, total anthocyanin and total carotenoids content at different maturity stages of Amrit sagor banana**

Stages	Reducing Sugar (%)	Non-Reducing Sugar (%)	Total Sugar (%)	Total Anthocyanin (mg/100 g)	Total Carotenoids (mg/100 g)
Stage 1	0.31 <sup>c</sup>	0.08 <sup>c</sup>	0.39 <sup>e</sup>	0.36 <sup>d</sup>	0.23 <sup>d</sup>
Stage 2	0.32 <sup>c</sup>	0.08 <sup>c</sup>	0.41 <sup>e</sup>	0.37 <sup>cd</sup>	0.25 <sup>cd</sup>
Stage 3	0.52 <sup>d</sup>	0.10 <sup>c</sup>	0.62 <sup>d</sup>	0.41 <sup>c</sup>	0.29 <sup>bc</sup>
Stage 4	0.62 <sup>c</sup>	0.15 <sup>b</sup>	0.78 <sup>c</sup>	0.48 <sup>b</sup>	0.31 <sup>b</sup>
Stage 5	0.69 <sup>b</sup>	0.19 <sup>ab</sup>	0.89 <sup>b</sup>	0.51 <sup>ab</sup>	0.36 <sup>a</sup>
Stage 6	1.04 <sup>a</sup>	0.20 <sup>a</sup>	1.25 <sup>a</sup>	0.55 <sup>a</sup>	0.38 <sup>a</sup>
LSD	0.046	0.046	0.046	0.046	0.046
CV (%)	0.40	0.00	0.46	0.99	1.69

Significant at 1% level of probability

### Total sugar

The total sugar content of fruit at different stages under the study varied from 0.39-1.25% depending on maturity stages (Fig. 11). The lowest total sugar stage-1 (0.39%) was recorded followed by stage-2 (0.41%) and stage-3 (0.60%). Then the total sugar was increased up to fully ripen. The highest total sugar (1.25%) was recorded at stage-6 (Table 3).

Zomo *et al.*, (2014) observed that green bananas are almost all starch and have low sugar content and increased when ripening. As the bananas ripen, the starch content decreases, then sucrose appears. Next, fructose and glucose appear and increase. After about 6 days of ripening, sucrose begins to decline. The sugar content in overripe bananas can be dramatically higher than in bananas that are under ripe and optimally ripe. The results indicated that a progressive increase in total sugar content and decrease in starch content was observed during ripening. This could be due to the hydrolysis of starch into sugar during ripening. The most striking chemical changes occurred during the postharvest ripening of banana fruits were hydrolysis of starch and accumulation of sugars (Patil and Magar, 2006).

### Total anthocyanin content

Anthocyanins have powerful antioxidant capability and are responsible for the color of banana. It was found that, the anthocyanin content was more in ripe banana peel and it was found highest at stage-6 (0.55 mg) and lowest in stage-1 (0.36 mg) respectively (Fig. 12 and

Table 3). The anthocyanin content of fruits varied significantly at different stages during storage. In aqueous solution, anthocyanins undergo structural transformations that are pH-dependent. Anthocyanin below pH 2 exist primarily in the form of flavyllium cation. Processing and storage under low temperature can improve the stability of anthocyanins. When temperature is increased, anthocyanins can be transformed into unstable formation of chalcone, and the chalcone is further degraded to brown products (Takeoka and Dao, 2002).

**Total carotenoids content:** Carotenoids, also called tetraterpenoids, are organic pigments. The carotenoids content of banana was increased at different stages during storage. The carotenoids content of fruit at different stages under the study varied from 0.23-0.38 mg/100g depending on maturity stages of banana (Fig. 13). The lowest carotenoids at stage-1 (0.23 mg) and the highest carotenoids content (0.38 mg) at stage-6 (Table 2). The carotenoids content was increased very slowly up to fully ripen of fruits. As ripening proceeds, the green pigment of unripe banana is converted to carotenoids in ripe banana. It forms a non-enzymatic covalent bonding with chlorophyll thus its conversion to carotenoids. This explains why the levels of carotenoids increase with ripening. In carotenogenic fruits and fruit vegetables, ripening is usually accompanied by enhanced carotenogenesis as chlorophylls decompose and the chloroplasts are transformed into chromoplast (Gerard *et al.*, 2009).



Fig. 2. Different maturity stages of Amritsagor banana.

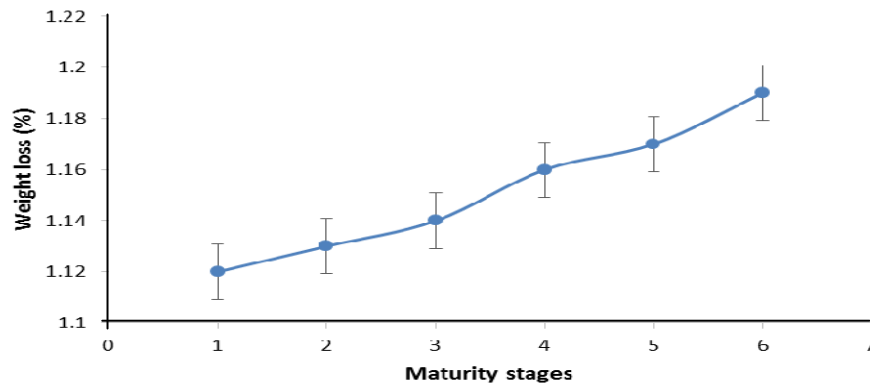


Fig. 3. Percent weight loss of Amritsagor banana at different maturity stages.

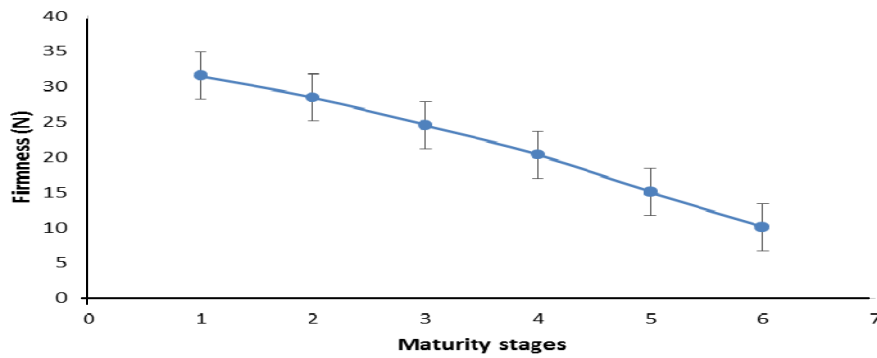


Fig. 4. Firmness of Amritsagor banana at different maturity stages.

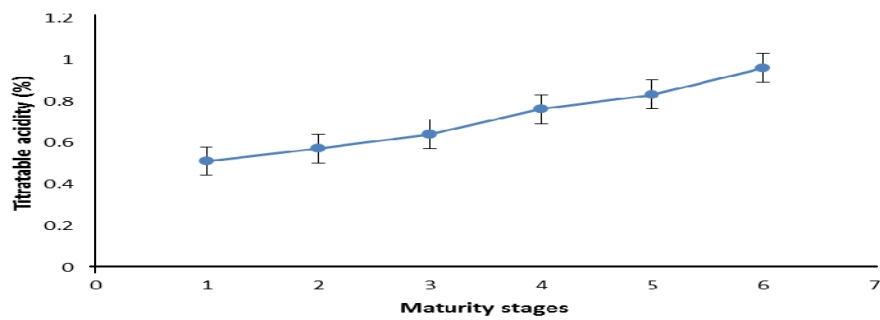


Fig. 5. Titrable acidity of Amritsagor banana pulp at different maturity stages.

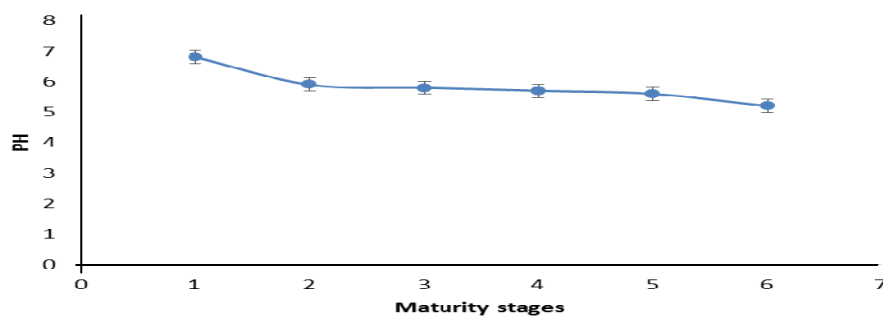


Fig. 6. pH of Amritsagor banana at different maturity stages.

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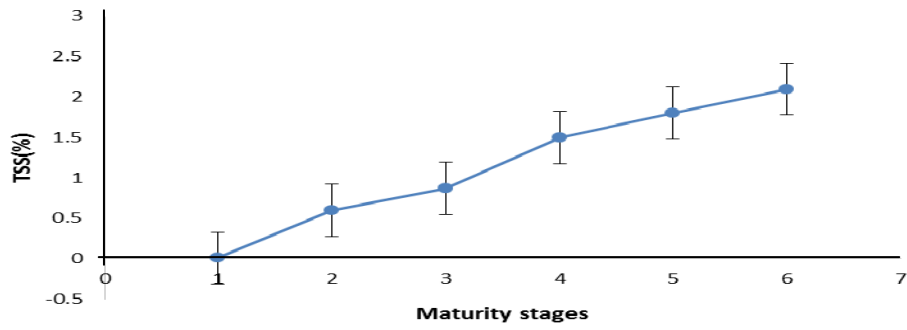


Fig. 7. TSS of Amritsagor banana pulp at different maturity stages.

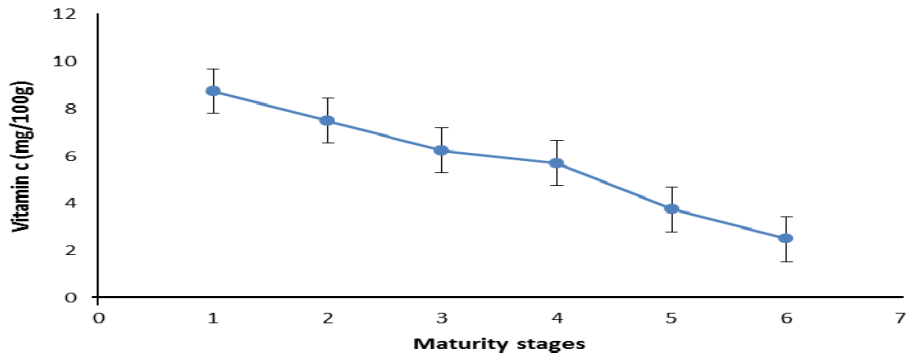


Fig. 8. Vitamin C content of Amritsagor banana pulp at different maturity stages.

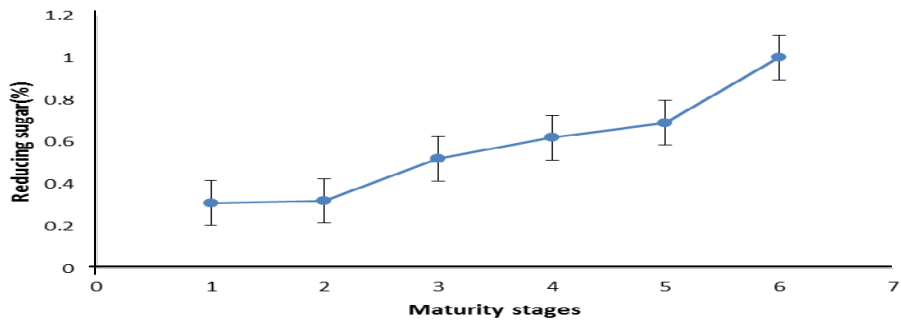


Fig. 9. Reducing sugar content of Amritsagor banana pulp at different maturity stages.

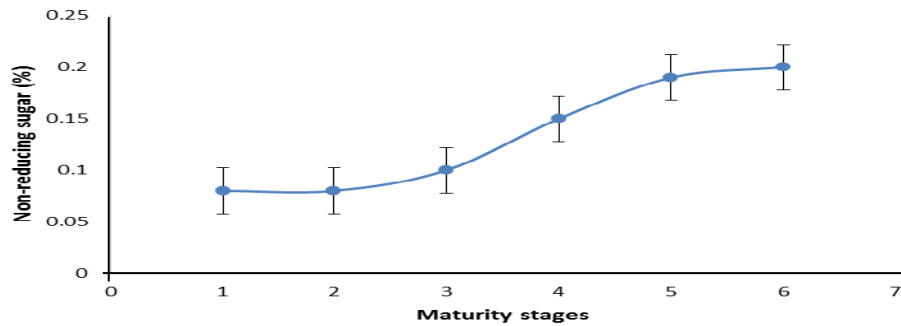


Fig. 10. Non-reducing sugar content of Amritsagor banana pulp at different maturity stages.



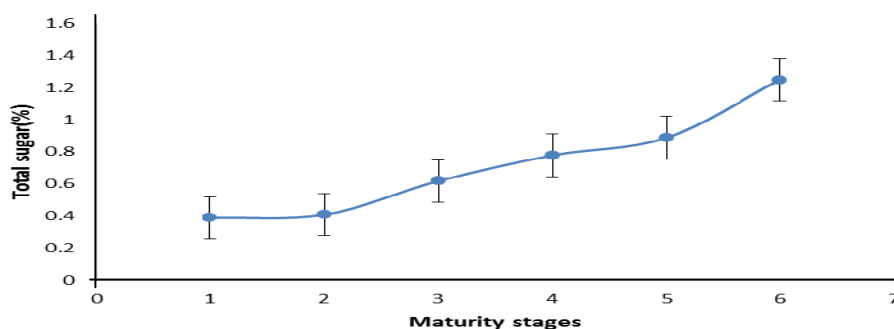


Fig. 11: Total sugar content of Amritsagor banana pulp at different maturity stages.

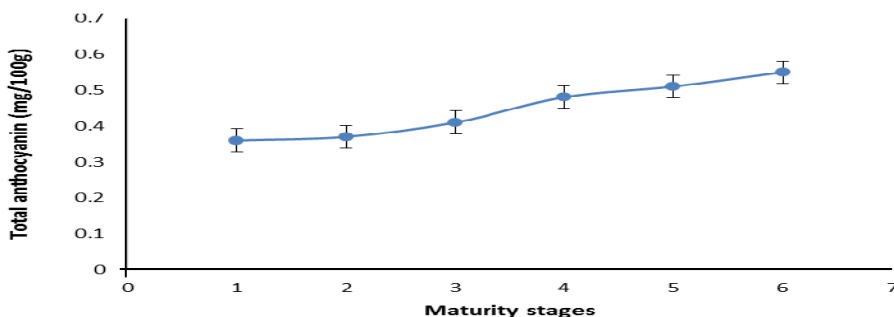


Fig. 12. Anthocyanin content of Amritsagor banana peel at different maturity stages.

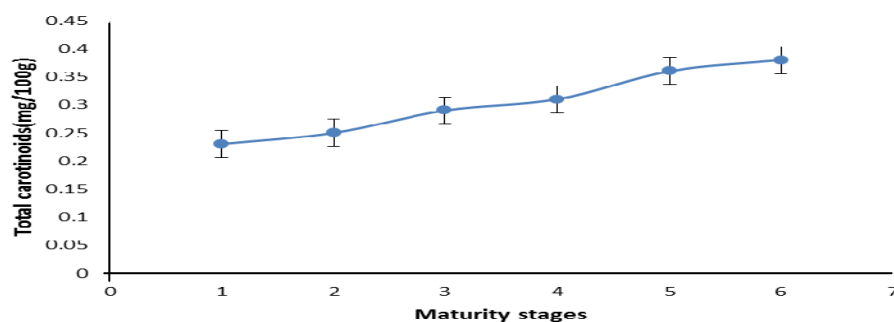


Fig. 13. Carotenoids content of Amritsagor banana peel at different maturity stages.

## Conclusion

The present study was conducted to characterize the maturity stages and physicochemical properties of Amritsagor banana. Results showed the significant differences in color, firmness, pH and TSS subjected to the different stage of ripeness. However, it is important to select quality related attributes that best define the actual ripening stages to perform better classification in the production of banana. The producers, distributors and handlers, must be able to meet consumer demand with support from researchers, by developing advance post-harvest technologies that translate the related sensory attributes of specific physicochemical properties of the fruits. From the findings it could be concluded that the physical quality is highest at stage-1 (olive green). This stage is suitable for harvesting and transportation. The chemical composition is highest at

stage-6 (golden rod) color and this stage is suitable for consumption.

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